ICMIAM 2026

ABSTRACT BOOKLET

Message from Executive Chairs

Dear Esteemed Delegates,

It is our great pleasure to welcome you to the 7th International Conference on Maintenance and Intelligent Asset Management (ICMIAM 2026), hosted by the University of Huddersfield, UK, from 1–3 September 2026. Building on the success of previous conferences, ICMIAM 2026 brings together researchers, practitioners, industry leaders, students, and policy stakeholders to exchange knowledge and advance the theory and practice of maintenance and intelligent asset management.

The programme reflects the increasingly multidisciplinary nature of asset management. Across five principal themes: Asset Management & Maintenance Systems; Diagnostics, Monitoring & Smart Sensing; Energy Systems, Built Environment & Sustainability; Safety, Risk, Security & Ethics; and Advanced & Emerging Applications, the conference showcases work spanning lifecycle optimisation, reliability and predictive maintenance, AI- and IoT-enabled diagnostics, digital twins, sustainable engineering, smart buildings, energy systems, risk and cybersecurity, manufacturing, transport, healthcare, and other emerging technologies. We hope that these contributions will stimulate constructive discussion and demonstrate how research can be translated into practical solutions that improve asset performance, resilience, safety, sustainability, and value.

The conference is also an important forum for strengthening the connection between academic research and industrial practice. We encourage delegates to engage actively with the technical sessions, share experience across disciplines, challenge ideas constructively, and make full use of the opportunities for networking and collaboration. The most significant advances in maintenance and asset management increasingly arise at the interfaces between engineering, data science, digital technologies, human factors, sustainability, and decision-making, and ICMIAM 2026 has been designed to support exactly this kind of exchange.

We extend our sincere appreciation to everyone who has contributed to the development and delivery of ICMIAM 2026. In particular, we thank the organising and technical committees, reviewers, keynote and invited speakers, session chairs, authors, volunteers, administrative colleagues, and all supporting partners whose time, expertise, and commitment have made the conference possible. We are equally grateful to the authors whose work is represented in this abstract booklet; the breadth and quality of the contributions reflect the vitality of the international asset-management community.

Above all, we thank you, our delegates, for joining us in Huddersfield. We hope that the conference provides valuable technical insight, inspires new research and industrial partnerships, creates opportunities for future collaboration, and contributes to the development of smarter, safer, more reliable, and more sustainable engineering assets and systems. We wish you an enjoyable, productive, and memorable ICMIAM 2026.

Sincerely,

Professor Rakesh Mishra and Professor Leigh Fleming

Executive Chairs, ICMIAM 2026
University of Huddersfield, UK

Speakers

Professor (Emeritus) Andrew Ball
Department of Engineering, School of Computing and Engineering, University of Huddersfield, UK
Email: A.Ball@hud.ac.uk

Professor Andrew Ball was the former Pro Vice-Chancellor for Research and Enterprise and Professor of Diagnostic Engineering at the University of Huddersfield, UK. He is internationally recognised for his work in machinery condition monitoring, diagnostics, and predictive maintenance, with extensive engagement across industry sectors. He obtained a First-Class Honours degree in Mechanical Engineering from the University of Leeds and a PhD in Machinery Condition Monitoring from the University of Manchester, where he later held senior academic leadership roles before joining the University of Huddersfield in 2007. Professor Ball established a globally recognised research group in plant maintenance and diagnostics, focusing on fault detection, signal processing, vibro-acoustic analysis, and predictive methods. He has authored over 500 publications, supervised more than 60 research degrees, and received major honours including the Sure. I'm going to include them. Condition Monitoring Society Prize and the British Institute of Non-Destructive Testing COMADIT Prize.

Time/location: 2 September 2026, 11:30 AM - 12:00 PM, OA4/02 (Online)

Professor Parikshit Goswami
Director- Research, Innovation, and Knowledge Exchange. Director, Technical Textiles Research Centre Management Group, Institute of Skin Integrity and Infection Prevention Centre for Functional Materials, University of Huddersfield, UK
Email: P.Goswami@hud.ac.uk

Professor Goswami is a professor of Technical Textiles and the Director of Research and Innovation at the University of Huddersfield. Previously, Professor Goswami was the Associate Dean for Research, Innovation, and Knowledge Exchange for Arts and Humanities, Head of the Department for Fashion and Textiles and then of Music and Design Arts at the University of Huddersfield. He is also the Director of the Technical Textiles Research Centre. Before joining the University of Huddersfield, Professor Goswami was the Director of Research and Innovation at the School of Design at the University of Leeds and led the Fibre and Fabric Functionalisation Research group at Leeds. He is committed to multidisciplinary research and is working towards building constructive collaborations with the University of Huddersfield and industries. Professor Goswami's domains of research are product development using flexible materials and the application of chemistry for functionalising textiles. Professor Goswami manages a large profile of research concerned with fibre/polymer science, nonwovens, medical textiles (implantable materials and non-implantable materials), sustainable materials (fundamentally understanding the properties of new material), application and development of nano/submicron fibres for novel applications, and plasma treatment for functionalising textiles and textile chemistry. Professor Goswami is also the first academic to be appointed to the board of the UK

Fashion and Textile Association (UKFT). Professor Goswami is a Freeman of the City of London and the Worshipful Company of Woolmen.

Time/location: 2 September 2026, 9:30 AM - 10:00 AM, OA4/02

Professor Leigh Fleming
Dean, School of Computing and Engineering, University of Huddersfield, UK
Email: l.t.fleming2@hud.ac.uk

Prof. Leigh Fleming is the Dean for the School of Computing and Engineering at the University of Huddersfield, UK. She previously served as Acting Head of the Department of Engineering & Technology, becoming the first female to hold this role in the school. She holds a BEng (Hons) in Engineering Design, and her PhD focused on 3D analysis techniques for investigating wear in total hip replacements. She also gained industrial research experience at DePuy International. Her research focuses on the application of metrology to novel surface characterisation, particularly skin interfaces, with applications in wound care, pressure ulcer prevention, and assistive technologies to improve health-related quality of life, as well as predictive health maintenance systems in smart homes. She has contributed to major research initiatives including SOLADIM, NanoMEND (FP7), and multiple industrial and collaborative projects involving surface metrology, defect detection, and orthopaedic implant wear analysis. Her current work emphasizes collaboration with clinicians and industry partners to improve the quality of basic healthcare provision. She is a Fellow of the Higher Education Academy and is passionate about equality, diversity, and widening participation in higher education.

Time/location: 3 September 2026, 4:00 PM - 5:00 PM, OA5.5

Ms Fiona Conor
Chief Executive Officer (CEO), Trust Electric Heating, Leeds, UK
Email: fiona@trustelectricheating.co.uk

Ms Conor is the CEO of Trust Electric Heating, a leading UK-based industry providing innovative electric heating solutions for residential and commercial applications. With extensive experience in sales, marketing, and leadership, she has guided the company to the forefront of the UK heating industry. Ms Conor is passionate about smart, sustainable technology and supporting the UK's transition toward Carbon Zero by 2050. Under her leadership, Trust Electric Heating has developed patented, award-winning products, including the fully recyclable NEOS radiator, grown rapidly, and built a reputation for energy-efficient, customer-focused solutions. She is committed to people-first leadership, fostering innovation, and promoting professional development within her team. In recognition of her achievements, she received the SME Managing Director of the Year Award 2025 for her outstanding leadership and contribution to the heating industry.

Time/location: 3 September 2026, 12:00 PM - 12:30 PM, OA4/02

Professor (Hon.) Gopinath (Gopi) Chattopadhyay
Maintenance and Reliability Engineering Programs, Federation University, Churchill, Australia
Email: g.chattopadhyay@federation.edu.au

Prof. Gopinath (Gopi) Chattopadhyay, Ph.D. (University of Qld), has 40 years of experience in industries and Universities in Maintenance, Reliability Engineering, Risk Engineering and Asset Management. He is Postgraduate Programme Coordinator for Maintenance and Reliability Engineering in Federation University, Australia, Chair of Gippsland, past Chairs of Brisbane and Gladstone of Asset Management Council, past President of Australian Society for Operations Research (Qld) and Vice President of Maintenance Engineering Society of Australia (MESA, Qld), industry reviewer of ISO55000 series of standards on Asset Management and Total Asset Management Plan of Queensland Government. Gopi supervised 24 PhD and Master students, secured over 2.5 million Australian dollars of funding and published 200 international journal and conference papers.

Time/location: 1 September 2026, 11:00 AM - 11:30 AM, OA4/02

Dr Raghuvir Pai
Professor (Retd.), Manipal Institute of Technology, MAHE, India
Email: rbpai@yahoo.com

He completed his bachelor's degree in mechanical engineering from Manipal Institute of Technology, Mysore University. Later he pursued his PhD in Tribology from the Indian Institute of Technology, Kharagpur. Subsequently he has worked as a Department of Science and Technology, Government of India, BOYSCAST postdoctoral research fellow at Cranfield University, England. He was a research fellow at Queensland University of Technology, Brisbane and an Endeavour Executive Fellow, Australian Government at Federation University Australia. He was the Dr T.M.A. Pai endowment chair in Tribology at MAHE, Manipal. He has held various administrative positions in MAHE, Manipal over the past 20 years. He was the Head of Department, Mechanical and Manufacturing Engineering, Joint Director at Manipal Institute of Technology, Director of International Centre for Applied Sciences and Director Research (Technical), MAHE, Manipal. He was the founder Dean of the School of Engineering at Manipal's Dubai campus. He was also the founder Dean of the School of Science and Engineering at Manipal International University, Malaysia. He has a number of research publications in journals and international and national conferences. His expertise in research is in the field of water lubricated bearings, externally adjustable bearings, tri-taper bearings, tribology of machining metal matrix composites, Nano lubricants in bearings and Biomechanics. Ten students have completed their Ph D dissertation with him and currently there are six other students pursuing their PhD. He is the founder President of Asset Management Society, India.

Time/location: 2 September 2026, 1:30 PM - 2:00 PM, OA7/29 (58) Hybrid

Professor Jyoti K. Sinha
Head of Dynamics Laboratory, University of Manchester, UK
Email: jyoti.sinha@manchester.ac.uk

Prof. J. K. Sinha is a leading expert in vibration and structural dynamics and currently serves as Head of the Dynamics Laboratory. His research focuses on vibration analysis, structural health monitoring, plant reliability, and maintenance engineering. He works extensively on rotor dynamics, finite element model updating, vibration control, and condition monitoring of rotating machinery. He has published more than 300 technical works including journal papers, conference papers, reports, and books. He received the prestigious Young Scientist (BOYSCAST) Fellowship from the Department of Science and Technology India. His research has supported major industrial projects worth over £3 million. These projects involve vibration analysis of steam turbines, wind turbines, and gearboxes with companies like EDF Energy and QinetiQ. Prof. Sinha has solved many industrial vibration problems, saving industries significant maintenance costs. He has trained engineers from more than 350 industries worldwide in vibration monitoring and reliability engineering. He currently supervises several PhD and professional doctorate students in condition monitoring and bioengineering. So far, he has successfully supervised more than 20 PhD researchers and over 325 postgraduate dissertations. He is Editor-in-Chief of the journal Maintenance, Reliability and Condition Monitoring (MARC) and serves on multiple journal editorial boards. Prof. Sinha also chairs the International Conference on Maintenance Engineering and contributes actively to global research and industry collaboration.

Time/location: 1 September 2026, 1:30 PM - 2:00 PM, OA6/10 (36) (Online)

Professor Prashant Kumar
Founding Director, Global Centre for Clean Air Research (GCARE), University of Surrey, UK
Email: p.kumar@surrey.ac.uk

Professor Prashant Kumar is a distinguished academic and global research leader in air quality, environmental engineering, and public health. His research focuses on air pollution, exposure assessment, urban sustainability, and the health impacts of airborne pollutants. He has made significant contributions to understanding urban air quality, including transport emissions, indoor-outdoor pollution dynamics, and emerging challenges such as airborne transmission of contaminants. Professor Kumar has published extensively in leading international journals and has received several prestigious awards and recognitions for his contributions to air quality research and environmental sustainability. He has led and contributed to numerous high-impact projects funded by UK Research and Innovation (UKRI), the European Commission, and other international agencies, including major initiatives on urban air quality monitoring, low-cost sensing technologies, and clean air solutions for cities. His work has informed policy development at national and international levels, and he collaborates widely with academia, industry, and government organisations worldwide. His leadership and impactful research continue to play a vital role in shaping healthier and more sustainable urban environments.

Time/location: 2 September 2026, 1:30 PM - 2:00 PM, OA7/02 (30)

Professor Sauvik Banerjee
Department of Civil Engineering, IIT Bombay, India
Email: sauvik@civil.iitb.ac.in

Prof. Sauvik Banerjee, Ph.D. (UCLA, California, Los Angeles, USA), currently a faculty in the Department of Civil Engineering, IIT Bombay. He has 22+ years of experience in academia and industry. Prof. Banerjee's research includes structural health monitoring, non-destructive testing and evaluation, wave propagation, acoustic emission (AE), vibration-based damage detection, structural retrofitting, and elastodynamic modelling of advanced composite structures. Prior to joining IIT Bombay, he served for three years as an Assistant Professor at the Parks College of Engineering, Aviation and Technology, Saint Louis University, USA. Over the course of his academic career, he has published numerous research papers, supervised many PhD and master's students, and contributed significantly to the advancement of modern structural health monitoring (SHM) methods. His work connects theoretical modelling with real-world engineering applications aimed at improving the safety and reliability of infrastructure. He has also provided consultancy services to more than 100 organizations in areas such as evaluation of structural design, structural audit and condition assessment of RCC and steel structures, structural health monitoring, structural retrofitting using FRP and FRCM technologies, and on-site supervision of structural strengthening.

Time/location: 2 September 2026, 4:00 PM - 4:15 PM, OA7/29 (58) Hybrid

Professor Patricia Tzortzopoulos
School of Architecture Design and the Built Environment, Nottingham Trent University, UK
Email: patricia.tzortzopoulos@ntu.ac.uk

Professor Patricia Tzortzopoulos is Professor of Architecture at Nottingham Trent University, where she leads the BE: SMART - Smart Built Environment research group. She holds a degree in Architecture and Urbanism and a master's degree from the Federal University of Rio Grande do Sul, Brazil, and completed her PhD in Design Management at the University of Salford, UK. Before joining Nottingham Trent University in 2024, she held several senior leadership roles at the University of Huddersfield, including Head of Department for Architecture and 3D Design and Associate Dean for Research and Enterprise in the School of Art, Design and Architecture. Her research focuses on design management and value generation in the built environment, particularly in healthcare design, social housing, and sustainable construction. Her work addresses areas such as lean construction, building information modelling (BIM), collaborative design, retrofit for energy efficiency, and the relationship between design and health outcomes. Prof. Tzortzopoulos is Chair of the Global Leadership Forum for Construction Engineering and Management Programmes (GLF-CEM) and a board member of the International Council for Research and Innovation in Building and Construction (CIB). She is also a Fellow of the Higher Education Academy and the Chartered Management Institute.

Time/location: 3 September 2026, 9:30 AM - 10:00 AM, OA4/02

Professor Uday Kumar
Division of Operation and Maintenance Engineering Department of Civil, Environmental and Natural Resources Engineering Luleå University of Technology, Sweden
Email: uday.kumar@ltu.se

Professor Uday Kumar is Chair Professor of Operation and Maintenance Engineering and Director of the Luleå Railway Research Center (JVTC) at Luleå University of Technology (LTU). He has held visiting positions at Imperial College London, Helsinki University of Technology, the NSF-sponsored Center of Excellence for Intelligent Maintenance Systems at the University of Cincinnati, and Tsinghua University, Beijing, and serves as Honorary Professor at Beijing Jiao Tong University. With over 30 years of experience in research and industrial consultancy, Prof. Kumar has authored more than 350 publications, including one textbook, eight reference books, and contributions to the World Encyclopaedia on Risk Management. He has led major EU-funded projects and advised global industries such as CRRC, Vale, LKAB, Coal India, and NMDC. He has held leadership roles in professional organisations, including the Swedish National Maintenance Society, RAILENIUM (France), and the European Federation of National Maintenance Societies. Prof. Kumar is Editor-in-Chief of the International Journal of System Assurance and Area Editor (Europe) for the Journal of Quality in Maintenance Engineering. His awards include the Nordea Science Foundation Award, Distinguished Alumnus of IIT BHU, Lifetime Achievement Award from the Society of Reliability and Safety, and he is a Fellow of the Royal Swedish Academy of Engineering Sciences (IVA).

Time/location: 1 September 2026, 11:30 AM - 12:00 PM, OA4/02

Professor Jhareswar Maiti
Chairman, COE-SEA, IIT Kharagpur, India
Email: jmaiti@iem.iitkgp.ac.uk

Prof. Jhareswar Maiti, P C Mahalanobis distinguished Educator and Suresh & Vidya Nair Chair Professor, Department of Industrial and Systems Engineering at Indian Institute of Technology, Kharagpur. He is the founder chairman of the Centre of Excellence on Safety Engineering and Analytics at IIT Kharagpur. He has more than 23 years of experience in teaching, research, and consulting, guided 24 PhD students, executed over 35 funded projects and conducted over 30 training programs for industry. He authored over 220 publications and is in the Editorial Board of Process Safety and Environmental Protection, Safety Science, International Journal of Injury Control and Safety Promotion, and Safety & Health at Work. Prof Maiti's research interests include safety analytics, risk assessment, AI and data science, quality management, and human factors engineering & ergonomics. He authored the textbook "Multivariate Statistical Modeling in Engineering and Management", published by CRC Press. Prof Maiti works with world leading companies like Tata Steel Limited, Adani Group, Coal India, Haldia Petrochemicals, etc. He is Fellow Member of Royal Statistical Society, UK and Institute of Engineers (India). He is also member of ASQ, INFORMS, IISE, IEEE, etc.

Time/location: 1 September 2026, 1:30 PM - 2:00 PM, OA7/26 (30) (Online)

Professor Prabhakar V. Varde
CEO and Director, ERAMC Mumbai, Maharashtra, India
Email: varde@eramc.in

Professor Prabhakar V. Varde is a distinguished expert in nuclear safety, risk, reliability, and asset management. He served for 35 years at Bhabha Atomic Research Centre (BARC), retiring as Outstanding Scientist and Associate Director, Reactor Group. He earned his PhD from IIT Bombay and has held research and visiting positions at KAERI, South Korea, the University of Maryland, USA, IIT Madras, and Luleå University of Technology, Sweden. He has also served as an expert for the IAEA and Nuclear Energy Agency. Professor Varde has published more than 270 international works, including over 21 authored and edited books, and founded the Society for Reliability and Safety (SRESA). His research focuses on risk and reliability engineering, operations and maintenance safety, and AI/ML applications for complex engineering systems.

Time/location: 2 September 2026, 9:00 AM - 9:30 AM, OA4/02

Mr. Matthew Charlton
Technical Director, KOSO Kent Introl Ltd, Brighouse, England, United Kingdom
Email: matthew.charlton@kentintrol.com

Mr. Charlton is the Technical Director at KOSO Kent Introl Ltd, where he leads engineering strategy, product innovation, and technology development for a globally recognised manufacturer of severe-service control, choke, and subsea valves. A Chartered Engineer and Fellow of the Institution of Mechanical Engineers (CEng FIMechE), he has over 15 years of experience delivering advanced engineering solutions across the oil & gas, power generation, and nuclear sectors. Throughout his career, Matthew has developed a strong focus on bridging the gap between academic research and industrial application. Working in close collaboration with the University of Huddersfield, he has successfully delivered five Knowledge Transfer Partnerships (KTP), including an Accelerated KTP (AKTP), helping translate emerging technologies and research outputs into commercially viable engineering solutions and business value. His work has included the industrial application of additive manufacturing, digital engineering technologies, multiphase and multicomponent fluid dynamics, advanced product development, and innovation management. Through these projects, he has gained extensive experience operating as the interface between academia and industry, overcoming the technical, organisational, and commercial challenges associated with innovation adoption. Matthew holds an MSc with Distinction in Mechanical Engineering from the University of Huddersfield, where his research focused on additive manufacturing, and a Postgraduate Certificate in Business Administration and Management from the University of Strathclyde. Through his leadership of collaborative innovation programmes, he has developed a particular interest in accelerating the journey from research to industrial impact, creating practical value from emerging technologies, and fostering long-term partnerships between universities and industry.

Time/location: 1 September 2026, 12:00 PM - 12:30 PM, OA4/02

Dr. Anne Gibbs
Chief Executive Officer (CEO), Asset Management Council, Oakleigh, Melbourne, Victoria, Australia

Dr Anne Gibbs is the Chief Executive Officer of the Asset Management Council, Australia. She is an executive engineering management professional with extensive experience in infrastructure and asset management across Australia and internationally. Her work has spanned water, wastewater, transport, social infrastructure, municipal engineering, humanitarian engineering and disaster-resilient infrastructure. Anne has worked across developed and developing contexts, including projects in the UK, Denmark, Russia, Argentina, Tanzania, Indonesia and Timor-Leste. She holds qualifications in civil engineering, municipal engineering and management, and business administration.

Time/location: 2 September 2026, 12:00 PM - 12:30 PM, OA4/02

Mr. François-Baptiste Cartiaux
Civil Engineer, Head of Research, OSMOS Group, Paris, France
Email: cartiaux@osmos-group.com

Mr François-Baptiste Cartiaux is leading the research activities of OSMOS Group, Paris, France, an engineering company specializing in Structural Health Monitoring (SHM) and digital infrastructure asset management. He has extensive expertise in structural monitoring, bridge weigh-in-motion (WIM), predictive maintenance, digital twins, and data-driven decision support for critical infrastructure. Throughout his career, he has led and contributed to numerous national and international projects involving the long-term monitoring and performance assessment of bridges, tunnels, railways, metro networks, and other critical infrastructure, along with industrial assets and heritage buildings. His notable projects include the implementation of the innovative OSMOS WiM+D® system for bridge weigh-in-motion and structural monitoring on several road bridges in France, Greece and Italy, the structural health monitoring of the Mont Blanc Tunnel, and infrastructure monitoring projects for the Paris Metro in collaboration with RATP. He has also contributed to major SHM initiatives across Europe, Asia, and the Middle East, advancing intelligent monitoring technologies for safer, more reliable, and sustainable infrastructure. Working closely with infrastructure owners, research institutions, and industry partners, he has helped translate advanced sensing technologies and engineering analytics into practical asset management solutions. Mr Cartiaux has authored numerous technical publications and is a frequent speaker at leading international conferences on structural engineering, maintenance engineering, and infrastructure asset management, where he shares his expertise in developing smarter, more resilient infrastructure systems.

Time/location: 3 September 2026, 9:00 AM - 9:30 AM, OA4/02

Professor Jan Harm Christiaan Pretorius
Engineering and the Built Environment, Postgraduate School of Engineering Management, University of Johannesburg, South Africa
Email: jhcpretorius@uj.ac.za

Professor Jan Harm Christiaan Pretorius obtained his BSc Hons (Electrotechnics) (1980), MIng (1982) and DIng (1997) degrees in Electrical and Electronic Engineering at the Rand Afrikaans University and an MSc (Laser Engineering and Pulse Power) at the University of St Andrews in Scotland (1989), the latter *cum laude*. He worked at the South African Atomic Energy Corporation (AEC) as a Senior Consulting Engineer for 15 years. He also worked as the Technology Manager at the Satellite Applications Centre (SAC) of the Council for Scientific and Industrial Research (CSIR). He is currently a professor: Postgraduate School of Engineering Management in the Faculty of Engineering and the Built Environment where he worked since 1998. Head of School: Postgraduate School of Engineering Management (1 July 2015 – Aug 2021). Vice Dean of the Faculty (2005–2010). Departmental Head of Electrical and Electronic Engineering Science (Oct 2003–Feb 2005). He has co-authored over 300 research papers and supervised over 88 PhD and over 400 master's students. He is a registered professional engineer, professional Measurement and Verification (M&V) practitioner, senior member of the Institute of Electrical and Electronic Engineering (IEEE), fellow of the South African Institute of Electrical Engineers (SAIEE) and a fellow of the South African Academy of Engineering.

Time/location: 3 September 2026, 11:30 AM - 12:00 PM, OA4/02

Dr. Mourad Bentahar

Associate Professor, Laboratoire d'Acoustique de l'Université du Mans (LAUM), CNRS UMR 6613, Le Mans Université, France

Email: mourad.bentahar@univ-lemans.fr

Dr. Mourad Bentahar is a lecturer at the National School of Engineering of Le Mans (ENSIM), Le Mans Université, France, and a researcher at the Laboratoire d'Acoustique de l'Université du Mans (LAUM). He received his Ph.D. from INSA Lyon, France, in 2005, where his research focused on the application of nonlinear acoustics to the ultrasonic characterization of damage in heterogeneous materials and the assessment of their remaining service life. His research focuses on nonlinear acoustics, ultrasonic non-destructive evaluation, structural health monitoring, and damage characterization in advanced materials and structures. His expertise spans guided waves, acoustic emission, ultrasonic imaging, air-coupled ultrasonics, phased-array systems, electromagnetic acoustic transducers (EMATs), and signal processing for condition monitoring and integrity assessment. Dr. Bentahar has led and contributed to numerous collaborative research projects with major industrial partners, including Airbus, Safran, Daher Aerospace, Institut de Soudure, CETIM, and the OSMOS Group. His work has advanced innovative acoustic and ultrasonic techniques for the monitoring and assessment of composite aerospace structures, concrete structures, metallic components, bonded joints, and

other safety-critical engineering assets. Through his research, he has made significant contributions to improving the reliability, safety, and lifetime assessment of engineering systems across aerospace, manufacturing, and civil infrastructure sectors.

Time/location: 3 September 2026, 11:00 AM - 11:30 AM, OA4/02

Mr. Alistair Carvell
National Gas Transmission, UK
Email: Alistair.Carvell@nationalgas.com

Alistair is an Innovation Engineer at National Gas Transmission, who operate the gas transmission system in the UK. Alistair has spent several years developing and delivering research projects to support the development of future hydrogen systems, with a focus on measurement, inspection and asset integrity. Alistair now leads the 'Low Carbon Transition' research theme, which is supporting the business to realise it's ambition of net zero operations by 2050 – with an expanded remit which includes the reduction of methane emissions.

Time/location: 2 September 2026, 11:00 AM - 11:30 AM, OA4/02

Conference aims

ICMIAM 2026, the 7th International Conference on Maintenance and Intelligent Asset Management, will be hosted by the University of Huddersfield, UK, from 1–3 September 2026. The conference provides an international forum for sharing advances in maintenance, reliability, intelligent asset management, monitoring, sustainability, and emerging engineering technologies. This abstract booklet is organised according to the conference's five principal research themes, enabling delegates to navigate contributions by their primary area of research.

Conference aims

- Raise awareness of new and emerging developments, technologies, and opportunities in maintenance, reliability, and intelligent asset management.
- Disseminate best practice, high-quality research, industrial applications, and successful approaches to the effective management of engineering assets.
- Encourage knowledge exchange, interdisciplinary discussion, networking, and collaboration among engineers, researchers, industry professionals, policymakers, and practitioners.
- Promote sustainable, resilient, reliable, and performance-driven approaches to the design, operation, maintenance, and lifecycle management of engineering assets.
- Strengthen the connection between academic research and industrial practice, supporting the translation of innovative methods and technologies into real-world asset-management solutions.

Major research themes

The ICMIAM 2026 technical programme is structured around five major research themes, reflecting the conference's multidisciplinary focus on maintenance, intelligent asset management, diagnostics, sustainability, safety, and emerging engineering technologies.

Theme	Research area
Theme 1	Asset Management & Maintenance Systems
Theme 2	Diagnostics, Monitoring & Smart Sensing
Theme 3	Energy Systems, Built Environment & Sustainability
Theme 4	Safety, Risk, Security & Ethics
Theme 5	Advanced & Emerging Applications

Theme scope

Theme 1 – Asset Management & Maintenance Systems

Covers intelligent and standards-based asset management, lifecycle optimisation, reliability engineering, maintenance planning, predictive and condition-based maintenance, and data-driven decision support for engineering assets.

Theme 2 – Diagnostics, Monitoring & Smart Sensing

Focuses on structural health monitoring, non-destructive testing, smart sensing, signal processing, AI- and IoT-enabled diagnostics, condition monitoring, fault detection, and remaining-useful-life estimation.

Theme 3 – Energy Systems, Built Environment & Sustainability

Addresses energy technologies, smart and healthy buildings, net-zero systems, sustainable manufacturing, circular engineering, low-carbon infrastructure, resource efficiency, and environmentally responsible asset management.

Theme 4 – Safety, Risk, Security & Ethics

Encompasses safety and risk engineering, cybersecurity, risk-informed asset-management frameworks, trustworthy artificial intelligence, privacy, resilience, governance, and regulatory considerations.

Theme 5 – Advanced & Emerging Applications

Brings together innovative applications in aerospace engineering, cyber-physical systems, digital twins, smart manufacturing, healthcare and biomedical engineering, robotics, intelligent systems, and other emerging technologies.

Abstract index.

Theme 1 | Asset Management & Maintenance Systems (28 abstracts)

Theme 2 | Diagnostics, Monitoring & Smart Sensing (36 abstracts)

Theme 3 | Energy Systems, Built Environment & Sustainability (40 abstracts)

Theme 4 | Safety, Risk, Security & Ethics (13 abstracts)

Theme 5 | Advanced & Emerging Applications (19 abstracts)

Theme 1: Paper 9

Improving Turbocharger Reliability in Diesel Freight Locomotive Engines Using CBM

Presentation time/location: 3 September 2026, 2:30 PM - 2:45 PM, OA6/07 (30)

Mohamed Ali Mohamed Alaswed*, Jyoti K. Sinha
Department of Mechanical and Aerospace Engineering, The University of Manchester, Manchester M13 9PL UK
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The present work is a case study representing a condition-based maintenance approach to improve the reliability of locomotive diesel engine turbocharger. In this paper, a diesel-electric locomotive in operation within harsh and hot desert environment and its maintenance model are analyzed with focus on its turbocharged engine failures, and particularly the turbocharger failures. A critical review of the current maintenance model is conducted including a failure modes and effects analysis (FMEA), Weibull analysis and reliability block diagram (RBD) analysis using real life turbocharger failure data. Followed by this critical review is an improved maintenance model with details on its implementation and its benefits that relies on condition-based-maintenance (CBM) techniques to detect anomalies on the turbocharger by monitoring parameters such as vibrations, rotational speed, and exhaust temperature. This study is expected to provide greater understanding of the practical implementation of CBM on diesel-electric locomotives in operation within harsh and hot desert environments, and other environments in general. Research at this stage is theoretical, no practical aspects have been implemented and therefore any conclusions are limited until implementation is completed. Published studies using real life data are many in the public domain, what is still limited, however, are studies specific to freight locomotive turbocharged engines with particular focus on the turbocharger failures and how CBM can be implemented as a maintenance strategy to improve reliability, increase uptime, reduce downtime and reduce maintenance cost.

Keywords: -Freight locomotive, turbocharger, turbocharged engine, Condition-Based Maintenance, CBM

Theme 1: Paper 20

DASH: A Real-Time Visualisation and Monitoring Platform for Heterogeneous Precision Manufacturing Equipment

Presentation time/location: 1 September 2026, 4:15 PM - 4:30 PM, OA6/07 (30)

Veda Salkar1*, Ashley Cusack1, Andrew Longstaff1, Andrew Bell1, Joe Kelly1, Derry Falkner2, and Michael Skinner2
1 University of Huddersfield, Huddersfield HD1 3DH, United Kingdom
2 Fives Landis Ltd, Skipton Rd, Keighley BD20 7SD
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Precision manufacturing environments typically operate a variety of multi axis CNC machines and robots, each generating sensor data through distinct interfaces and communication protocols. This variation presents a persistent obstacle to unified monitoring: comparing readings across machine types requires switching between disconnected, vendor specific tools, and configuring a new visualisation typically depends on developer involvement. This paper presents DASH (Data Analytics for Smart WorksHop), a platform designed to allow engineers, rather than dedicated software teams, to integrate variety of sensor data, observe it in real time, and act on the resulting insight. DASH enables a user to construct a agnostic machine manufacturer dashboard by selecting machines, sensor fields, and chart types directly, without requiring a query language or programming knowledge. A built in snapshot and annotation workflow converts a transient anomaly into a documented, severity rated record available for future collaborative review. The underlying architecture comprises a React.js frontend, a Django REST Framework backend, an InfluxDB time series store, and a MySQL relational store, communicating over Server Sent Events with a polling fallback and secured through token based authentication and TLS. The successful implementation of DASH within the Advanced Manufacturing Research Group at the University of Huddersfield has enabled researchers to develop bespoke visualisations for over 250 sensors across 13 assets, supporting improved monitoring and analysis of machine behaviour including the workshop environment itself.

Keywords: Intelligent Asset Management · Real-Time Monitoring · Heterogeneous Manufacturing Assets · CNC Machine Tools · User-driven dashboard · Decision Support Systems.

Theme 1: Paper 22

Stage-Wise Uncertainty Scores in Agentic RAG: An Exploratory Study of Deterministic Failure-OR Fusion

Presentation time/location: 2 September 2026, 4:30 PM - 4:45 PM, OA6/07 (30)

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Multi-stage Retrieval-Augmented Generation (RAG) systems can fail during planning, evidence assessment, or answer generation. This paper introduces and evaluates a stage-wise monitoring baseline that combines semantic-instability scores from the Planner and Evaluator with a Generator P(True) self-assessment through a Bayesian Network (BN) with a deterministic failure-OR-based Conditional Probability Table (CPT). The method is evaluated on 200 StrategyQA and 200 HotpotQA examples using GPT-3.5-Turbo and GPT-4.1-Nano. On StrategyQA, the Generator score is more discriminative than the Overall BN score. On HotpotQA, Overall score improves AUROC over the Generator by 0.0167 and 0.0095 for the two models, respectively, although these differences lack confidence intervals and may reflect sampling variation. Because the stage scores are uncalibrated proxies, ECE and Brier scores are descriptive rather than evidence of probabilistic calibration. The results characterise benchmark-dependent behaviour of fixed stagescore fusion and provide a

transparent baseline for future calibrated and learned fusion models; however, they do not establish superiority over alternative fusion operators, error localisation, probabilistic calibration, or suitability for safety-critical deployment.

Keywords: Agentic RAG · Uncertainty Quantification · Runtime Monitoring · Selective Prediction

Theme 1: Paper 24

Maturity assessment of maintenance management practices: A ferro-alloy smelter case-study.

Presentation time/location: 2 September 2026, 3:45 PM - 4:00 PM, OA7/29 (58)

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South Africa is one of the leading exporters of Ferro-alloy metal in the world. In 2024 South Africa generated an export value of $4.18 Billion which accounted for 10.48% of the overall international export value. The research herein evaluates maintenance management practices at one of the ferro-alloy producing companies in South Africa using a maintenance maturity model. The study determines the current level of maintenance maturity within the company. To run a competitive ferroalloy producing organization, a well-managed maintenance engineering department is a pre-requisite. For an organization to embark on a maintenance improvement journey, a comprehensive understanding of current status of maintenance management practices needs to be sought to evaluate where the organization is in terms of maintenance, where it is headed and how it will get there. Fifteen participants were sampled to take part in the study by responding to a close-ended research questionnaire distributed to their respective email addresses. The data obtained from the study revealed that the current overall maturity level of maintenance management practices within the case-study organization is 2.99/5, indicating that practices are well defined and balanced. However, they are not yet advanced or world class. Further analysis indicated few performance classes where the organization can deploy its resources to gradually elevate to higher maturity levels.

Keywords: Ferroalloy, Maintenance management practices, Maintenance maturity model, purposive sampling, performance classes.

Theme 1: Paper 29

Health-Centric Risk-Weighted Maintenance Decision Models for Smart Home Asset Management

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA6/07 (30)

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Asset management decision making, as formalised in ISO 55000, has traditionally prioritised physical degradation, reliability, and cost-based risk to realise value from assets across their lifecycle. In prior work, health and wellbeing were positioned as assets within intelligent smart home environments, bringing human consequence to the forefront of asset management thinking. However, while this reframing establishes conceptual alignment, smart home maintenance and control actions largely remain governed by static sensor thresholds that do not explicitly account for risk to occupant health. As a result, identical environmental conditions may trigger identical responses, despite markedly different health risks arising from variations in occupancy, exposure duration, and occupant vulnerability. This paper extends the health-centred asset management perspective by proposing a health risk–weighted maintenance decision model that adapts established risk-based maintenance principles to domestic smart environments. Health is inferred using environmental and contextual proxies, supporting non-diagnostic risk assessment while enabling clinically relevant environmental insight. Decision making is supported through a structured and interpretable prioritisation framework that integrates environmental deviation, exposure duration, occupant vulnerability, and consequence severity to rank maintenance and control actions according to potential impact on health-related asset value. Using illustrative scenarios from a smart house research facility, the paper demonstrates how risk-weighted decision support moves beyond rule-based automation to support preventive, human-centric asset management. The proposed approach aligns with ISO 55000 principles of value, risk, and lifecycle thinking, while remaining compatible with existing smart home sensing and control architectures.

Keywords: Intelligent asset management, smart homes, health risk, maintenance decision support, condition monitoring.

Theme 1: Paper 37

Impact of Data Resolution on Machine Learning-based Predictive Maintenance on a heavy-duty automated door system: Local vs Cloud Storage Approaches

Presentation time/location: 2 September 2026, 5:15 PM - 5:30 PM, OA7/29 (58)

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Heavy-duty automated door systems must operate with high dependability to guarantee the continuous functioning of commercial and industrial facilities. The overall performance and efficiency of such systems are heavily influenced by their reliability and maintenance strategies. However, unexpected system downtime and regulated maintenance cycle both contribute significantly to the increased long-term operational costs of the system. Predictive maintenance (PdM) incorporating the remaining useful life (RUL) estimation offers a proactive approach to addressing this problem. Thus, reducing the unplanned failures and optimising the

maintenance cycles. Recorded statistical datasets were used to make predictions based on machine learning (ML) algorithms that were implemented while monitoring an automated remote industrial heavyduty sliding door system. The goal was to manage and predict the mechanical degradation of the critical operational and load-bearing components by evaluating degradation in energy efficiency, consumption, and cycle time drift of the system. The research employs Random Forest (RF), Gradient Boosting (GB), and Linear Regression (LR), and applies them to cloud-recorded datasets to develop a PdM model that can foresee the degradation and predict RUL of an element. In this regard, RF achieved the best performance in predicting performance at 0.85, followed by GB at 0.81, while LR had a performance of 0.60. Local data was collected and analyzed using the same algorithms as the cloud data; significant differences in performance were thereby looked into. This paper considers trade-offs between low-sampling cloud data and high-resolution local data for insights into industrial remote monitoring and predictive maintenance.

Keywords: Predictive Maintenance (PdM), Remaining useful Life (RUL), Automation, Control, Heavy Doors.

Theme 1: Paper 39

Improvement of FMECA Framework: A Case Study

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA6/07 (30)

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Failure Mode Effects and Criticality Analysis (FMECA) is a powerful tool for reliability analysis. While the framework of the concept has stayed the same since it developed, a number of modifications are observed in various literature. These studies provide improvement opportunities in the FMECA methodology based on some practical issues identified like duplicate Risk Priority Numbers (RPN), high sensitivity to small changes, gaps in the range, subjectivity, dispersion of RPNs etc. These issues can result in overestimation or under estimation of the criticality of various failure modes. In this paper, the main challenges to proper implementation of FMECA framework are briefly described using a case study, and some initiatives for improvement in the FMECA framework are also proposed. The proposed improvements are based on the quantification of relative weightage of occurrence, severity and detectability of failure modes. Analytic Hierarchy Process (AHP) is used to calculate these weightages by further analysis of different contributions (both process and technical parameters) for each failure mode.

Keywords: FMECA, RPN, AHP, Priority Vector.

Theme 1: Paper 56

Comparative Evaluation of Bagasse Dryers: Selection, Maintenance and Parameter Analysis

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA6/07 (30)

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The effective utilization of sugarcane bagasse in developing countries is constrained by its high moisture content and the limited availability of suitable drying technologies. Although several commercial dryers exist, their adoption is often hindered by high capital costs, complex fabrication requirements, and demanding maintenance needs. This study presents a comparative evaluation and selection of a low-temperature pneumatic dryer with a focus on ease of maintenance, operational simplicity, and suitability for resource-constrained environments. A weighted analysis of common drying technologies was conducted using criteria including cost, energy consumption, ease of fabrication, maintenance requirements, and drying efficiency. The pneumatic dryer emerged as the most suitable option due to its simple configuration, low maintenance demands, compact footprint, and reduced risk of fire hazards when operated at moderate temperatures. A preliminary parameter analysis using a Page model was applied to estimate optimal drying conditions. Results indicate that operation at approximately 78°C with controlled air velocity can achieve rapid moisture reduction suitable for briquette production while maintaining safe operating conditions. The findings highlight the importance of incorporating maintenance and practical deployment considerations into technology selection. This work provides a foundation for subsequent detailed design and development of a locally manufacturable drying system.

Keywords: Sugarcane Bagasse; Pneumatic Dryer; Maintenance; Comparative Analysis; Biomass Drying; Appropriate Technology; Parameter Optimisation.

Theme 1: Paper 67

A Multi-Criteria Framework for Prioritising Robotic Automation of Rolling Stock Maintenance and Inspection Task

Presentation time/location: 1 September 2026, 2:00 PM - 2:15 PM, OA6/07 (30)

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Robotic automation has the potential to improve efficiency, safety, and consistency of railway rolling stock maintenance. However, it is not always clear which maintenance tasks should be prioritised for automation, especially when many routine depot tasks differ in frequency, complexity, safety risk, and practical feasibility.

This paper presents a multi-criteria framework for prioritising light maintenance and inspection tasks for robotic automation. The framework combines three main criteria: Task Frequency and Effort (TFE), Task Complexity (TC), and Long-Term Wellbeing and Safety Risk (LTWSR). The relative contribution of these operating parameters to a task was established using the Analytic Hierarchy Process (AHP). The method was applied to 163 preventative maintenance tasks from a mid-life Diesel Multiple Unit. Expert judgement was also used to classify each task by automation feasibility, complexity, task type, and suitable robotic technology. The results show that 22.5% of tasks were considered feasible for full automation, while 75.5% could benefit from robotic assistance. Robotic arm was identified as the most suitable technology for 106 tasks, representing 65% of the analysed maintenance activities. The computed task complexity score showed a strong positive correlation with expert complexity ratings, with (r = 0.752) and (R^2 = 0.566). The framework provides a practical decision-support tool for identifying maintenance tasks that are both beneficial and realistic candidates for robotic automation.

Keywords: Railway Maintenance, Robotics, Automation Prioritisation, Multi-Criteria Decision Making, Rolling Stock Maintenance, Artificial Intelligence

Theme 1: Paper 70

A Predictive Maintenance Framework for Multi-Mode Damper-Failure Detection in Railway Vehicle Dynamics

Presentation time/location: 3 September 2026, 2:15 PM - 2:30 PM, OA6/07 (30)

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Vertical-damper failure in railway bogies has long resisted inservice detection because its acceleration signature closely resembles normal running over track irregularities. This paper contributes: (i) a multimode formulation that detects yaw-, lateral-and vertical-damper failures jointly as a four-class problem over a 36-scenario Vampire simulation matrix (three speeds, three wheel–rail conicities, measured UK track geometry, 42 sensor channels, 292,525 labelled samples); (ii) physics-informed asymmetry features, left/right power-imbalance ratios and inter-channel correlation loss, that isolate the symmetry breaking caused by unilateral failure; and (iii) a class-balanced LightGBM pipeline reaching 96.1 % balanced accuracy and 0.996 macro ROC-AUC under five-fold crossvalidation, with held-out MCC and Cohen's kappa of 0.95, verticalfailure recall of 0.94, and above 94 % accuracy in every speed and conicity stratum. Feature importance confirms the hypothesised asymmetry mechanism, and carbody-mounted sensors dominate, enabling low-power retrofit monitoring as the detection layer of an integrated predictivemaintenance stack.

Keywords: Predictive Maintenance · Vertical-Damper Detection · Light-GBM Classification · Physics-Informed Features · Vampire Simulation · Railway Condition Monitoring.

Theme 1: Paper 84

Meta-Model for Comparing Process Models for Developing Data-Driven Industrial Services and Derived Differentiation Criteria

Presentation time/location: 1 September 2026, 2:15 PM - 2:30 PM, OA6/07 (30)

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This paper contributes to a comparison of existing process models for the development of Data-Driven Industrial Services (DDIS). These process models are increasingly important as the role of data in asset management grows. This paper answers the following research questions: (1) How can process models be described in a systematic and comparable way? and (2) Which differentiation criteria can be derived based on this systematic and comparable description? A qualitative content analysis establishes a novel meta-model for data-driven industrial service development process models (MM-DDIS-PM), and derives 14 differentiation criteria across 17 process models for DDIS development. The novel MM-DDIS-PM can be applied to both existing and newly developed process models in the DDIS domain and consequently also in asset management. The derived differentiation criteria represent a first step toward enabling practitioners to identify process models that best fit the requirements and interests of their DDIS development projects. The novel MM-DDIS-PM enables future researchers to develop and analyze process models in the DDIS domain as well as in other domains.

Keywords: IndustrialService Development, Data-Driven Industrial Services, Process Models, Qualitative Content Analysis, Meta-model, Comparison

Theme 1: Paper 86

Exploring Hybrid Working Approaches in Oil and Gas Project Management

Presentation time/location: 2 September 2026, 4:15 PM - 4:30 PM, OA7/31 (60) Hybrid

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This study explores hybrid working in oil and gas project management, aiming to enhance understanding of its benefits and challenges. Hybrid working refers to the blending of remote and on-site working modalities. Employing an interpretivist, exploratory design with qualitative methods, the research involved semi-structured interviews with industry experts. Thematic analysis, triangulated with other sources, ensured data reliability and validity, while ethical considerations were prioritized. Findings highlight the need for oil and gas project management to adapt, requiring revised communication, flexible workflows, digital integration, and a focus on well-being and trust. The industry should implement a flexible hybrid model with robust communication tools, inclusive protocols, and advanced technology, fostering collaboration and supporting employees. Embracing digital transformation through real-time project management tools, agile methodologies, and innovative solutions is crucial.

Keywords: Hybrid Working Models; Oil and Gas Project Management; Digital Transformation; Human Factors and Well-Being; Risk-Aware Project Governance

Theme 1: Paper 89

Application of Digital Twin technology in Predictive Failure Analytics for Control Valve Systems: Integrating CFD for Cavitation Mitigation and Flow Visualization

Presentation time/location: 1 September 2026, 2:30 PM - 2:45 PM, OA6/07 (30)

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This paper explores the application of Digital Twin technology in control valve systems, particularly focusing on predictive failure analytics. A 1D numerical model is developed to predict regional flow within a control valve, serving as a basis for trim design and optimisation. The study uses computational fluid dynamics (CFD) to simulate the internal flow of a control valve at various opening positions. These simulations are validated against experimental data, demonstrating high accuracy. The paper also presents a 2D reduced-order model to visualise pressure and velocity within the valve, enabling the identification of potential cavitation areas. By monitoring these areas, the system provides predictive maintenance alerts, helping to prevent operational disruptions and optimise maintenance costs. The findings emphasise the effectiveness of the trim in maintaining vapour pressure and preventing cavitation, particularly in the valve body region.

Keywords: Digital Twin, Control valves, flow coefficient, numerical simulation, valve design, pressure distribution, computational fluid dynamics, local flow analysis.

Theme 1: Paper 92

Beyond Digital Planning: Embedding Last Planner Routines for Reliable Production Control

Presentation time/location: 1 September 2026, 3:15 PM - 3:30 PM, OA6/07 (30)

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Although digital planning tools are widely adopted on industrial construction projects, workflow reliability often remains weak because implementation of software does not necessarily result in adoption of production-control practices. This study examines a large industrial brownfield project at Tata Steel's Port Talbot works where an established digital planning platform provided planning visibility, reporting, and programme alignment, but Last Planner System (LPS) routines were not consistently embedded in day-to-day operations. Using action research, the study compared 16 baseline weeks with a 10-week intervention that introduced six-week lookahead planning, structured constraint management, readiness-based weekly work planning, and daily commitment control while retaining the existing digital platform. Planning reliability improved, with PPC increasing from 79% to 90%, alongside improved work-release discipline, coordination, and workforce planning stability. The findings suggest that production-control capability emerges from the interaction of digital tools, planning routines, governance structures, and commitment practices rather than technology alone. The study contributes practical and theoretical insights into how organisations can realise additional value from existing digital planning investments through behavioural and process improvements.

Keywords: Last Planner System, Digital Planning Tools, Production Control, Industrial Construction, Workflow Reliability

Theme 1: Paper 93

An Asset-Centric Cost Optimization Framework for Slurry Transport in Non-Circular Ducts

Presentation time/location: 1 September 2026, 3:00 PM - 3:15 PM, OA6/07 (30)

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Efficient slurry transport requires a design strategy that balances hydraulic performance with the economic consequences of duct sizing, pumping energy demand and fabrication cost. This paper presents an asset-centric cost optimization framework for slurry flow in rectangular, non-circular ducts by integrating CFD-generated data, artificial neural network (ANN) prediction and lifecycle cost analysis. A full-factorial CFD dataset containing 81 cases was used to relate four non-dimensional operating and material parameters, namely velocity ratio, solid concentration, hydraulic diameter ratio and solid-to-water density ratio, to two key responses: relative pressure drop and concentration ratio. Separate feed forward ANN models were trained for each response using normalized data and an 80/10/10 split for training, validation and testing. The models showed excellent agreement with CFD simulations, achieving R^2 values of approximately 0.999 and a maximum re-evaluation error of 6.10%. The validated predictive model was then coupled with head loss, pumping power, manufacturing cost and operating cost equations to evaluate the total cost of slurry transport for zinc, coal and iron ore slurries. The results show that increasing hydraulic diameter reduces head loss and pumping power, while increasing manufacturing cost; therefore, the total cost exhibits a clear economic optimum. For the investigated cases, minimum cost values occurred close to a hydraulic diameter of 0.2 m, while a zinc slurry design example identified 0.24 m as the lowest-cost diameter for the specified flow rate. The proposed framework provides a rapid decision support approach for selecting economically efficient duct designs while reducing reliance on repeated CFD simulations.

Keywords: Slurry Transport; Cost Optimization; Non-Circular Ducts; Computational Fluid Dynamics (CFD); Artificial Neural Networks (ANN); Lifecycle Cost.

Theme 1: Paper 111

Intelligent Asset Management of EOT Cranes: A Data-Driven Approach

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA6/07 (30)

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Operation of an Electric Overhead Traveling (EOT) crane, as an overhead material handling system, is inherently critical and necessitates stringent safety protocols. These cranes are indispensable in heavy industries, facilitating both vertical lifting and horizontal transportation of loads. However, their overhead nature significantly amplifies operational risks, particularly in the event of load drops, thereby making robust maintenance practices and reliability assurance essential to prevent accidents. A systematic analysis of historical failure data across multiple EOT cranes can provide valuable insights into critical components and recurring failure modes. Such analysis supports the development of predictive maintenance strategies aimed at reducing failure frequency and improving operational reliability. In this study, around 15 years' worth of operational and failure data from a fleet of EOT cranes in a heavy industrial workshop is examined. This paper proposes a stochastic synthetic maintenance log generator that learns empirical failure distributions, transition probabilities, and inter-arrival time distributions directly from historical maintenance records. The generated maintenance logs preserve the key statistical characteristics of the original data and provide scalable datasets for benchmarking predictive maintenance algorithms when real industrial data are limited. The framework further highlights the potential of Industry 4.0 by enabling data-driven maintenance research using historical maintenance logs and offers a practical solution for legacy industrial systems where continuous condition-monitoring data are unavailable.

Keywords: Overhead crane · Predictive maintenance · Reliability · Synthetic data generation · Data-driven decision-making · Industry 4.0.

Theme 1: Paper 113

Real-Time Digital Shadow Development of an Electric Radiator

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA6/07 (30)

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The increasing demand for smart energy monitoring and predictive maintenance has accelerated the adoption of digital representations of physical systems. This work investigates a digital shadow of an electric radiator, defined as a virtual representation that receives data through a oneway physical-to-virtual connection. The primary objective is to acquire real-time electrical measurements from a physical radiator using a PZEM-004T power-monitoring module and transmit the measurements to a MATLAB/Simulink environment containing the virtual counterpart. Radiator and room temperatures are also measured using DS18B20 temperature sensors. A physics-based radiator-room model is implemented in Simscape and driven by the measured active power. The streamed measurements are logged for further analysis, while the virtual-model response is compared with the measured behaviour of the physical system. The preliminary results show that the digital shadow can provide real-time visibility of the radiator's electrical and thermal behaviour. Changes in power consumption and equivalent resistance provide useful indicators of operating conditions. The developed

framework provides a foundation for future closed-loop digital-twin implementation involving predictive control, energy optimisation, thermal-comfort assessment, and distribution-grid impact analysis.

Keywords: Digital shadow · Electric radiator · MATLAB/Simulink · Simscape · PZEM-004T · Condition monitoring

Theme 1: Paper 115

Testing Economies of Heavy-Duty Compressors Facilities

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA6/07 (30)

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Energy efficiency is a critical priority for heavy engineering industries aiming to reduce operational costs and enhance sustainability. Compressed air systems, being among the most energy-intensive utilities, present significant opportunities for optimization, particularly in facilities operating multiple high-capacity compressors. This study evaluates the energy performance of an industrial setup comprising of 16 compressors with capacities of 500 CFM and above. A detailed analysis of energy consumption patterns and load distribution is conducted to identify inefficiencies in current operations. The study investigates energy-saving potential through improved asset management, optimized scheduling, and demand-based utilization of compressed air. Emphasis is placed on operational and managerial interventions that enhance system efficiency without requiring additional capital investment. The results demonstrate that substantial energy savings can be achieved through better planning, control, and utilization of existing infrastructure. This approach challenges the conventional reliance on capital-intensive upgrades, highlighting instead the effectiveness of low-cost, strategy-driven optimization. The proposed framework offers a practical pathway for industries to achieve immediate financial benefits while advancing energyefficient operations.

Keywords: Compressed Air System · Energy Optimization · Compressor Scheduling · Binary Integer Linear Programming (BILP) · Cubic Feet minutes (CFM)

Theme 1: Paper 127

Technology Barrier to Predictive Maintenance in the Railway Sector: DEMATEL Causal Analysis

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA6/07 (30)

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The increasing complexity of railway assets, compounded by decades of underinvestment in the South African rail sector, has created a need for data-driven maintenance strategies to improve reliability and reduce failure risks. Predictive maintenance, enabled by advances in sensing technologies, data analytics, and artificial intelligence, offers a shift from reactive and time-based maintenance practices toward proactive asset management. Despite its potential, implementation remains constrained by several technological barriers within the local operating environment. This study combines a comprehensive literature review, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, and insights from 15 senior railway engineering practitioners to examine these challenges. The findings identify eight key technological barriers. Among these, inadequate interoperability between legacy systems and modern IoT platforms, insufficient sensor infrastructure, and limited real-time connectivity in remote areas emerge as the most critical obstacles. Challenges related to cybersecurity, digital twin maturity, machine learning interpretability, and data quality are found to be largely influenced by weaknesses in the underlying digital infrastructure. Overcoming these barriers is essential for enabling the successful adoption of predictive maintenance and supporting the digital transformation of the South African railway sector.

Keywords: Predictive Maintenance, DEMATEL, IoT, Railway Engineering, Digital Transformation.

Theme 1: Paper 130

Design and Implementation of an IoT Telemetry Database for Sensor-Informed Digital Twins in the Huddersfield Smart House

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA6/07 (30)

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A building Digital Twin requires a dependable telemetry layer before sustained simulation, prediction or automation can be validated. This paper presents an operational proof-of-concept data layer for the Huddersfield Smart House. Room 2 indoor measurements and an outdoor boundary node are transported through MQTT, parsed by Telegraf and stored in InfluxDB for Grafana visualisation and downstream engineering interfaces. The implemented schema separates temperature and relative humidity, CO2, equipment power and model outputs. A 15-min export provided initial evidence of ingestion and retrieval at a nominal 10-s cadence. Indoor temperature, relative humidity and CO2 achieved 100% regular-grid completeness; the outdoor stream achieved 98.9%, with one 20-s gap. No duplicate or range-rejected values were found. The evaluated dataset comprised Room 2 indoor temperature, Room 2 relative humidity, Room 2 CO2, outdoor temperature and outdoor relative humidity. Radiator-power telemetry, CFD coupling and MATLAB integration were complete in the wider system setup but were not demonstrated in the reported 15-min study; automation was also not demonstrated. The contribution is a transparent MQTT–Telegraf–

InfluxDB– Grafana backbone and a reproducible distinction between implementedand-evaluated functions and implemented-but-unevaluated Digital Twin interfaces.

Keywords: Digital Twin · Internet of Things · MQTT · InfluxDB · indoor environmental quality · smart house

Theme 1: Paper 142

Failure Behaviour Fragmentation Analysis of Aircraft Maintenance Narratives for Component-Level Reliability Interpretation

Presentation time/location: 3 September 2026, 3:30 PM - 3:45 PM, OA7/29 (58) Hybrid

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Unstructured maintenance records contain operational evidence relevant to reliability analysis, but variability in technical language and inconsistent representation of failure information limit their direct use in engineering interpretation. Existing maintenance text analytics research has focused predominantly on classification, prediction, and information extraction, with limited attention to how failure behaviour is distributed at component level. This study proposes a structured framework for interpreting failure behaviour from aviation maintenance narratives using dual-field mechanism extraction and distribution-based analysis. Historical records from the MaintNet University of North Dakota aviation dataset were analysed for three engine-related components: intake gaskets, rocker cover gaskets, and baffles. Failure mechanisms were extracted from both labelled Problem and Action fields, because field orientation is not consistent across component datasets, and corrective actions were excluded unless an explicit mechanism term was present. Concentration and fragmentation measures were then applied at component level. The results show a monotonic fragmentation gradient. Intake gaskets are almost entirely leak-dominated, rocker cover gaskets remain concentrated, and baffles are strongly fragmented across eight mechanism categories. The unclassified rate rises in the same order, from 0.6 to 18.2 per cent, indicating that fragmented failure representation co-occurs with reduced documentation completeness. Baffle fragmentation computed from raw narrative text matches that computed from independently assigned categories, supporting measurement robustness. The proposed approach improves the engineering interpretability of maintenance narratives by addressing variability in failure representation and incomplete mechanism identification. It provides a transparent and extensible framework for mechanism-level reliability interpretation in data-limited maintenance environments.

Keywords: Maintenance narratives, Failure behaviour fragmentation, Component-level reliability, technical language processing, Maintenance text analytics, Aviation maintenance

Theme 1: Paper 143

LLM-Based Structuring and Reliability Analysis of SDR Logs for Aircraft Maintenance

Presentation time/location: 3 September 2026, 3:15 PM - 3:30 PM, OA7/29 (58) Hybrid

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Organisations involved in aircraft maintenance receive large numbers of service difficulty reports (SDRs) and maintenance logs daily. The majority of records are stored in free-text format, which is very difficult and time-consuming for aircraft maintenance engineers and continuing airworthiness management organisations (CAMOs) to analyse. The current work proposes a system for converting unstructured aircraft maintenance records into structured records useful for reliability analysis and Reliability-Based Control (RBC). This study employed a dataset of 500 Boeing 737 SDRs acquired from the FAA SDR Database. The proposed approach used Python and the Streamlit library to develop web-based applications. The large language model (LLM), Phi-3, deployed via the local server Ollama, is used to perform Natural Language Processing tasks on unstructured maintenance records and extract maintenancerelevant data. Various categories, such as Component, Failure mode, Location, Reliability action, and Severity, are automatically detected using the LLM. The generated structured dataset was then used to produce reliability graphs, including monthly defects trend analysis, the ATA distribution graph, the Pareto analysis, the severity distribution graph, and recurring defect detection. High extraction precision for each category, particularly for Component, with validation accuracy up to 91%, has been obtained. The lowest precision is observed for Severity, with 73% validation accuracy, owing to its semantic dependence within the context of a maintenance record narrative.

Keywords: Large Language Model, Aircraft Maintenance, Reliability-Based Control (RBC), SDR Analysis, Reliability Analysis, Streamlit.

Theme 1: Paper 153

Insights from a Correlational Analysis of Indian Railways Key Performance Indicators

Presentation time/location: 2 September 2026, 3:15 PM - 3:30 PM, OA7/29 (58) Hybrid

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This paper presents insights from a quantitative analysis of the operating dynamics, financial metrices, and socio-environmental contributions of the Indian railway (IR) network over a 20-year longitudinal period (FY2003-04 to FY2023-24). Utilising an empirical dataset compiling official Ministry of Railways annual report and statistical statements. The paper reveals the systemic coupling of seven core key performance

indicators (KPIs): Operating Ratio (OR), freight tonnage, route electrification, passenger volume, labour headcount, average employee wage, and capital expenditure (CapEx). Statistical correlational modelling via Pearson correlation reveals a strong correlation between elevated operating ratios and the passenger sector deficit, which is systematically offset by a cross-subsidisation surcharge on high-value freight. Quantitative assessment of a strategic 5-percentage-point modal shift of freight traffic (230 billion tonne-kilometres) from road to rail demonstrates a significant base macroeconomic benefit. Our analytical framework validates that while massive capital injections have scaled CapEx by over 13-fold, IR's true OR reaches over 100% when pension liabilities are fully recognised, indicating that physical expansion has bypassed financial sustainability. The study evaluates these findings against the systemic challenges of internal crosssubsidisation, where freight earnings offset passenger losses, and examines the performance limits of semi-high-speed rolling stock due to various limiting factors. The paper concludes with policy recommendations designed to improve multimodal integration and financial sustainability.

Keywords: Strategic Asset Management, Capital Planning, Key Performance Indicators, Performance Analysis.

Theme 1: Paper 159

Mobilizing Domain Expertise through Ontology-Based Neurosymbolic AI: An Action Design Research Study in Industrial Maintenance

Presentation time/location: 3 September 2026, 1:45 PM - 2:00 PM, OA6/07 (30)

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Industrialized economies such as Germany derive substantial competitive advantage from deep, tacit domain expertise embedded in skilled service technicians and complex industrial machinery. However, mobilizing this expertise through artificial intelligence remains challenging: generative AI approaches typically lack semantic grounding in the underlying service system, while purely technical solutions often neglect the socio-technical nature of industrial maintenance work. This paper addresses this gap through a case study of industrial machine maintenance, in which a service technician is supported by a hybrid human-AI system during diagnostic and problem-solving tasks. Following the Action Design Research methodology, the AI system is developed through iterative Build–Intervention–Evaluation cycles across three interlocking design phases. Phase 1 builds a semantic service model based on a structured ontology that formalizes actors, artifacts, process steps, and settings of the maintenance service as a machine-interpretable representation. Phase 2 designs a neurosymbolic AI architecture that combines hybrid retrieval with large language model capabilities, enabling reasoning over both formalized knowledge and unstructured data. Phase 3 integrates the human-centered design dimensions – AI adoption, human-AI dynamics, technology, AI implementation, and AI ethics – that shape design decisions in the other phases. Building on the case findings, this study derives an integrative framework that abstracts the design phases into six design principles for hybrid human-AI services in industrial settings. The framework contributes to research on intelligent asset management and Industry 5.0 and offers practical guidance for designing trustworthy, expertise-mobilizing AI-enabled services in knowledge-intensive industrial domains.

Keywords: hybrid intelligence, human-AI interaction, neurosymbolic AI, service prototyping, action design research, industrial maintenance

Theme 1: Paper 167

Predicting water main failures from climate-driven soil movement: a correlation-based approach for future risk assessment

Presentation time/location: 2 September 2026, 4:45 PM – 5:00 PM, OA7/31 (60)

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Soil movement has continually been a driver of water main failures, and as climate change becomes an increasingly recognised risk, understanding its influence on soil movement and the resulting impacts on water infrastructure has become vital. This case study investigates the relationship between climatedriven soil movement and water main failures within a regional water distribution network in Victoria, Australia. Using historical water main failure records from 2018 to 2025 and climate data obtained from Bureau of Meteorology weather stations across the region, a correlation-based approach was developed to assess the influence of soil moisture conditions on pipe failure occurrence. Soil moisture was represented using an Antecedent Precipitation Index (API), which incorporates both rainfall and temperature effects. The likelihood of failure occurrence was then assessed against API conditions for different pipe materials while also accounting for reporting and detection delays, which can be common in regional water networks. The outcomes indicate that lower API values, corresponding to drier soil conditions, are associated with increased water main failure occurrence particularly for asbestos cement (AC) pipes. Future climate projections from three different climate models suggest a shift towards drier soil conditions, therefore suggesting a possible increase in the likelihood of failure occurrence events (days with at least one failure) across the network. However, the magnitude of future impacts is also strongly influenced by asset management strategies such as accelerated replacement of vulnerable AC mains which was shown to minimise projected failure occurrence. The methodology provides a practical and transferable approach for regional water utilities to assess climate-

related asset vulnerability, evaluate climate adaptation strategies and support long-term asset management under future climate scenarios.

Keywords: Soil Movement, Climate Change, Water Mains, Rainfall, Temperature, Correlation Analysis

Theme 1: Paper 190

Reinforcement Learning-EnhancedStochastic Petri Net Framework for Opportunistic Maintenance of Offshore Wind Turbine Blades

Presentation time/location: 3 September 2026, 2:00 PM - 2:15 PM, OA6/07 (30)

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Offshore wind turbine operations and maintenance (O&M) significantly impact the levelized cost of energy, with vessel logistics representing a major expense. Although condition-based maintenance (CBM) reduces corrective interventions, it often triggers independent vessel dispatches for individual faults, leading to unnecessary mobilisation costs when concurrent blade degradation occurs. This paper addresses this inefficiency by extending a previously developed stochastic Petri net (SPN) Monte Carlo simulation framework, while retaining the original model parameters, by introducing a reinforcement learning (RL) decision layer for opportunistic scheduling. A tabular Q-learning agent monitors detected but unserved blade defects and decides whether to dispatch a vessel immediately or wait for a limited period so that additional blade repairs can be bundled into the same vessel trip. The agent was trained over 3,000 simulated 25-year lifecycles and evaluated across 3,000 paired test episodes using identical stochastic realisations against a rule-based CBM baseline, in which each detected blade defect triggers immediate maintenance scheduling without intentional waiting for additional defects. The results show that the RL framework reduces mean vessel dispatches from 43.54 to 42.29 trips per lifecycle, achieving a 2.9% reduction, equivalent to 1.25 fewer trips on average. At the same time, the approach increases turbine availability by 0.0499% and decreases mean turbine downtime by 109.3 hours. These findings suggest that RL-driven opportunistic scheduling can improve vessel utilisation and operational performance within the assumptions of the proposed offshore wind O&M simulation framework.

Keywords: Offshore Wind Turbine, Stochastic Petri Net, Reinforcement Learning, Opportunistic Maintenance, Condition-based Maintenance, Monte Carlo Simulation

Theme 1: Paper 205

Digital Twin Integration of Hazard-Based Maintenance Scheduling: An Advisory Architecture with Auditable Decision Triggers

Presentation time/location: 1 September 2026, 4:30 PM – 4:45 PM, OA6/07 (30)

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A maintenance plan commits labour, spares, and downtime against the chance of failure inside a defined future window. Hazard-based decision models now supply that chance, yet the operational route from a model output to an accountable maintenance instruction inside a Digital Twin remains only partly specified. This paper addresses that integration stage in an offline, operator-in-the-loop advisory Digital Twin, extending two earlier studies in the same programme rather than proposing a new hazard model or a second framework. The architecture consumes a versioned decision package produced upstream. That package holds the deployed risk score, the fleet baseline cumulative hazard, the rolling conditional failure probability, the selected review interval and percentile, the derived dynamic threshold, and an absoluterisk safeguard. Three elements are specified. The first is a maintenanceadvisory integration contract stating the artefacts, compatibility checks, and interface fields required before an advisory is valid. The second is a governed pathway separating a calculated probability, a deterministic trigger, a maintenance candidate, an operator-facing advisory, and an authorised action. The third is an audit specification covering model-path transparency, uncertainty labelling, abstention states, operator disposition, and reproducible replay. Requirement-based conceptual verification is reported, and a staged evaluation protocol is proposed. No performance result is claimed, and the output is an integration specification that will require implementation and validation.

Keywords: Digital Twin, Maintenance decision support, Rolling-window failure probability, Auditable advisory, Survival analysis, Operator-in-the-loop.

Theme 1: Paper 206

Lifecycle Costing and Maintainability-Informed Replacement Decision-Making for Mining Haul Trucks: A Western Australian Case Study

Presentation time/location: 3 September 2026, 2:45 PM - 3:00 PM, OA7/29 (58) Hybrid

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Mining haul trucks are capital-intensive production assets, yet replacement decisions are often based on asset age, immediate repair cost or short-term operating expenditure, which can lead to sub-optimal lifecycle outcomes. This paper develops and applies a two-stage case-study framework that integrates maintenance-performance evidence with lifecycle-cost and engineering-economic analysis to support defensible retain, rebuild, replace and lease decisions for mining mobile equipment — forms of evidence that are often considered in isolation. Stage one establishes baseline performance for a Komatsu HD1500-8 using availability, maintainability and lifecycle-cost analysis, finding achieved availability of 94.8% against a 95% target and mean time to repair (MTTR) of 74.5 minutes, with 97th-percentile repair times exceeding the 72-minute limit. Stage two evaluates four capital alternatives for a Caterpillar 777F using present worth, annual worth, internal rate of return, benefit–cost and after-tax cash-flow analysis. Overhaul and replacement lowered operating expenditure but did not recover the additional capital within the study period; leasing was preferred on a revenue basis, while ownership was preferred on an after-tax cost basis. On balance, the evidence supported retaining the asset with targeted reliability and maintainability improvements rather than immediate replacement, demonstrating a practical, ISO 55001-aligned basis for haul-truck life-extension decisions.

Keywords: Asset management; Availability; Engineering economics; Lifeextension decisions; ISO 55001; Open-pit mining.

Theme 2: Paper 2

Hydrodynamic Performance and Reliability of Multi-Capsule Pipeline Transport Systems

Presentation time/location: 3 September 2026, 2:00 PM - 2:15 PM, OA6/10 (36)

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Hydraulic capsule-in-pipeline transport systems (CPTS) offer a low-carbon, automated and asset-efficient solution for material transport in industrial, offshore and specialised logistics applications. However, in multi-capsule operation, capsule–fluid and capsule–capsule interactions strongly influence wake development, pressure recovery, drag and pumping-power demand. This study combines CFD and Response Surface Methodology (RSM) to investigate a twin spherocylindrical capsule train in a horizontal hydraulic pipeline. Three-dimensional simulations were performed in ANSYS Fluent using the finite volume method, incompressible water and the SST k–ω turbulence model, with mesh-independence testing and validation against experimental pressure-drop data from the literature. A Box– Behnken RSM design was then used to assess the effects of capsule length, diameter and inter-capsule spacing on pressure drop and drag coefficient. The CFD results show that reduced annular clearance accelerates the carrier fluid, while downstream separation generates low-velocity wakes and delayed pressure recovery. Capsule diameter was the dominant parameter because it controls blockage ratio and annular-gap acceleration, whereas spacing mainly affected wake recovery and hydrodynamic shielding. The RSM models showed high predictive accuracy, with R^2 values of 99.15% for pressure drop, 99.19% for Capsule 1 drag coefficient and 99.85% for Capsule 2 drag coefficient. The proposed CFD– RSM framework provides a practical basis for optimising capsule geometry and spacing to improve energy efficiency, reliability and asset management in hydraulic capsule pipeline systems.

Keywords: Hydraulic capsule pipeline, multi-capsule transport, pressure drop, drag coefficient, wake interaction, CFD, response surface methodology, asset management

Theme 2: Paper 6

Computational Analysis of Multiphase Flow in Complex Piping Systems for Performance and Reliability Evaluation

Presentation time/location: 3 September 2026, 2:30 PM - 2:45 PM, OA6/10 (36)

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Slurry transport through helically coiled pipes is governed by interaction between axial momentum, centrifugal forcing, curvature-induced Dean vortices, particle inertia, and interphase drag. These mechanisms redistribute solids across the pipe section, distort the velocity field, and influence pressure loss and wallloading risk. This study develops a Eulerian-Eulerian CFD and response surface methodology framework for turbulent water-solid flow in a helically coiled pipe. Numerical reliability was established through grid verification, with the mesh differing by 1.77% from the finest grid, while validation against measurements produced a maximum deviation of 5.7%. A 31-run central composite design was used to quantify the effects of inlet velocity, solids volume concentration, coil pitch, and particle diameter on pressure drop. Across this domain, ΔP increased from 6.67 to 49.82 kPa, with inlet velocity emerging as the dominant control parameter. The contour maps showed that velocity governs the primary hydraulic response, whereas concentration, pitch, and particle diameter provide secondary nonlinear adjustment. Flow-field analysis revealed that the maximum-loss condition develops particle segregation, near-wall solids enrichment, and an asymmetric velocity profile caused by the interaction of Dean vortices and particle-induced resistance. These features link hydraulic inefficiency to higher pumping demand and increased wear potential. The results identify a favorable operating window near 17-20% solids concentration, 30-31 mm pitch, and $d \approx 0.8$ mm, subject to maintaining the minimum velocity required for stable suspension. The proposed CFD-RSM framework provides a grounded basis for balancing energy consumption, transport stability, and reliability in industrial slurry piping systems.

Keywords: Computational Fluid Dynamics (CFD), Multiphase flow, Helically coiled pipe, Pressure drop, Response Surface Methodology (RSM).

Theme 2: Paper 7

Ultrasonic Guided Wave Based Multi-Level Damage Assessment in Composite Pressure Vessels for Hydrogen Storage

Presentation time/location: 3 September 2026, 2:45 PM - 3:00 PM, OA6/10 (36)

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Composite pressure vessels (CPV's) are key to high pressure hydrogen storage and transport. Matrix Cracking, fibre fracture and delamination all occur due to cyclic pressurization and thermal cycling long before any external sign of damage. Periodic hydrostatic testing cannot track the degradation between inspections. This study provides an ultrasonic guided wave structural health monitoring (SHM) framework for a type-V carbon fiber reinforced polymer (CFRP) hydrogen vessel. It combines explicit finite element simulation, experimentation, and signal processing. First, the FE model was compared with surface bonded piezoelectric measurements at 150kHz; it achieved a waveform correlation coefficient of 0.93, an average RMSD error of

0.17, and both TOF & GV Errors less than1.2% and over 1.32%, respectively. The validated FE model was then used as a numerical test bed for how the fundamental S0 & A0 Lamb Modes interacted with surface breaking cracks of varying depth and In plane orientation. Transversely aligned, inclined, or perpendicular cracks produce distinct reflections, transmissions, mode conversions, and time delay signatures that vary systematically with crack length. The feature set produced supports detection, classification and severity quantification strategy for hydrogen storage vessels.

Keywords: Hydrogen storage, Composite pressure vessels, Guided waves, Structural health monitoring, Lamb waves, Damage assessment.

Theme 2: Paper 8

Ultrasonic Guided Wave-Based Structural Health Monitoring of Stainless Steel Pipes

Presentation time/location: 1 September 2026, 2:15 PM - 2:30 PM, OA6/10 (36)

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Ensuring the operational safety, reliability, and cost-effective maintenance of industrial pipelines is critical in sectors such as oil and gas, energy production, and water distribution. This study investigates a non-destructive approach using ultrasonic guided wave (GW) to monitor the structural health of AISI 316L stainless steel pipes. The method provides a practical solution for identifying internal defects such as erosion, pitting, wall thinning, and micro-cracks. Experiments were conducted by applying controlled ultrasonic excitations to cylindrical pipe sections, and the resulting wave signals were analyzed. Piezoelectric transducers were employed to generate precise GW pulses, while a high-resolution data acquisition system captured the signal response. Variations in wave propagation characteristics including velocity, phase shift, and mode amplitude were examined as indicators of internal damage. The findings demonstrate that the proposed GW-based technique is effective for rapid, accurate, and non-invasive pipeline health monitoring.

Keywords: Pipeline inspection; Ultrasonic guided waves; Structural health monitoring; damage; hairline crack; Piezoelectric transducers

Theme 2: Paper 10

Intelligent Health Assessment of Globe Valves using Ultrasonic Guided Waves and Machine Learning

Presentation time/location: 3 September 2026, 3:15 PM - 3:30 PM, OA6/10 (36)

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This work presents a structural health monitoring (SHM) framework for real-time assessment of globe valves using ultrasonic guided waves (UGW). The methodology targets damage detection through the combination of internal degradations such as erosion-corrosion and fatigue-induced cracks. Artificial defects are introduced within the valve's internal walls to replicate realistic damage scenarios, and critical regions susceptible to deterioration are identified through stress and deformation profiles from fluid-structure interaction simulations in ANSYS Fluent. Finite element models of both intact and damaged valve samples are then constructed in SolidWorks and imported into ANSYS for transient simulations of UGW propagation. The resulting time-domain signals are analysed to extract time-frequency features, which are subsequently used to train a custom machine learning model for automated detection and classification of damage. Results demonstrate that the proposed framework can accurately identify multiple types of defects, providing robust diagnostic performance across varying conditions. This approach highlights the potential of integrating guided wave sensing with data-driven models for intelligent SHM of essential mechanical components such as metallic globe valves.

Keywords: Globe Valve, Piezoelectric Sensors, Damage Detection, Machine Learning, Crack, Erosion-Corrosion, Structural Health Monitoring.

Theme 2: Paper 13

Design of an Interdigitated Capacitive Sensor for Microfibre Detection in Indoor Environment

Presentation time/location: 1 September 2026, 4:45 PM - 5:00 PM, OA6/10 (36)

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The detection of airborne microfibres in indoor environments remains a significant challenge due to the lack of scalable, real-time sensing technologies capable of operating outside laboratory conditions. This paper presents the design and numerical evaluation of an interdigitated electrode (IDE) capacitive sensor for microfiber detection, based on dielectric perturbation of fringing electric fields. The sensing mechanism is governed by electrostatic field coupling between adjacent electrodes, where the mutual capacitance is sensitive to variations in the effective permittivity of the surrounding medium. As microfibre accumulation results in a measurable change in capacitance, a finite element model is developed to solve the quasi-static

electromagnetic problem and extract the capacitance response under varying material and deposition conditions. Parametric studies are conducted to evaluate the influence of deposition layer thickness and material dielectric properties on sensor response and sensitivity. Comparative simulations are performed for representative textile materials and household dust, while additional simulations investigate the influence of environmental humidity on the sensor response. The results demonstrate systematic, material-dependent changes in capacitance magnitude with increasing deposition thickness, with household dust producing the largest simulated response and nylon exhibiting the strongest response among the investigated textile materials. Humidity introduces an additional dielectric contribution while maintaining the overall thickness-dependent response. These numerical findings provide design guidance for the development of IDE-based indoor particulate sensing systems; however, experimental validation is required to establish practical detection sensitivity, selectivity and environmental robustness.

Keywords: Microfibers, Capacitive sensing, Interdigitated electrodes, Environmental monitoring, Structural health monitoring, Indoor air quality, Dielectric modelling, Humidity effects.

Theme 2: Paper 14

Ultrasonic Guided Wave based Damage Assessment for Wind Turbine Blades

Presentation time/location: 2 September 2026, 4:00 PM - 4:15 PM, OA7/26 (30)

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Composite wind turbine blades are extensively used in wind power generation; however, they are prone to a variety of damage conditions such as delamination, debond, and fatigue cracking. This paper introduces an efficient, data-driven structural health monitoring framework that integrates the ultrasonic guided wave technique with a novel deep learning model for automated damage evaluation. A comprehensive signal directory is constructed by combining numerical simulations with laboratory experiments to cover multiple damage scenarios. The proposed pipeline is assessed on a multi-class problem including the healthy state and different damaged cases. The classification outputs demonstrate high accuracy, reliable class differentiation, and consistent performance across repeated executions. Moreover, the model shows strong generalization capability when applied to datasets of varying damage characteristics and sizes. The findings highlight the effectiveness and strength of the suggested deep learning-assisted guided wave approach for damage detection in wind turbine blades and similar composite components, which supports its suitability for practical health monitoring of wind turbines and other industrial equipment.

Keywords: Damage, Wind Turbine Blade, Ultrasonic Guided Waves, Structural Health Monitoring, Deep Learning.

Theme 2: Paper 18

From RUL Estimation to Risk-Informed Decision Support: A Bayesian Framework for Long-Life Industrial Assets under Data Scarcity

Presentation time/location: 2 September 2026, 4:30 PM - 4:45 PM, OA7/29 (58) Hybrid

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Long-life, capital-intensive industrial assets are routinely operated beyond their original design lives, yet decisions governing maintenance and life extension must be made under conditions of sparse failure data, heterogeneous evidence, and compounded uncertainty. Conventional Remaining Useful Life (RUL) estimation approaches, whether parametric or data-driven, are structurally inadequate for this context. This paper presents an integrated Risk-Informed Decision-Making and Bayesian Belief Network (RIDM–BBN) framework that shifts focus from isolated probabilistic prediction to end-to-end decision support. Bayesian Belief Networks encode causal dependencies among degradation mechanisms, subsystem health states, and system-level RUL. Gamma–Poisson and Beta–Binomial conjugate formulations enable stable posterior failure rate estimation from limited Computerized Maintenance Management System (CMMS) records, supplemented by structured expert elicitation. The framework is validated on the Long Travel subsystem of a bucket wheel reclaimer, a 40-year-old asset operating 165% beyond its design life, using 237 annual failures across 80 assets and 225 distinct failure modes. Sensitivity analysis identifies gearbox oil degradation as the primary controllable reliability driver (+0.44 system failure probability from baseline). Expected utility comparison across three maintenance strategies demonstrates that predictive monitoring reduces expected annual failure costs by 59% (benefit-cost ratio ≈ 4:1), and component redesign achieves payback within 0.49–2.3 years when tail risk costs are incorporated.

Keywords: Bayesian Belief Networks; Risk-Informed Decision-Making; Remaining Useful Life; Data Scarcity; Life Extension; Asset Management; Expected Utility; Bucket Wheel Reclaimer.

Theme 2: Paper 21

An AI-Driven Model for Monitoring Control Valve Pressure Drop in Multiphase Pipelines

Presentation time/location: 1 September 2026, 4:15 PM - 4:30 PM, OA6/10 (36)

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Valve trim components are crucial for regulating pressure drops in industrial applications, particularly in the process and oil & gas transportation sectors, where maintaining safety is paramount. Current methods for optimising flow-control valve designs, especially for two-phase fluid flow, require a comprehensive understanding of fluid properties and system behaviour. This study combines Computational Fluid Dynamics (CFD) simulations and machine learning (ML) techniques to predict and optimise flow conditions through complex valve trim geometries. ANSYS Fluent 2022 was used to generate a dataset of 450 flow dynamics cases under varying valve opening positions (VOPs) of 20%, 40%, 60%, 80%, and 100%. Key inputs into the model are the inlet velocities (V) of 1, 2, and 3 m/s, air volume fractions (α) of 5%, 10%, and 15%, as well as geometric factors including plane number, L/D location, the length between planes (L), curve surface area), cross-section area (AP), and pressure drop (AC), hydraulic diameter (DH), hydraulic diameter average (DH ($\Delta P(kPa)$) were analysed. The data extracted from energy loss and pressure drop across local planes were used to train machine learning models. The trained machine learning models, including Artificial Neural Networks (ANN) and the XGBoost algorithm, demonstrated strong predictive capabilities, with high R2 >0.90 each. The models achieved low Mean Absolute Error (1.169) and Mean Squared Error (2.3 × 10− 7) with an average error of 5.798, indicating their effectiveness in capturing non-linearities and complex interactions effectively. This study underscores the accuracy and robustness of machine learning models in validating CFDgenerated fluid flow data under multiphase conditions, offering valuable insights for optimising valve performance. These optimisations can underpin cost reductions, improve safety, and enhance energy efficiency in industrial applications.

Keywords: Control valve, ML, Artificial neural network, Multiphase flow, Pressure drop

Theme 2: Paper 26

A data-driven approach for fault severity classification using acoustic emission signals in a globe valve.

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA6/10 (36)

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This paper proposes a data-driven approach for fault severity classification in a globe valve of a fluid transport system using acoustic emission signals. The complex interactions among fluid flow, rotating/moving mechanical components, and structures create mixed-signal features in industrial environments. Hence, making a reliable condition assessment of a fluid transport system is challenging. To develop a reliable fault-identification method for the fluid transport system, a non-intrusive method based on acoustic emission signal analysis is investigated. In this method, acoustic emission signals are captured from a globe valve in a fluid transport system comprising a motor and a recirculation tank. The experimental design is adapted by adjusting various flow rates and valve opening positions (VOPs), representing different levels of flow restriction and fault severity. The signal captured by the acoustic emission sensor is transformed into the time-frequency domain to analyse both temporal and frequency features of the fluid transport system's behaviour. A data-driven model is developed to learn from graphical representations of acoustic emission signal patterns and classify fault severity under different operating conditions. This work presents a non-intrusive approach for assessing fault severity using acoustic emission signals. This work has been validated through experiments conducted on a globe valve under various operating conditions.

Keywords: Fault Severity Classification, Acoustic Emission, Condition Monitoring, Globe Valve, Flow Systems.

Theme 2: Paper 32

Numerical Investigation of Flow Behaviour and Separation Performance in a Deoiling Hydrocyclone

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA6/10 (36)

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Produced water treatment remains an important challenge in offshore oil and gas production, where compact and reliable separation systems are required. Deoiling hydrocyclones are widely used for this purpose because they provide high-throughput oil-water separation. In this study, three-dimensional transient Computational Fluid Dynamics (CFD) simulations are carried out to examine the internal flow behaviour and separation performance of a Colma-Thew deoiling hydrocyclone. The oil-water flow is modelled using the Eulerian Mixture approach, with turbulence closure provided by the Reynolds Stress Model. A 20-bin Population Balance Model is coupled to the flow solution to account for droplet breakage and coalescence. The analysis focuses on oil volume fraction distribution, tangential velocity, static pressure, turbulent kinetic energy, turbulent dissipation rate and separation efficiency. The predictions show that the hydrocyclone develops a distinct oil-rich core along the central axis, with the highest oil accumulation occurring near the vortex finder.

The tangential velocity field produces the swirling motion required for radial phase segregation, while the associated low-pressure core promotes inward migration of the dispersed oil phase. The turbulence analysis shows that the most energetic flow region occurs in the upper part of the hydrocyclone, while the highest dissipation is concentrated near wall-bounded regions. The predicted separation efficiency is 86.67%, indicating effective oil recovery under the simulated baseline condition. The study provides a flow-diagnostic interpretation of how velocity, pressure, turbulence and oil distribution combine to govern oil migration, core formation and separation performance in a deoiling hydrocyclone.

Keywords: Deoiling hydrocyclone, produced water, computational fluid dynamics, oil-water separation, separation efficiency, swirling flow

Theme 2: Paper 65

An Intelligent IIoT and Edge-Enabled Framework for Safe Real-Time Monitoring of Petroleum Storage Tanks

Presentation time/location: 2 September 2026, 4:00 PM - 4:15 PM, OA7/02 (30)

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Petroleum storage tanks are safety-critical assets in downstream oil and gas operations. At many depots, including legacy facilities in Libya, level, water-bottom, density and temperature checks still depend heavily on manual dipping, roof access and delayed reporting. This exposes workers to falls and vapour hazards, while also reducing measurement frequency and delaying operational decisions. This paper presents an Industrial Internet of Things (IIoT) and edge-enabled decision-support framework for real-time petroleum storage-tank monitoring, developed from smart monitoring work for the Marsa Brega oil depot of Brega Petroleum Marketing Company in Libya. The framework integrates smart tank gauging, multi-parameter sensing, edge validation, auditable alarm logic and a supervisory dashboard. It is designed to support faster local awareness, reduce routine tank access, and improve the visibility of abnormal operating conditions before they develop into major safety events. A LabVIEW-style prototype is represented through a reproducible simulation-calibrated dataset covering filling, outlet operation, level tracking, temperature variation, density drift, water ingress and high-high/low-low alarm conditions. Prototype evaluation indicates a reduction in mean absolute level error from 44.9 mm for manual dipping to 3.8 mm for edge-recorded smart gauging, a reduction in median recording delay from 36.5 min to sub-second edge decision latency, and earlier visibility of high-high level and water-bottom events. The results demonstrate the value of placing validation and advisory alarm logic close to the tank, while keeping certified protection and shutdown functions subject to formal engineering assessment. Although validation remains prototype based, the work offers a practical pathway for moving petroleum tank operations from reactive manual inspection towards safer and more connected monitoring environments.

Keywords: IIoT · Edge monitoring · Petroleum storage tanks · Smart tank gauging · Industrial safety · Autonomous monitoring · LabVIEW

Theme 2: Paper 69

A Lifecycle-Aware Evaluation Framework for Battery State-of-Health Estimation

Presentation time/location: 1 September 2026, 3:00 PM - 3:15 PM, OA6/10 (36)

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Condition-based maintenance of battery energy-storage assets requires State-of-Health (SoH) estimation deployable on the asset itself. This paper establishes a rigorously evaluated gradient-boosted-tree baseline against which edge-native neural architectures can be benchmarked. A reproducible LightGBM regression pipeline is developed on the NASA battery dataset (34 cells, nine protocols, 4–44◦C, 1–4 A constantcurrent and pulsed discharge); automated quality flagging retains 20 cells for supervised learning. A systematic ablation crosses three feature sets (31, 61, 134 features) with three model configurations under leaveone-battery-out cross-validation at two tiers: same-protocol and crossprotocol. Performance is reported through regression metrics and a fourband maintenance classification (Good, Fair, Poor, Critical). Three findings emerge. First, feature-count ablation produces an inverted-U curve with optimum at 61 features (MAE 0.031, R20.862), degrading beyond this regardless of model capacity. Second, Critical-band recall is weak (7.1 % same-protocol; 5.2 % cross-protocol), concentrating error in the knee-point region most relevant to maintenance. Third, cross-protocol evaluation reveals catastrophic generalisation failure on out-of-envelope cells, making protocol conditioning essential for any deployable successor. Tree-ensemble inference is further shown to be structurally ill-suited to Cortex-M-class targets, while a preliminary 10k-parameter depthwiseseparable 1D CNN evaluated under the same harness matches the baseline on same-protocol regression (MAE 0.028) and remains quantisable to microcontroller scale.

Keywords: Battery State-of-Health · TinyML Edge Deployment · Light-GBM Baseline · Cross-Protocol Generalisation · Lifecycle Classification · NASA Battery Dataset.

Theme 2: Paper 71

Integrating LoRaWAN with the UK Fixed Telecom Network for Railway Predictive Maintenance

Presentation time/location: 1 September 2026, 3:15 PM - 3:30 PM, OA7/27 (40)

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Condition-based railway maintenance depends on moving sensor data continuously from distributed trackside and rolling-stock assets to centralised analytics platforms. The UK rail communications landscape, which spans Network Rail's Fixed Telecom Network (FTN) and its IP-based successor programme FTNx, the Global System for Mobile Communications – Railway (GSM-R), dedicated supervisory control and data acquisition (SCADA) links and legacy copper, is fragmented, while conventional cellular IoT imposes recurring costs, rural coverage gaps and energy budgets incompatible with multi-year battery-powered deployments. This paper reviews the UK railway communications stack and proposes an integration pathway deploying LoRaWAN as a complementary sensor-data layer hosted on existing FTN/FTNx infrastructure. The methodology comprises a comparative analysis of low-power widearea network (LPWAN) protocols (LoRaWAN, NB-IoT, Sigfox, LTE-M) against railway-specific requirements; a quantitative link-budget and gateway-density analysis for gateway co-location at FTN primary exchanges and Relocatable Equipment Buildings; and a reference architecture covering end-device selection, gateway placement and edge-side anomaly filtering, with security treated as first-order through VLAN segmentation within the FTN's critical-national-infrastructure (CNI) grade backhaul and AWS IoT certificate management. The link-budget analysis indicates rural corridor cell radii of 5–10 km at high spreading factors, implying that a few hundred co-located gateways could cover the majority of the UK rural rail network without new civil works; dutycycle and energy-budget analyses confirm generous headroom for compact feature-vector telemetry from the companion damper-detection and battery-health work and a node battery life exceeding ten years on a single cell. Regulatory obligations (Ofcom IR 2030 spectrum conditions, the Network and Information Systems (NIS) Regulations and railway cybersecurity codes of practice) are mapped to architectural decisions. A three-phase rollout strategy (ghost-mode validation, rural extension, full scaling), supported by the operational national LoRaWAN precedent of the French railway operator SNCF, contains deployment risk while providing a pragmatic migration route toward a unified IoT backbone for predictive maintenance.

Keywords: LoRaWAN Railway Integration · Fixed Telecom Network · Critical Infrastructure Cybersecurity · LPWAN Protocol Evaluation · Phased IoT Deployment · Condition-Based Maintenance.

Theme 2: Paper 73

Machine Learning-Based Flame Colour Classification for Intelligent Automation of LPG Fired Heaters

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA7/29 (58) Hybrid

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Fired heaters are safety-critical units in liquefied petroleum gas (LPG) fractionation plants because combustion quality directly affects heat-transfer efficiency, emissions, tube reliability, and operator exposure. In the earlier automation framework developed for the Zueitina Oil Company LPG case study, flame colour was used with air–fuel ratio (AFR) control and shutdown logic to identify stoichiometric, lean, rich, and unsafe combustion. That approach is practical, but its fixed colour thresholds can become fragile when camera exposure, flame intensity, burner condition, and background illumination change. This paper presents a machine learning-based flame-colour classification framework for intelligent fired-heater automation. The proposed method converts flame images into colour-space and morphology features, trains supervised classifiers, and links the predicted state to deterministic control responses (air-damper correction, fuel trimming, alarms, and shutdown). A reproducible simulation-calibrated proxy dataset of 1,000 labelled flame images was generated to support the study, with four combustion classes and a stratified 70:15:15 train-validation-test split. The selected radial basis function support vector machine (RBF-SVM) achieved 90.0% heldout accuracy and macro F1 of 0.899 using visual and optical features only, demonstrating pipeline feasibility. As the dataset used colour-based generation rules, this accuracy reflects pipeline feasibility, not real-flame performance. Most residual errors occurred at intentional boundary conditions between normal/lean and rich/unsafe-rich flames, which are also the cases where conservative alarm handling is needed. The results demonstrate that data-driven flame classification can replace rigid colour-code logic while preserving transparent safety interlocks. Although the evaluation does not represent full plant deployment, the work provides a practical research pathway for adding machine learning-based visual feedback to Aspen Plus, MATLAB, LabVIEW, PLC, and SCADA fired-heater automation workflows.

Keywords: Machine learning · Flame colour classification · Fired heater automation · LPG fractionation · Combustion monitoring · Process safety · Computer vision

Theme 2: Paper 75

An Unsupervised Learning Framework Using Narrow Bands for Acoustic Emission Source

Detection in Composite Wind Turbine Blades

Presentation time/location: 1 September 2026, 2:00 PM - 2:15 PM, OA6/10 (36)

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Wind turbines (WTs) are required to operate reliably to meet the increasing global demand for renewable energy. However, their efficiency and safety can be compromised by damage developing within the WT blades. Acoustic emission (AE) is highly sensitive to damage initiation and propagation, making it a promising technique for structural health assessment. Despite this advantage, conventional time-domain approaches for locating AE sources can be challenging in structures with anisotropic materials and complex geometries, including curved profiles and non-uniform thickness. To address these challenges, this study proposes an unsupervised narrow-band frequency-domain methodology for identifying artificial AE sources in composite WT blades. Unlike conventional localization techniques that rely on multiple sensors and timeof-arrival measurements, the proposed approach uses data acquired from a single sensor and extracts source-related information from selected frequency components of AE signals. The proposed framework identifies patterns within high-dimensional narrow-band features obtained from AE data and groups the signals according to their spatial regions of origin within the blade structure. Since only a single sensor is required, the approach is particularly suitable for large-scale structures with complex geometries. The high localization accuracy achieved demonstrates the potential of the proposed method for real-world applications where conventional time-domain approaches are difficult to implement. Furthermore, the framework has strong potential for integration into digital twin environments to support predictive monitoring of AE sources in composite WT blades.

Keywords: wind turbine; acoustic emission; structural health monitoring; damage localization; machine learning; frequency domain.

Theme 2: Paper 87

Guided Waves based Monitoring of Degradation Levels in Orthopedic Implants

Presentation time/location: 1 September 2026, 4:15 PM - 4:30 PM, OA7/26 (30)

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Self-degradable orthopedic implants are increasingly being investigated as temporary fixation devices that provide mechanical support during fracture healing and gradually degrade after tissue recovery. Reliable assessment of implant degradation is essential to ensure adequate load-bearing capacity throughout the healing process and to prevent premature implant failure. This study presents a numerical investigation of degradation-sensitive ultrasonic guided-wave features in biodegradable orthopedic implants using COMSOL Multiphysics. A three-dimensional finite element model consisting of skin, muscle, cortical bone, and a polycaprolactone fixation implant was developed. Implant degradation was represented by progressive reductions in implant thickness. The influence of degradation on guided-wave propagation was evaluated through time-domain response analysis, Fast Fourier Transform, signal energy, and peak amplitude. The results demonstrate that progressive implant degradation modifies the transmitted guided-wave response, resulting in distortion, attenuation, and changes in spectral characteristics. While peak amplitude exhibits non-monotonic behaviour owing to wave interference effects, signal energy shows a substantial reduction for severe degradation levels, indicating its potential as a robust degradation-sensitive feature. Physics-consistent timefrequency representations were also generated using the Continuous Wavelet Transform and subsequently imported into a tailored deep learning based health monitoring architecture for degradation rate classification. The health monitoring model showed effective performance across zero, low, and high degradation levels. The findings demonstrate the feasibility of ultrasonic guided waves for non-invasive monitoring of implant integrity and provide a foundation for future development of smart biodegradable orthopedic fixation systems.

Keywords: Guided Waves, Health Monitoring, Orthopedic Implant, Degradation, Numerical Simulation, Deep Learning.

Theme 2: Paper 95

Early-stage failure detection in mechanical components within Industry 4.0: a systematic review

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA7/29 (58) Hybrid

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Within Industry 4.0, maintenance strategies have rapidly evolved. The constant need to extend the lifespan of industrial equipment, limit downtime, and minimize component breakdowns has driven the development of smarter and more efficient maintenance solutions. Predictive maintenance anticipates failures, prevents equipment damage and unplanned production stoppages, improves performance, and reduces costs. We will explore scientific research on early-stage failure detection practices and predictive maintenance methods for mechanical components in Industry 4.0 and identify potential research gaps for future contributions. A systematic literature review was conducted using PRISMA guidelines through Scopus and Web of Science databases, analyzing 56 articles published between 2020 and 2025. The review examines the typology of mechanical failures, the families of physical characteristics used for fault detection, the modeling paradigms adopted, and the indicators used to evaluate predictive performance. The results reveal a strong concentration of research on rotating systems, particularly bearing-motor assemblies, where mechanical degradation mechanisms such as wear, imbalance, and misalignment are predominant. Vibrational characteristics remain

the primary source of diagnostic information, while electrical, thermal, and operational variables are used as complementary signals. Deep learning models, particularly CNNs, LSTMs, and autoencoders, constitute the dominant paradigm, although classical machine learning approaches remain widely used in structured industrial settings. The analysis highlights a structural gap in the integration of multi-physics sensing, model interpretability, and large-scale industrial validation. Future research should prioritize integrating multimodal characteristics and robust deployment strategies under real-world conditions to improve the generalizability and industrial applicability of predictive maintenance solutions for mechanical systems.

Keywords: Predictive Maintenance, Failure Detection, Mechanical Components, Industry 4.0, Deep Learning, Rotating Systems.

Theme 2: Paper 98

An advanced analysis method of acoustic emission signals for characterization of cracking modes in reinforced concrete structures

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA6/10 (36)

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Acoustic emission (AE) has been widely recognised as an effective non-destructive technique for detecting and monitoring crack development in engineering materials and structural systems. AE signals can be interpreted using either physically based approaches derived from seismology or through analyses of their temporal and frequency-domain characteristics. However, the existence of numerous AE parameters and different analytical methodologies makes it challenging to identify the most appropriate approach, particularly for heterogeneous materials such as reinforced concrete. This study investigates the evolution of microcracking in reinforced concrete T-beams subjected to quasistatic four-point bending tests at different loading rates. Acoustic emission activity was continuously monitored using a network of AE sensors during the experiments. Three commonly adopted definitions of the b-value were evaluated and compared to assess their effectiveness in characterising damage progression. In addition, the evolution of the RA value and average frequency (AF) was analysed throughout the loading history to distinguish the dominant cracking mechanisms. Furthermore, a supervised machine learning approach based on the Support Vector Machine (SVM) algorithm was employed to identify different damage regions along the load-displacement response. The study highlights the limitations of supervised classification when multiple damage mechanisms coexist within the same loading stage. To address this limitation, an unsupervised learning framework was adopted to cluster AE signals using both physical descriptors and time–frequency features. Finally, the strengths and limitations of the investigated AE parameters and data analysis techniques are discussed in relation to the underlying micro-and macro-cracking mechanisms in reinforced concrete structures. .

Keywords: Acoustic emission, concrete, RA value, b-value, average frequency, partial power, support vector machine

Theme 2: Paper 105

Spatio-Temporal Dynamics of the Recirculating Bubble in Oscillating Jet Nozzles

Presentation time/location: 2 September 2026, 3:15 PM - 3:30 PM, OA6/10 (36)

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Oscillating jet nozzles are widely used in a range of different applications requiring flow control, including heating/cooling, mixing, and wellbore descaling. The dominant flow features that dictate the oscillating behaviour of the jet are the vortical structures that form inside the mixing chamber of the nozzle. These structures evolve as the jet oscillates, propagates downstream through the mixing chamber, and eventually dissipate into the feedback channels. The spatio-temporal dynamics of these vortical structures are complex and necessitate an in-depth analysis for a better understanding of the nozzle's operation and flow control. In the present study, three-dimensional, transient computational fluid dynamics (CFD) simulations have been used to evaluate the dynamics of the vortical structures inside an oscillating jet nozzle. The CFD investigations have been carried out for the wall-bounded turbulent flow inside the nozzle. The birth, growth and dissipation of the vortical structures have been investigated through tracking their spatio-temporal motion, size, shape and strength. The results show that the alternating vortical structures in the mixing chamber start to form when the jet propagates from either extreme towards the centre. After their birth, they grow as the jet approaches the opposite extreme, while the return journey is associated with their dissipation. These findings help understand the complex hydrodynamic behaviour of vortical structures in oscillating jet nozzles and provide valuable insight for better control of the oscillatory motion.

Keywords: Oscillating jet nozzle, Recirculating bubble, Spatio-temporal dynamics, Computational fluid dynamics, Mixing chamber, Feedback channel.

Theme 2: Paper 108

Diagnosing Recurring Subsystem Faults in a Newly Commissioned Electric Multiple Unit Fleet: A Mixed-Methods Case Study from South Africa

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA7/31 (60) Hybrid

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The South African government has invested heavily in modernising its ageing rail network through the adoption of Electric Multiple Unit (EMU) trains. Despite this investment, the TS225– TS283 fleet has continued to experience recurring failures across several subsystem components, including looming (wiring harness assembly), Heating, Ventilation and Air Conditioning (HVAC) units, the Passenger Announcement and Communication Information System (PACIS) and passenger doors. This study investigated the root causes of these recurring faults, with particular emphasis on determining whether they result from manufacturing, assembly or operational factors, and proposed evidence-based interventions to improve fleet reliability. A convergent parallel mixed-methods case study design was adopted. The quantitative strand analysed twelve months (June 2024 to May 2025) of fault, reliability and maintenance records for 435 documented incidents across the ten most failure-prone subsystems. The qualitative strand collected open-ended questionnaire responses from six purposively sampled expert engineers one reliability test engineer, one safety engineer, two testing engineers and two maintenance engineers directly involved in the manufacture, assembly and maintenance of the fleet. The study found that supplier quality defects accounted for 65.7% of all analysed faults, while assembly process gaps were the dominant internal cause in the Looming (36.7%) and ERTMS (34.6%) subsystems. Environmental and operational stressors specific to South Africa, including dust accumulation, moisture ingress and voltage fluctuations from load shedding, were also significant contributors. Three engineer-validated interventions are proposed: mandatory pre-shipment burn-in testing, formal operator certification for safety-critical assembly tasks, and environmental hardening with voltage stabilisation.

Keywords: Electric Multiple Unit (EMU) trains, Failure Modes and Effects Analysis (FMEA), supplier quality management, mixed-methods research, railway modernisation.

Theme 2: Paper 126

Remaining Useful Life Prediction for Locomotive Compressor Systems Using Machine Learning: A Heavy-Haul Fleet Case Study

Presentation time/location: 1 September 2026, 4:45 PM - 5:00 PM, OA7/27 (40)

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A South African company has faced a significant rise in compressor failures on diesel locomotives operating on the heavy haul line, which impacts braking performance and can lead to cancellations or derailments. To address this, a structured fleet condition assessment was conducted between March 9 and April 20, 2026. The assessment included 186 timed pressure tests, with a sample of 87 out of 96 units, achieving a confidence level of 95% and a margin of error of approximately ±3.6%. The analysis involved 22 features derived from raw sensor readings, such as compressor and engine speeds and intermediate pressure readings at 1 to 4 minutes. Two machine learning approaches were tested: binary classification of potential failures and regression for estimating remaining useful life. Random Forest exhibited the highest classification accuracy (AUC of 1.000), while XGBoost excelled at regression (RMSE of 0.815, R^2 of 0.882). Feature importance analysis identified time-to-850 kPa as the key predictor, highlighting the utility of early testing for potential failures after just 2-3 minutes. The system successfully categorized all 87 units into four health states, pinpointing 19 highrisk locomotives that needed immediate attention.

Keywords: remaining useful life, compressor condition monitoring, random forest, XGBoost, predictive maintenance.

Theme 2: Paper 134

A Prognostics and Health Management (PHM) Inspired Framework for Vibration-Based Fall Detection in Independent Living

Presentation time/location: 3 September 2026, 2:15 PM - 2:30 PM, OA6/10 (36)

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Falls are a leading cause of injury, loss of independence, and premature mortality among elderly individuals, creating a growing need for reliable, nonintrusive monitoring systems that support independent living. Existing fall detection solutions based on wearable devices or vision sensors often suffer from user compliance issues, privacy concerns, and environmental limitations. This paper presents a privacy-preserving fall detection framework based on the condition monitoring principles of ISO 17359 and ISO 13374-2, integrating floor-mounted vibration sensing with AI-driven data analytics. The proposed framework maps the fall detection process onto the standard condition monitoring functions of Data Acquisition (DA), Data Manipulation (DM), State Detection (SD), and Health Assessment (HA). Vibration signals generated by daily activities and fall events are transformed into decibel-normalized time–frequency spectrograms using the Short-Time Fourier Transform (STFT). The spectrograms are analysed using a two-stage detection framework. The first stage investigates two alternative State Detection (SD) strategies: anomaly detection using a convolutional autoencoder and supervised fall detection using a deep learning classifier (ResNet18). In

the second stage, corresponding to Health Assessment (HA), detected falls are classified into three categories, hard falls, slip/trip falls, and controlled falls, using three deep learning architectures: a two-layer CNN, a fourlayer CNN, and ResNet34. Experimental results obtained using a laboratory dataset demonstrate the feasibility of the proposed approach. The convolutional autoencoder achieved an anomaly detection accuracy of 92%, while the supervised deep learning classifier achieved 98% accuracy. For fall-type classification, the two-layer CNN, fourlayer CNN, and ResNet34 achieved accuracies of 67%, 68%, and 73%, respectively. The results demonstrate that combining an ISO-compliant condition monitoring framework with vibration sensing and AI-driven analytics may provide an effective, non-intrusive, and privacy-preserving solution for intelligent domestic fall monitoring, while illustrating the potential for transferring industrial Prognostics and Health Management (PHM) methodologies to healthcare applications.

Keywords: Fall detection; Vibration sensing; Condition monitoring; Artificial intelligence; Convolutional Autoencoder; ResNet; ISO 13374-2; Independent living.

Theme 2: Paper 135

A Dual-Layer Framework for Condition Monitoring of Wind Turbine Blades

Presentation time/location: 2 September 2026, 3:15 PM - 3:30 PM, OA7/31 (60) Hybrid

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Bridging the gap between AI-based damage detection and engineering maintenance decision-making remains a key challenge in wind turbine blade condition monitoring. This paper proposes a dual-layer framework comprising a Data-Driven Diagnostics Module and a Knowledge-Driven Advisory Module. The Data-Driven Diagnostics Module employs the YOLO11 object detection model to detect and localise thermal turbulence patterns associated with leadingedge damage in infrared thermograms. Radiometric analysis extracts the temperature difference from calibrated thermal images to provide a damage severity indicator. Subsequently, Eigen-CAM performs model attention analysis. The YOLO detection confidence, thermal data quality, and the Eigen-CAMderived Attention Focus Ratio (AFR) are combined to compute a Trustworthiness Index that quantifies the trustworthiness from each diagnosis. The Knowledge-Driven Advisory Module integrates diagnostic outputs with engineering knowledge using Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG) to generate evidence-based maintenance advisories. By combining data-driven diagnostics with knowledge-driven engineering reasoning, the proposed framework transforms thermal anomaly detections into transparent, trustworthy, and actionable maintenance recommendations, supporting proactive maintenance planning and improved asset integrity management for offshore wind turbine blades.

Keywords: Computer vision; Condition monitoring; Digital Twin; Large Language Models (LLMs); Retrieval-Augmented Generation (RAG); Thermal turbulence; Wind turbine

Theme 2: Paper 139

Swirl-Induced Phase Redistribution for Enhanced Oil-Water Separation Downstream of a Control Valve

Presentation time/location: 2 September 2026, 3:00 PM - 3:15 PM, OA6/10 (36)

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Oil and gas production systems extensively operate with multiphase mixtures in which gas, oil and water must be separated into individual components in downstream separators. Control valves are essential components in these systems as they control separator levels and regulate pressure and flow rates. However, the complex internal geometry of control valves can generate strong velocity gradients, local turbulence and high-shear regions. These hydrodynamic effects promote oil droplet breakage and emulsification, which reduces downstream separation efficiency and increases the need for longer residence times, larger separator volumes and chemical treatment. In the present work, a downstream swirler was investigated as a low-shear flow-conditioning component to improve the hydrodynamic performance of the valve and enhance oilwater separation efficiency. A Computational Fluid Dynamics based model of a 4-inch globe valve fitted with a single-stage high-friction trim was developed. The swirler with 30, 45, 60 and 70 degrees vane angle was installed at the valve outlet and evaluated at different inlet velocities (3, 6 and 10m/s), oil volume fractions and oil droplet diameters. Local pressure, velocity and oil volume fraction fields were extracted to quantify phase redistribution. The results show that the baseline globe valve produces a highly mixed oil-water flow due to concentrated pressure drop and high-velocity jet interaction within the trim. The swirler introduces tangential momentum and generates a centrifugal field, which moves the lighter oil phase towards the pipe core while displacing water towards the outer wall. Increasing swirl angle and inlet velocity improve oilcore concentration, with the 60-degree swirler providing the strongest separation performance. A corrected valve capacity method was also developed to include the additional pressure loss caused by the swirler in valve sizing.

Keywords: Computational Fluid Dynamics, Low-shear control valve, oil-water separation, swirl-induced flow, low-shear flow, multiphase flow.

Theme 2: Paper 140

A Novel SHM architecture based on Electro Mechanical Impedance Guided by Physics Informed Digital Twins and Machine Learning for Steel Structure Monitoring

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA6/10 (36)

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Electromechanical impedance (EMI) based monitoring methods have emerged as a promising approach for damage assessment in steel structures. However, limited sensor data remains a challenge in building a digital twin of such structures. In this study, we present a novel framework that integrates EMI based monitoring by using deep learning driven data augmentation and physics informed hixon model-based digital twin for facilitating the development of a real time structural damage warning system. A steel portal frame with weld connection has been selected for capturing impedance data in healthy and different damaged states. The weld connection of the frame is damaged using manual saw cut of varying configuration to generate impedance spectrum. A physics informed digital twin has been developed which continuously updates virtual representations of the steel portal frame to simulate a realistic and dynamic impedance datasets for varying damage states. Subsequently, different damage conditions are simulated in the COMSOL multiphysics to make a robust damage prediction in terms of variation of stiffness and damping parameters using Hixon models. A machine learning-based data augmentation approach is employed which incorporates impedance spectrum reconstruction from limited experimental measurements to identify damage characteristics. The augmented data is subsequently used to formulate a digital twin for predicting localized stiffness degradation under different joint damage conditions. The results demonstrate the capability and performance of the framework using EMI guided digital twin and machine learning model in detecting and localizing various weld damage states in steel portal frames. The research provides a new idea in structural health monitoring through EMI-digital twins and has potential to be used in data driven autonomous monitoring systems.

Keywords: Electromechanical impedance · Hixon models · Digital twin · Damage identification · Machine learning · Generative adversarial network.

Theme 2: Paper 144

Identifying electrical and mechanical fault in induction motor using Temporal Convolution Network on limited dataset

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA7/29 (58) Hybrid

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Induction motors are extensively used in plethora of industrial applications from pumps and conveyor belts to electric and hybrid vehicles. These motors are prone to mechanical or electrical failure such as unbalance or misalignment in rotor, bowed rotor, broken rotor bar, faulty bearings, stator winding fault and voltage unbalance fault due to prolong operation, inadequate maintenance and environmental conditions. Therefore, accurate and automated fault diagnosis of motor is essential for ensuring their availability and reliability. This study proposes a lightweight, vibration-based motor fault diagnosis framework using a Temporal Convolutional Network (TCN). Each 10-second recording is split into 8 s for training and 2 s for testing, with a sliding-window approach further segmenting the signals into shorter sequences to capture localized fault features and expand the dataset. The TCN combines dilated 1D convolutions, residual connections, batch normalization, and global average pooling to learn multi-scale temporal features directly from raw signals, without manual feature engineering. The model was trained and evaluated on eight motor conditions (independent of load condition) at a fixed 60 Hz operating speed, achieving high diagnostic accuracy. To assess robustness beyond this fixed condition, the model was further evaluated across a range of constant and variable operating speeds, achieving 100% accuracy at constant speeds (~15–60 Hz) and 73.8-82.1% under variable-speed operation, outperforming benchmark models such as Random Forest and SVM across all conditions. This indicates that the model generalizes better to changing operating conditions than the baseline approaches.

Keywords: Motor, Fault Diagnosis, Temporal Convolution Network, Industry 4.0, Lightweight Neural Networks.

Theme 2: Paper 147

A robust SHM framework for autonomous diagnosis using reusable acoustic emission (AE) sensors via electro mechanical impedance (EMI) for weld damage in steel structures

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA6/10 (36)

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In the recent past, the demand for reliable sensing methods have been increasingly used particularly for steel portal frame structures to ensure its long term performance and early maintenance. Electro mechanical

impedance (EMI) using Conventional PZT sensors though effective for local level monitoring, possesses two critical limitations like sensor reusability and built in sensor condition assessment. To address this, the present research introduces a robust framework using reusable Acoustic Emission (AE) sensors based on EMI techniques. In this investigation, EMI based AE sensors have been used for detecting weld damages in steel portal frame structures. Conductance signals obtained from AE sensors have been acquired for healthy and different levels of weld damages. The acquired signatures have been quantified using various statistical indices like root mean square deviation (RMSD), correlation coefficient deviation metric (CCDM). Furthermore, wavelet mean parameters have been used to characterize various weld damage states. The result obtained via shifting of resonance peaks, statistical and wavelet indices indicates the ability of the reusable AE sensors in accurately detecting the weld damage states. The proposed study establishes a robust sensing platform for steel component health monitoring and extends the practical lifecycle of reusable sensors in critical applications.

Keywords: Electromechanical impedance (EMI), Acoustic Emission (AE), Wavelet, Damage identification, Weld connection, Structural Health Monitoring (SHM).

Theme 2: Paper 149

Graph Neural Network-Based Degradation Modelling Using Industrial SCADA Data

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA7/29 (58) Hybrid

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Industrial asset systems operate across various dynamic acceptable states, driven by scenarios of demand fluctuations, sub-system inefficiencies, variability in fluid properties and changes to control settings. This variability poses significant challenge for conventional data-driven health monitoring approaches, which could mistake operational variability for genuine degradation. Existing SCADA-based PHM and GNN approaches typically construct sensor graphs once or per operating segment and incorporate domain knowledge only as a one-time correction, leaving operational variability to be managed outside the graph structure itself, due to which interpretability and root-cause attribution remain unresolved. This paper proposes a Graph Convolutional AutoEncoder (GCAE) framework applied to SCADA data streams for fault diagnosis and failure prediction in industrial systems, in which the graph adjacency is recomputed daily and enforced at every convolutional layer, and an operating-point conditioning vector is injected at the latent bottleneck to separate conditiondriven variation from genuine degradation. The graph representation encodes essential operating parameters as nodes, with edges capturing the underlying system dynamics governing their interactions over time. Graph features, together with their temporal changes, are used to distinguish fault signatures from normal-state operational variations. The framework is applied on an industrial SCADA dataset demonstrating early degradation detection ahead of a recorded trip event, with node-level attribution that narrows troubleshooting to a small, persistent subset of sensors.

Keywords: Industrial AI, Graph Neural Networks, SCADA, PHM

Theme 2: Paper 160

Quantifying Human Emotions: A Multi-Modal Framework using Facial Expressions and Physiological Signals

Presentation time/location: 1 September 2026, 4:00 PM - 4:15 PM, OA7/26 (30)

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Human emotions strongly influence perception, cognition, attention, and decision-making, making accurate emotion quantification essential for adaptive intelligent systems in domains such as intelligent transportation, healthcare, workplace safety, and human–computer interaction. Existing emotion recognition approaches often rely on single modalities or static multimodal fusion, limiting their ability to capture the dynamic nature of emotional responses. To address these limitations, this study proposes a multimodal framework that integrates facial expressions and physiological signals using an adaptive modality-aware fusion strategy. The framework introduces the Emotional Valence Index (EVI) and the Emotion Arousal Index (EAI) as continuous, objective measures of emotional intensity, enabling robust, interpretable quantification of emotion. Experimental results demonstrate improved robustness and reliability over single-modal approaches, highlighting the framework's potential for real-time emotion monitoring in intelligent transportation, healthcare, workplace safety, virtual reality, and other human-centred applications.

Keywords: Human emotion, Emotion induction, Facial expression, Physiological signals.

Theme 2: Paper 177

Baseline-free damage detection under environmental variability using a normalized FRF–WPPE–LOF approach

Presentation time/location: 1 September 2026, 3:15 PM - 3:30 PM, OA6/10 (36)

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The variability of the environment remains a major challenge in vibration based structural health monitoring, as temperature changes, boundary conditions, and changes in the operating environment may cause

fluctuations in response comparable to those caused by structural damage. To address this issue, a baseline free damage detection method based on frequency response function (FRF), wavelet packet permutation entropy (WPPE), and local anomaly factor (LOF) is proposed. Firstly, FRF is constructed through structural dynamic response to reduce the impact of excitation uncertainty. Then, the obtained FRF signal is decomposed using wavelet packet analysis, and permutation entropy is calculated for each frequency band to extract damage sensitive features. In order to improve robustness under environmental variability, the Normalized WPPE (N-WPPE) index is introduced, which suppresses global feature drift while preserving local anomalies related to damage. Finally, the LOF algorithm is used to unsupervised identify abnormal locations and quantify the severity of damage. A numerical steel box girder model operating under various environmental conditions and damage scenarios was used to evaluate the proposed method. The results indicate that the framework based on N-WPPE effectively reduces the impact of environmental changes and achieves more reliable damage localization than traditional WPPE basic methods. The proposed method provides a simple and effective solution for benchmark free structural damage detection under different environmental conditions.

Keywords: Structural health monitoring, Baseline-free damage detection, Frequency response function, Wavelet packet permutation entropy, Environmental variability, Local outlier factor.

Theme 2: Paper 178

CFD Analysis of Flow Distribution in a Complex-Pipe System with Sudden Junction and Inline Flow Control Devices (Kulabs)

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA6/10 (36)

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This study presents a three-dimensional CFD investigation of steady, incompressible turbulent flow in a reservoir-pipe distribution system comprising three inlet branches (350 mm diameter) merging through a sudden combining junction into a single 700 mm main pipeline, with flow distributed through three outlet branches equipped with inline flow control devices (kulabs, 30 mm throat diameter). The Reynolds-Averaged Navier-Stokes (RANS) equations are solved using the finite volume method with the k-ω SST turbulence model, selected for its accuracy in resolving near-wall turbulence and flow separation at sudden expansions. Mesh independence is confirmed across three progressively refined grids, with area-averaged velocity changes below 2% between medium and fine meshes, and results are validated against Darcy-Weisbach analytical estimates, with CFD friction pressure drops agreeing within 8% across all pipe segments. Key findings include: a total head reduction from 16.81 m at the inlets to near-zero at the outlets; inlet pressures of 160-162 kPa reducing to near-zero gauge at outlets; an inlet Reynolds number of 7.71×10^5 confirming fully turbulent conditions; and kulab throat velocities peaking at 9.81 m/s against branch pipe velocities of 0.7-1.3 m/s. Kulabs raise upstream back-pressure by approximately 71.7 kPa relative to the no-kulab baseline. The study demonstrates that CFD reveals flow behaviour that standard analytical methods cannot predict: the velocity field at the combining junction is asymmetric and persists well downstream; successive kulabs interact hydraulically, with downstream restrictions raising upstream pressures beyond values the orifice equation predicts independently; and discharge varies non-uniformly across kulabs on the same branch, affecting irrigation performance. These findings provide practical design guidance that empirical methods alone cannot offer.

Theme 2: Paper 188

From Signal to Latent-Space: A Review of Representation Reduction and Recalibration in Deep Learning for Vibration-based Fault Diagnosis

Presentation time/location: 1 September 2026, 2:30 PM - 2:45 PM, OA6/10 (36)

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Deep learning has been widely applied to vibration-based fault diagnosis of rotating machinery, but improved diagnostic capability is often accompanied by deeper networks, larger representations and higher computational cost. This review examines how diagnostic representations are selected, reduced and recalibrated across deep learning pipelines for vibration fault diagnosis. Instead of organising the literature only by model architecture, it proposes a two-axis taxonomy: stage of operation, distinguishing input-level and latent-space methods, and mode of operation, distinguishing hard selection and soft recalibration. Existing studies are reviewed across four groups: input-level hard selection, input-level soft recalibration, latent-space soft recalibration and latentspace hard selection. The review shows that input-level hard selection and latent-space soft recalibration are the most established directions, whereas input-level soft recalibration and latent-space hard selection remain less systematically developed. Hybrid frameworks are also discussed as multi-stage designs that combine representation reduction before deep learning with feature recalibration inside the model. This taxonomy provides a structured perspective for interpreting, comparing and designing efficient deep learning models for vibration-based fault diagnosis.

Keywords: Fault diagnosis · Vibration signal · Deep learning · Attention mechanism · Representation reduction.

Theme 2: Paper 189

Torsional Load Estimation and Stiffness Degradation Detection in Wind Turbine Blades: A Review of Measurement, Simulation, and Data-Driven Approaches

Presentation time/location: 2 September 2026, 4:15 PM - 4:30 PM, OA7/26 (30)

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Operational reliability of wind turbine rotor blades depends on the timely detection of structural degradation, yet most conditionmonitoring research has concentrated on flapwise and edgewise blade loading, leaving torsional loads comparatively unexamined. This paper presents a critical review of torsional load monitoring and stiffness degradation detection methods for wind turbine rotor blades, synthesising contributions spanning direct structural measurement, high-fidelity aeroelastic simulation, virtual sensing, and emerging data-driven approaches. The literature is organised within a classification framework spanning measurement-based sensing (strain gauges, fibre Bragg gratings, accelerometers, optical methods), simulation-based estimation (OpenFAST, HAWC2, GH Bladed, coupled CFD-FSI methods, digital twins), observer-based virtual sensing (Kalman filtering, state and load reconstruction), and machine-learning frameworks (Random Forest, XGBoost, artificial and recurrent neural networks, and physics-informed neural networks). This organisation exposes a consistent and underaddressed gap: torsional load estimation and torsion-specific fault detection remain largely absent from the wind turbine structural health monitoring literature, despite torsional stiffness degradation being mechanistically linked to blade twist, angle-of-attack modification, and flutter-related instabilities. The review identifies the critical barriers to operational deployment of torsion-aware monitoring, including sensor inaccessibility at the blade root, the simulationto-reality transfer gap for healthy-trained virtual sensors, and load-and wind-regime-dependent fault thresholding, and outlines the most promising directions for closing these gaps, including torsion-specific virtual sensors, benchmark datasets, uncertainty-quantified residual thresholds, and digital twin integration relevant to intelligent asset management.

Keywords: Torsional Load · Stiffness Degradation · Wind Turbine Blades · Virtual Sensing · Structural Health Monitoring · Machine Learning · Physics-Informed Neural Networks · OpenFAST

Theme 2: Paper 202

A novel calibration approach for improved cavitation classification in control valves

Presentation time/location: 1 September 2026, 4:00 PM - 4:15 PM, OA6/10 (36)

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Cavitation in control valves can cause premature trim wear, unstable flow behaviour, and damage to downstream equipment. Accurate valve plug height is therefore important when assessing cavitation risk, particularly at low valve openings where pressure drop and local flow acceleration are expected to be greatest. This paper presents a calibration based method for improving cavitation classification in a 4 inch 300# globe control valve by linking the positioner signal to the actual plug height. A magnetic linear scale was used to measure plug travel, while the 4 mA to 20 mA positioner signal was converted to voltage using a shunt resistor circuit and recorded through a LabVIEW virtual instrument. The measured voltage and plug-height data were used to develop a calibration equation, allowing plug height to be displayed with higher resolution than the standard positioner output. A validated CFD model was used to highlight the cavitation regions within a control valve. The CFD model was then used to assess likely cavitation regions at 20% and 50% open using flow coefficients validated by an real world experiment. The study shows that improved height measurement can reduce uncertainty in valve position reporting and support more reliable cavitation predictions in a control valve.

Keywords: Control Valve, Cavitation, Valve Plug Height, CFD, LabVIEW calibration

Theme 2: Paper 210

Guided Wave based Structural Health Monitoring of a Stainless Steel Pressure Vessel used in Hydrogen Storage

Presentation time/location: 1 September 2026, 4:30 PM - 4:45 PM, OA6/10 (36)

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The structural integrity of hydrogen storage and transportation components is essential for the safe and reliable deployment of hydrogen energy systems. This study presents an intelligent structural health monitoring (SHM) framework for the automated detection of internal-wall damage in a stainlesssteel pressure vessel using ultrasonic guided waves and deep learning. Guidedwave signals acquired from pristine and damaged structural conditions are transformed into two-dimensional time-frequency representations using the Continuous Wavelet Transform (CWT), generating scalograms that effectively capture damage-sensitive wave propagation characteristics. These scalograms are subsequently used to train a convolutional neural network capable of automatically distinguishing different structural conditions without manual feature engineering.

Visual comparison of the CWT scalograms demonstrates noticeable variations in the spatial distribution and intensity of wavelet energy caused by internal damage, highlighting the effectiveness of the time-frequency representation for damage characterization. The results confirm that integrating guided-wave sensing, CWT-based feature representation, and deep learning provides an accurate and reliable approach for automated damage identification in hydrogen pressure vessels. The proposed SHM methodology offers significant potential for real-time condition monitoring, predictive maintenance, and improved operational safety of critical hydrogen energy infrastructure.

Keywords: Structural Health Monitoring, Hydrogen Pressure Vessel, Ultrasonic Guided Waves, Continuous Wavelet Transform, Deep Learning, Damage Classification.

Theme 3: Paper 1

Effect of Anti-stripping Agents on Adhesion between Aggregates and Bitumen

Presentation time/location: 3 September 2026, 2:30 PM - 2:45 PM, OA7/02 (30)

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In this experiment, four types of anti-stripping agents (vegetal based, silane-based, amino-based and phosphoric-based) were added to three different aggregates (granite, limestone and tuff) and 40/60 bitumen in different percentages to create 31 different mixture types. Boiling water tests were conducted on these mixtures to determine the degree of stripping of bitumen from the aggregates. Visual inspection of boiled samples compared to un-boiled samples, based on BS EN 12697-11, demonstrated that the use of anti-stripping agents improved mixture resistance to stripping with certain combinations showing superior performance. Limestone exhibited the highest anti-stripping resistance for the control mixture and showed most effective performance in combination with the vegetal-based anti-stripping agent. Tuff showed high performance with the amino-based anti-stripping agent while granite showed most effective performance with the phosphoric based anti-stripping agents. The visual inspection results were validated by conducting Automatic Image Analysis that was based on an automated K-means clustering algorithm. The mixtures that showed superior performance were tested for stripping by the rolling bottle test.

Keywords: Anti-stripping agents, Moisture resistance, Adhesion, Boiling water test, Rolling bottle test, Automatic image analysis, K-Means clustering

Theme 3: Paper 3

Floating-Aware Blade Design for Fatigue Reduction in Offshore Wind Turbines

Presentation time/location: 2 September 2026, 4:15 PM - 4:30 PM, OA6/07 (30)

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Floating offshore wind turbines (FOWTs) experience additional aerodynamic loading due to platform pitch and surge motions, which alters the effective angle of attack along the blade span. Most blade designs are optimised for fixed-bottom conditions and do not account for the floating specific load perturbations. This paper presents a correction-based inverse blade element momentum theory (BEMT) methodology that redesigns the IEA 15 MW reference wind turbine blade to target the aerodynamic conditions encountered on the UMaine VolturnUS-S semisubmersible platform. The aerodynamic differences between floating and fixed-bottom operation are first characterised using 96 paired aeroelastic simulations, from which spanwise angle of attack and axial induction corrections are extracted. These corrections are then used as design targets in an inverse BEMT solver following dual-target formulation of Moghadassian and Sharma. Three blade variants are compared: the original IEA 15 MW blade, a fixed-condition redesign serving as a solver self-consistency check, and a floating aware redesign. Fatigue damage equivalent loads (DELs) are computed from 96 IEC 61400-1 compliant aeroelastic simulations (700s, 600 usable after transient removal) via rainflow cycle counting (ASTM E1049) and Rayleigh-weighted lifetime aggregation. The floating aware redesign achieves a 1.31% ± 0.32% reduction in lifetime blade root flapwise DEL (RootMyb1, m=10) relative to the original blade, with a negligible change of 0.15% in tower base fore-aft DEL (TwrBsMyt, m=4). The methodology shows that even modest, physically motivated blade geometry modifications-maximum twist change-0.160° and maximum chord change of 0.048m, can give measurable fatigue benefits without compromising tower loading or requiring structural redesign of support structure.

Keywords: floating offshore wind turbine; inverse blade element momentum theory; fatigue damage equivalent

Theme 3: Paper 5

Predictive modelling of indoor thermal comfort in retrofitted smart buildings for sustainable asset management

Presentation time/location: 2 September 2026, 4:30 PM - 4:45 PM, OA7/26 (30)

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Indoor thermal comfort is essential for sustainable operation of retrofitted smart buildings, where ventilation pathways, radiator heating, moisture transport and occupant-controlled openings can produce spatially non-uniform conditions. This study develops a coupled Computational Fluid Dynamics–Artificial Neural Network (CFD–ANN) framework for rapid, spatially resolved prediction of Predicted Mean Vote (PMV), with Predicted Percentage Dissatisfied (PPD) derived analytically from ANN-predicted PMV. A CFD–BIM model was used to simulate airflow, heat and moisture transport under varying window states, internal door positions, radiator operation and outdoor relative humidity. The CFD model was validated against Smart House temperature measurements, with a maximum normalised deviation of 2.90%. A total of 704 point-wise samples representing local environmental conditions, spatial coordinates and operating states were used to train an 11–32–16–1 feed-forward ANN. On the independent test subset, the model achieved $R^2 = 0.9945$ for PMV and $R^2 = 0.9907$ for derived PPD; across all samples, the corresponding values were 0.9964 and 0.9949. ASHRAE/ISO-informed classification identified 36 CFD-derived and 37 ANN-based comfortable samples,

yielding 99.86% binary agreement. The framework provides a validated foundation for Digital Twin-oriented comfort assessment, retrofit evaluation, predictive control and sustainable smart-building asset management, while preserving physical consistency through PMV–PPD coupling within the investigated design space.

Keywords: Thermal comfort, Computational fluid dynamics, Artificial neural network, Smart buildings, Digital Twin, Sustainable asset management.

Theme 3: Paper 15

Material Reuse in Circular Retrofit: Uncertainty and Information Requirements for Design Decision-Making

Presentation time/location: 2 September 2026, 4:15 PM - 4:30 PM, OA7/02 (30)

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Circular retrofit has gained increasing attention to reduce construction waste, improving resource efficiency and preserving embodied carbon. Yet, the practical adoption of material reuse in retrofit projects remains limited. This paper argues that circular retrofit should be understood not only as a technical or logistical challenge, but also as a design decision problem. In early project stages, designers are required to make decisions about materials, building systems and retrofit strategies under conditions of incomplete and uncertain information. Through a literature review, the paper identifies five key dimensions of uncertainty affecting reuse decisions: availability, condition, provenance, compliance and timing. These uncertainties influence perceptions of feasibility, risk and value, and may lead to reuse options being excluded before their suitability is fully assessed. The paper then examines the information requirements associated with each uncertainty dimension, arguing that the principal challenge is not simply the absence of data, but the lack of information that is sufficiently reliable, timely, traceable and actionable to support design judgement. A conceptual framework is proposed to link reuse uncertainties, information requirements, design decisions and circular retrofit outcomes. The paper highlights the need for future research to develop approaches that better support design teams in evaluating material reuse within retrofit contexts.

Keywords: Circularity, Retrofit, Material Reuse, Decision-making, Information

Theme 3: Paper 19

Hybrid ANN-Genetic Algorithm-Based Optimization of Indigenous Water-Droplet Based TENG for Sustainable Energy Harvesting Applications

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA7/02 (30)

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The growing demand for sustainable, clean energy solutions and battery independent sensing technologies has accelerated the development of triboelectric nanogenerators (TENGs). TENGs are the promising devices for harvesting low frequency energy for next generation industrial and environmental monitoring systems. Among various configurations of TENGs, Liquid-solid TENGs offer a significant potential due to their humidity sensitive nature and suitability for self-powered sensing applications. This study reports an indigenous design, fabrication and optimization of Water-solid TENG employing Polytetrafluoroethylene (PTFE) and Fluorinated Ethylene Propylene (FEP) as two different active tribo-negative materials. The fabricated TENG strips were experimentally tested to harvest energy of water droplets and successfully converting it into electrical energy. A data driven modelling approach using Artificial Neural Networks (ANN) was implemented to visualize the nonlinear relationship between input parameters and electrical output responses to improve optimization accuracy. Further, a Genetic Algorithm (GA) was integrated with ANN model to form a hybrid ANN-GA framework. Hybrid ANN-GA approach offered significantly improved prediction accuracy as well as the optimization efficiency compared to the results obtained from the stand-alone methods. An optimized AC voltage of 2.6 Volts and a current of 1-2 micro-amperes from PTFE based fabricated TENG strips and 3.64 Volts and a current of 1-3 micro-amperes from FEP based TENG strips was predicted by the developed ANN-GA framework under the corresponding optimized operating conditions. The proposed data driven optimization framework demonstrates the effectiveness of integrating intelligent modelling with experimental investigation to improve the design and operational efficiency of Liquid-solid TENGs. Beyond energy harvesting, this work highlights the potential of the optimized TENG as a sustainable power source for self-powered monitoring applications in water pipelines, cooling systems, waste water treatment facilities and environmental surveillance, where continuous water motion can be utilized to drive autonomous sensing devices. By reducing the dependence on conventional batteries and promoting renewable energy utilization, the current study offers a pathway practically towards the indigenous monitoring systems that enhance process reliability, operational safety and environmental sustainability. The findings establish a scalable strategy for the development of AI-assisted triboelectric harvesting technologies with significant potential for industrial and environmental applications.

Keywords: TENG · Artificial Neural Networks · Genetic Algorithm · FEP · PTFE

Theme 3: Paper 27

Waste-to-Energy Approach: Development of Tissue Paper-Derived Carbon Nanofluids for Solar

Thermal Energy Harvesting

Presentation time/location: 1 September 2026, 4:45 PM - 5:00 PM, OA7/02 (30)

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The energy sector is currently facing the challenge of meeting rising energy demands sustainably. Countries are pledging and striving to achieve their Sustainable Development Goal (SDG) 7 “Affordable and Clean Energy” through the energy transition through renewable energy sources such as solar, wind, biomass and others. Technological innovation is one of the key drivers for achieving energy transition and particularly the usage of nanoparticles for the harnessing of solar energy is proving to be a significant step in this direction. The nanoparticles improve the absorption capability of solar thermal collectors, gets heated and then transfers the heat to the working heat transfer fluid. These nanoparticles-laden solar collectors are advantageous than the commercially available solar thermal collectors because in the Nanofluid-based Solar Thermal Collector (NFSTC), the materials which like carbon soot, carbon dust can be used for the harnessing of solar energy. In this study, carbon nanoparticles from scrap (tissue) paper have been synthesized. The optical properties show that these nanoparticles improve the absorption capability of heat transfer fluid. The absorption capability depends on the volume fraction or mass concentration of the nanoparticles and increases with the increase of volume fraction. Further, the thermal performance of the NFSTC with three volume fractions (0.002%, 0.003% and 0.004%) has been compared with surface absorption-based collector (SAC) under identical conditions. It has been found that the temperature of the NFSTC at 0.004% was 9.6 °C higher than that of the SAC. The absorption increases with this range of volume fraction and this trend is for the tested range only.

Keywords: Nanofluid-based solar thermal collector, surface absorption-based collector, volume fraction, Solar energy, Scrap paper

Theme 3: Paper 31

Selecting spare parts technically feasible for additive manufacturing: a case study

Presentation time/location: 3 September 2026, 2:45 PM - 3:00 PM, OA7/02 (30)

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This study investigates the technical feasibility of additive manufacturing (AM) to produce metal spare parts for control valves. The focus lies on selecting feasible parts for AM. The study assumes a scenario in which the manufacturer produces spare parts in a decentralized manner, close to the customer, using its design drawings. This approach addresses key challenges of traditional spare parts provision, such as high inventory costs and long delivery times. Based on insights from a systematic literature review, a combined methodology is used to assess the feasibility of spare parts for AM. A control valve manufacturer provides a real-world case for our study. The assessment considers criteria such as material compatibility, geometric complexity and post-processing requirements. The methodology is applied to a set of spare parts from the case to categorize these parts according to their feasibility for AM production. The results show AM's strong potential to produce complex, customized spare parts, with 162 (36%) assessed parts rated as technically feasible. Material constraints represent the primary barrier to AM feasibility, excluding 53% of the parts. Other spare parts are deemed unfeasible due to complex post-processing requirements. In the case study, the feasibility of spare parts for AM production is not limited by size, manufacturing tolerances, or surface quality. Overall, the study contributes to the body of knowledge on AM by applying and validating a methodology for assessing spare parts’ feasibility for decentralized production.

Keywords: spare parts, part selection, part identification, multi-criteria decision-making, additive manufacturing, AM Service Bureau

Theme 3: Paper 33

Understanding Hygienic Surface Material Specification in Healthcare Facilities: Insights from International Stakeholder Interviews

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA7/02 (30)

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Healthcare-associated infections (HAIs) remain a major challenge for healthcare systems worldwide. Although national and international guidance defines broad principles for hygienic surface materials, it provides limited support for specifying materials that balance infection prevention with cost, maintenance, aesthetics, sustainability and procurement requirements. This study explores stakeholder perspectives on hygienic surface material specification in healthcare facilities and identifies the principal considerations influencing specification practice. Semi-structured interviews were conducted with twelve experienced stakeholders representing healthcare architects, biomedical planners, facilities managers and infection prevention specialists across five national contexts using purposive expert sampling. Data were analysed using reflexive thematic analysis. The findings show broad agreement on the characteristics of hygienic surface materials but differences in how stakeholders interpret guidance and balance competing specification priorities. Operating theatres and intensive care units were consistently identified as requiring the highest hygienic standards. The study identifies a translational gap between principle-based guidance and practical

specification, highlighting opportunities for clearer performance criteria, stronger interdisciplinary collaboration and better access to independent material performance evidence. These findings provide an empirical basis for the future development of evidence-informed decision-support frameworks for healthcare material selection.

Keywords: healthcare facilities; hygienic materials; material specification; infection prevention.

Theme 3: Paper 35

Self-Adaptive Passive Thermoelectric Energy Harvesting for Wireless Condition Monitoring of CNC Machine Tools

Presentation time/location: 1 September 2026, 4:00 PM - 4:15 PM, OA7/02 (30)

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Continuous wireless condition monitoring of CNC machine tools is central to predictive maintenance in Industry 4.0. Yet, battery-powered sensor nodes impose replacement downtime that intensifies precisely when bearing faults are developing. Thermoelectric generators (TEGs) that harvest machine waste heat offer a battery-free alternative, but no prior study has demonstrated a passively cooled multi-module array that meets the cold-start threshold of nano-power management integrated circuits (PMICs) at the sub-5 K surface-to-ambient differentials characteristic of CNC machine centres. This paper presents a controlled experimental investigation addressing the gap. A single-variable emissivity experiment demonstrated that black anodising the aluminium heat sink ($\varepsilon = 0.87$), rather than leaving it bare ($\varepsilon = 0.04$), widened the module differential by 20.4% through increased radiative cold-side dissipation, yielding a 45.0% gain in harvested power at matched load. Systematic contact-pressure optimisation across four clamping levels identified 3.83 kPa as the condition that maximises attainable power without risk of ceramic fracture. The complete system eight-module Bi2Te3 array, Texas Instruments BQ25570 PMIC, and 1.5 F supercapacitor delivered 2.80 ± 0.014 mW across five independent 60-minute tests at a steady-state differential of 3.38 K, generating an open-circuit voltage of 847 mV, a 2.6-fold margin over the 330 mV cold-start threshold and storing 0.324 mWh per session at a net system efficiency of 11.56%. The resulting 2.66 mW surplus over the target LoRaWAN node's mean demand of 0.144 mW confirms fully autonomous, battery-free operation.

Keywords: Thermoelectric energy harvesting, passive thermal management, predictive maintenance, Industry 4.0, wireless sensor networks, CNC condition monitoring.

Theme 3: Paper 40

Parallel operation and control for Hybrid Generators in wind farms.

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA7/26 (30)

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Renewable energy sources, particularly wind farms, have played a key role in addressing rising energy consumption over the past few decades. Offshore wind farms offer substantial capacity to harness wind with high frequency and intensity. Nonetheless, the challenges of operability, logistics, and maintenance are considerable due to their remote location. An alternative solution is the implementation of the Hybrid Permanent Magnet Generator, whose main feature is the presence of two magnetic fields (Permanent Magnet and Wound Field) in the same rotor. This feature eliminates the need for a capacitor, transformer, and active converters, whose maintenance and weight pose significant challenges. Another feature of the Hybrid Generator is the multiphase stator output, which helps to reduce ripple in the output voltage signal connected to the passive bridge rectifier. This paper presents a control system for Hybrid Permanent Magnet Generators operating in parallel in wind farms, where any voltage disparity may cause the rectifier bridge to shut down and stop generating electricity. The system comprises a power reference system based on an Artificial Neural Network and a Proportional-Integral-Derivative Controller, with the Wound Field as the control variable. The results were compared with the operational range for different values of the VDC-LINK and rotor speed, showing that the control system delivers the maximum available power without exceeding operational limits of 3.6 MW and 120 A rms. It is also designed to be integrated into a High-Voltage Direct Current transmission system.

Keywords: Wind Energy, HVDC, Hybrid Permanent Magnet Generator, PID, Artificial Neural Network.

Theme 3: Paper 44

A reduced ADM1 based model for mesophilic batch anaerobic digestion of oily food waste with biochar amendment

Presentation time/location: 1 September 2026, 3:00 PM - 3:15 PM, OA7/02 (30)

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Anaerobic digestion (AD) is widely used to treat biodegradable wastes such as food waste, while producing methane-rich biogas and a nutrient-rich digestate that can be used as biofertiliser. However, the process involves several linked biochemical reactions, and the presence of fats and oils can make the system more difficult to model. Biochar has been reported to improve process stability and methane production during the digestion of oily food waste. At the same time, the full Anaerobic Digestion Model 1 (ADM1) requires a large number of parameters and can be difficult to apply where experimental data are limited. This study therefore develops a reduced ADM1-based dynamic model for batch digestion of oily food waste with biochar addition.

The effect of biochar is represented using a time-dependent enhancement factor. The reduced model retains the main pathways involved in substrate breakdown and methane formation while using fewer states and parameters than the full ADM1. The model provides a simplified framework for examining the effect of biochar addition on methane production during the anaerobic digestion of oily food waste.

Keywords: Anaerobic digestion, reduced ADM1 model, oily food waste, batch reactor, biogas production, biochar.

Theme 3: Paper 49

A Comparative Evaluation of Reinforcement Learning and Model Predictive Control for Tomato Greenhouse Climate Control

Presentation time/location: 3 September 2026, 2:15 PM - 2:30 PM, OA7/02 (30)

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Greenhouse climate control requires a balance between crop productivity, operating costs, and environmental regulation. Reinforcement learning (RL) and Model Predictive Control (MPC) have both been applied to greenhouse control, but relatively few studies have evaluated standalone RL and MPC controllers within a common greenhouse framework using consistent operating conditions and performance metrics. This study presents a comparative evaluation of Proximal Policy Optimisation (PPO), Soft Actor-Critic (SAC), and economic MPC for tomato greenhouse climate control using a common GreenLight-based simulation environment. All controllers were evaluated under the same weather conditions, actuator constraints, economic assumptions, and environmental limits. Performance was assessed using Economic Performance Index (EPI), operating cost, fruit dry-matter growth, and violation metrics for temperature, CO_2, and relative humidity. Under deterministic validation, PPO achieved the highest EPI (3.26 €/m²), followed by SAC (1.09 €/m²) and MPC (0.50 €/m²). The higher EPI obtained by PPO was primarily associated with lower operating costs, while differences in fruit dry-matter growth were comparatively small. MPC achieved the lowest temperature and relative-humidity violation magnitudes, indicating tighter climate regulation. Under crop-parameter uncertainty, PPO maintained the highest mean EPI across all uncertainty levels, whereas MPC achieved the lowest overall environmental violation severity. The results show a clear trade-off between economic performance and climate regulation, with PPO delivering the strongest economic performance and MPC providing tighter environmental control.

Keywords: Reinforcement Learning; Model Predictive Control; Greenhouse Climate Control; Controlled Environment Agriculture; Benchmark Framework.

Theme 3: Paper 50

Comparative Performance and Emissions Analysis of Ammonia, Diesel, and Hydrogen in a Compression Ignition Engine

Presentation time/location: 2 September 2026, 2:30 PM - 2:45 PM, OA7/26 (30)

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Decarbonising compression ignition engines requires carbon to be removed from the fuel rather than from the exhaust. Hydrogen and ammonia are the leading carbon-free candidates, but they differ by a factor of 6.45 in lower heating value, so results obtained for one cannot be transferred to the other. This paper presents a onedimensional Ricardo WAVE study of a single-cylinder compression ignition engine of 115 mm bore, 125 mm stroke and 17.5 compression ratio, operated from 1000 to 2000 rpm in 100 rpm increments. Three fuelling cases are compared on a strictly energymatched basis of approximately 2.756 kJ per cycle, namely 100 % diesel, 30 % hydrogen with 70 % diesel, and 30 % ammonia with 70 % diesel, all shares defined on a lower heating value basis. Brake power, brake thermal efficiency, heat-transfer loss and brake-specific CO and NO2 emissions were extracted at eleven operating points. Relative to the diesel baseline, brake power fell by a speed-averaged 15.7 % for hydrogen and 14.1 % for ammonia, brake thermal efficiency fell by 15.5 % and 13.9 %, and heat-transfer loss rose by 82.8 % and 79.3 %. Brake-specific CO fell by more than 99 % in both cases, while brake-specific NO2 fell by 8.7 % for hydrogen and 38.4 % for ammonia. The ammonia case outperformed the hydrogen case on every available metric, and both exhibited a clear efficiency-for-emissions trade-off against the diesel baseline.

Keywords: Ammonia, Hydrogen, Compression ignition, Dual-fuel combustion, Ricardo WAVE, Brake thermal efficiency, Engine emissions, Alternative fuels.

Theme 3: Paper 51

Multi-Fuel Combustion Analysis of Ammonia, Gasoline, and Hydrogen in a Spark Ignition Engine

Presentation time/location: 2 September 2026, 4:45 PM - 5:00 PM, OA7/02 (30)

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Spark-ignition engines dominate light-duty transport and small stationary power, and their decarbonisation requires fuels that carry no carbon into the cylinder. Hydrogen and ammonia are the leading carbon-free candidates, but their heating values, stoichiometric air requirements and flame properties differ so widely that results obtained for one cannot be transferred to the other. This paper reports a onedimensional Ricardo WAVE study of a single-cylinder, direct-injection spark-ignition engine of 131 mm bore, 158 mm stroke and

11.8 compression ratio, operated from 1000 to 2000 rpm in 100 rpm increments. Three fuelling cases are compared, namely 100 % gasoline as the baseline at an air-to-fuel ratio of 16.5, 100 % hydrogen at 64.09 and 100 % ammonia at 8.7. Because each fuel is run at its own prescribed air-to-fuel ratio, the excess-air ratio differs between cases, at 1.10, 1.88 and 1.44 respectively, and the fuel energy admitted is a speed-averaged 26.9 % and 18.1 % below the gasoline baseline for hydrogen and ammonia. Gasoline consequently delivered the highest brake power throughout, from 13.11 to 30.09 kW, whereas ammonia gave the highest brake thermal efficiency at 27.93 % to 30.65 %. Both carbon-free fuels eliminated carbon monoxide entirely and reduced brake-specific NO2 by a speed-averaged 91.5 % for hydrogen and 81.2 % for ammonia. A fixed friction mean effective pressure was found to govern the brake efficiency ranking, reversing the indicated-efficiency advantage held by hydrogen.

Keywords: Ammonia, Gasoline, Hydrogen, Spark-ignition engine, Ricardo WAVE, Brake thermal efficiency, Engine emissions, Air-to-fuel ratio.

Theme 3: Paper 54

Assessment of VOF and Species Transport Models for Hydrogen-Methane Pipe Flows: Implications for Mixing, Stratification and Pressure Drop.

Presentation time/location: 2 September 2026, 3:00 PM - 3:15 PM, OA7/02 (30)

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The increasing integration of hydrogen into existing natural gas transmission systems requires Computational Fluid Dynamics (CFD) methodologies capable of accurately predicting hydrogen transport and mixing behaviour. This study compares the Volume of Fluid (VOF) and Species Transport modelling approaches for hydrogen-methane pipeline flows and investigates the influence of hydrogen injection orientation on downstream mixing. Simulations were performed using ANSYS Fluent 2024 R2 and benchmarked against published data. Pressure loss, hydrogen concentration distributions and downstream stratification were evaluated for hydrogen concentrations ranging from 0-100 vol.%. Additional simulations examined 5-25 vol.% hydrogen injection into a 900 mm transmission pipeline using both 6 and 12 o'clock injection configurations. Both modelling approaches produced comparable pressure loss predictions and showed good agreement with published data. However, significant differences were observed in the predicted concentration fields. The VOF model produced persistent interface-like structures that are not representative of fully miscible hydrogen-methane systems, whereas the Species Transport model maintained homogeneous distributions under premixed conditions while accurately capturing buoyancy-driven stratification following hydrogen injection. Stratification Index analysis showed that 6 o'clock injection promoted more rapid downstream homogenisation than the 12 o'clock injection. These findings demonstrate that the Species Transport approach provides the most physically representative model for hydrogen blending studies in high-pressure natural gas transmission pipelines.

Keywords: Hydrogen blending; Natural gas transmission; Species transport; Computational fluid dynamics; Stratification; Pipeline repurposing

Theme 3: Paper 55

A Review on Advancing Sustainability in Electropolishing: The Role of Eco-Friendly Electrolytes

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA7/02 (30)

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Electropolishing is a surface finish technique used in many industries to achieve highly smooth, corrosion-resistant and defect free metallic surfaces. In electropolishing process, electrolyte plays a crucial role in the process efficiency and has a significant impact on the product end quality. This paper investigates the behaviour, composition and interactions of electrolytes with different metal surfaces and to understand the crucial role of electrolyte in electropolishing. A wide range of electrolytes, including acidic and neutral solutions are examined, with a focus on their chemical characteristics, environmental impact and industrial applicability. The core elements like temperature, concentration, and flow dynamics are well examined in terms of their impact on surface finish and process efficiency. Recent development in eco-friendly electrolytes, particularly based on deep eutectic solvents, open a new era of promising alternatives to traditional hazardous solutions. This review aims to guide industry experts and researchers towards more cost-effective, sustainable and efficient surface finishing alternatives by addressing both environmental and technical concerns.

Keywords: Electrolyte, Surface finish, Electropolish, Sustainability, Corrosion.

Theme 3: Paper 58

A Degradation-Aware Mixed-Integer Linear Programming Framework for Stacked Grid Services from Battery Energy Storage Systems

Presentation time/location: 1 September 2026, 2:30 PM - 2:45 PM, OA7/02 (30)

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Battery energy storage systems (BESS) can deliver energy arbitrage, frequency-response reserve, demand flexibility, and reactivepower support from one asset, but these services compete for the same energy, power, and inverter headroom and create markedly different cycling patterns. This paper develops a degradation-aware mixed-integer linear programming (MILP) framework that couples the four services through the battery energy balance, operating modes, reserve headroom, and a conservative linearised inverter P–Q capability. Battery wear is represented at three complementary levels: a throughput cost for screening, a piecewise-linear SoC-movement surrogate for scheduling, and rainflow counting for maintenance-oriented evaluation of the completed SoC trajectory. A controlled half-hourly UK-style scenario study shows that annualised net value increases from £3.42k/year for arbitrage alone to £34.06k/year when frequency response and demand response are stacked. Preserving inverter capability for a full stack including reactive support gives £25.77k/year and reduces the representative-day rainflow stress index from 1.000 to 0.369 relative to the highest-stress portfolio. The results demonstrate that equal annual throughput does not imply equal cycling stress and establish a direct link from operational scheduling to service-contract screening, maintenance review, and control retuning.

Keywords: Battery energy storage systems · Service stacking · Mixedinteger linear programming · Degradation-aware optimisation · Rainflow counting · Reactive-power support · Asset management

Theme 3: Paper 59

Multi-Year Lifecycle Optimisation of Battery Energy Storage Systems with Degradation-Aware Service Stacking and Inverter Flexibility Management

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA7/02 (30)

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Battery energy storage systems (BESS) require lifecycle asset management that balances stacked-service income against degradation and replacement risk. This paper presents a two-layer framework linking daily mixed-integer dispatch with multi-year state-of-health (SoH) roll-forward, replacement planning and discounted cash-flow assessment. The inner layer co-optimises arbitrage, frequency response, demand response and reactive-power support subject to energy and inverter constraints. The outer layer compares throughput and rainflow degradation, benchmarks cycle extraction against NASA B0005–B0007 cell records, and normalises the life law to an explicit 4,000-full-cycle commercial assumption. A five-scenario evaluation varies degradation representation, inverter headroom and 3,000–6,000-full-cycle commercial anchors around a parameterised 500 kWh UK planning instance. Rainflow assessment increases annual SoH loss from 1.24% to 3.20% relative to throughput screening. Reserving 15% of a 250 kVA inverter (37.5 kVA) reduces effective annual wear to 2.72%, delays first replacement from Year 7 to Year 8 and increases Net Present Value from £41 865 to £46 846 under the stated single-replacement policy. Profit-per-Wear Efficiency improves from £10 583 to £11 928 per cumulative SoH percentage point. The 3,000–6,000-cycle sensitivity moves modelled first replacement from Year 5 to Year 10 and NPV from −£35 004 to £83 749, showing how expected cycle capability shapes lifecycle planning. The results inform service contracting, supplier selection, maintenance timing and capital budgeting.

Keywords: Battery energy storage systems · Lifecycle asset management · Service stacking · Rainflow cycle counting · Inverter headroom · Degradation modelling

Theme 3: Paper 81

State-of-the-Art Review of Flax–Hemp Circular Bricks for Sustainable Infrastructure Asset Management and Digital Opportunities

Presentation time/location: 2 September 2026, 3:15 PM - 3:30 PM, OA7/26 (30)

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The increasing degradation of infrastructure assets, coupled with resource depletion and the environmental impact of carbon emissions, has accelerated the transition toward bio-based and low-carbon construction materials. Among these, fibre-reinforced polymer composites, geopolymer systems, and lime-based composites incorporating natural fibres such as hemp, flax, and jute have gained significant attention. Existing studies demonstrate that these fibres enhance mechanical performance, reduce embodied carbon, and support circular economy principles through material reuse and waste valorisation. Flax–hemp composites exhibit high tensile strength, low embodied energy, and carbon sequestration capacity, while also improving thermal insulation and crack resistance compared to conventional fired clay bricks. Despite these advantages, their application in circular masonry units for load-bearing infrastructure remains underexplored. Hemp–lime composites, although environmentally favourable across their life cycle, typically exhibit low compressive strength (0.3–3.5 MPa), limiting their use to non-load-bearing systems. Flax fibres, with higher stiffness, have

shown potential in hybrid reinforcement strategies to enhance bonding and mechanical performance. This study offers a comprehensive review and promotes flax-hemp circular bricks as a viable option for environmentally friendly infrastructure. This review highlights important gaps and opportunities for further growth while offering a comprehensive understanding of the current situation of the field. The integration of data-driven approaches and artificial intelligence is emphasised as a crucial gateway to promote material optimisation, performance prediction, and lifecycle management in next-generation infrastructure systems in the context of sustainability and a digital era.

Keywords: Bio-based construction materials, Flax–hemp composites, Circular masonry bricks, Sustainable infrastructure; Fiber-reinforced composites, Artificial intelligence in material design.

Theme 3: Paper 85

Enhancing Interdisciplinary Collaboration in Infrastructure Development through BIM

Presentation time/location: 2 September 2026, 2:15 PM - 2:30 PM, OA7/31 (60) Hybrid

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In Infrastructure development projects, it is essential to apply interdisciplinary collaboration to achieve success in the projects implemented. This type of collaboration requires amalgamation among different project sectors, such as architecture, engineering, and project management. This research examines the role of Building Information Modelling (BIM) in enhancing interdisciplinary collaboration, improving efficiency, and enhancing project outcomes. BIM is a central digital platform throughout the project lifecycle that enhances coordination and decision-making by enabling real-time data sharing, clash detection, parametric modelling, and integrated design reviews. This study uses a mixed-methods approach. Both Interviews and surveys were used to get insights from industry experts on critical issues related to BIM. The interviews were analysed qualitatively, and the surveys were analysed quantitatively to evaluate BIM's effectiveness, challenges, and future potential in infrastructure projects. Results show that this digital platform significantly enhances infrastructure management aspects, including tracking project progress and communication among various stakeholders. Additionally, it was found that BIM also enhances design accuracy and reduces workloads. In addition to the significant barriers that face BIM in South Africa is the high implementation cost. In addition, skill gaps and software interoperability are hindering the widespread implementation. There is a strong resistance to accepting digital transformation generally among small and medium-sized enterprises. Therefore, this research also highlights the importance of improved education and training, standardized protocols (e.g., ISO 19650), and supportive government policies to encourage BIM acceptance. Modern technologies, such as AI, cloud platforms, and augmented reality, are identified as key players in the future of BIM, offering automation, visualization, and lifecycle management.

Keywords: Building Information Modelling (BIM); Interdisciplinary Collaboration; Infrastructure Development; Digital Transformation; Lifecycle Management

Theme 3: Paper 99

Hybrid Biomass-Geothermal Energy Integration for Thermochemical Hydrogen Production via the Cu-Cl Cycle

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA7/02 (30)

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Decarbonising hydrogen (H2) production is essential for achieving net-zero emissions. This necessitates the exploration of integrated multi-energy systems that are capable of producing clean fuels such as H2 whilst at the same time, minimising the resultant emissions from the production of the fuel itself. Biomass pyrolysis presents a pathway to producing fuels for combined heat and power (CHP) generation and biochar production for longterm carbon storage. To further utilise available energy potential, geothermal energy is extracted via ground source heat pumps (GSHPs), providing an additional source of heat and effectively utilising electricity produced in the CHP unit. Integrating the two technologies enables the investigation of the copper-chlorine (Cu-Cl) thermochemical hydrogen production cycle. Operating at temperatures below 550oC, the Cu-Cl cycle can be integrated into the hybrid energy system where high-temperature processes are supplied with heat via CHP and lower-temperature processes can be supplied with heat via the geothermal energy source. The work presented in this paper involves the development of a MATLAB based energy model to assess the effect of integrating the hybrid pyrolysis-geothermal energy system in a unified framework. The problem is presented as a steady-state model to quantify energy allocation, biomass consumption and biochar production for a given daily rate of 100 kg of hydrogen. Results obtained from the study indicate that the integration of the pyrolysis-geothermal energy systems is technically feasible within the Cu-Cl hydrogen production method. This provides a foundation for future optimisation studies on energy allocation and carbon intensity of the proposed hydrogen production route. 2 Utomo et al.

Keywords: Geothermal Energy; Hydrogen Production; Biomass Energy; Decarbonisation; Energy Integration

Theme 3: Paper 102

Comparative Analysis of Conventional and IEC 61850-Based Digital Substation Protection: A Hardware-in-the-Loop Evaluation

Presentation time/location: 3 September 2026, 2:00 PM - 2:15 PM, OA7/29 (58) Hybrid

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Conventional substation protection systems have long served as the foundation of power system protection due to their deterministic operation and established reliability. However, the increasing complexity of modern substations has exposed limitations associated with extensive copper wiring requirements, rigid physical signal paths, and reduced flexibility for system modification. These limitations have accelerated the transition toward IEC 61850 based digital protection architectures, where GOOSE messaging enables high speed exchange of protection signals through Ethernet communication networks. Despite the growing adoption of digital substations, a direct quantitative comparison between conventional hardwired protection and IEC 61850 based protection under identical operating conditions remains insufficiently explored. This paper presents a real-time hardware-in-the-loop (HIL) based comparative evaluation of conventional and IEC 61850 based protection conducted on the Typhoon HIL platform. Both protection schemes are implemented within the identical power system model with similar fault scenarios and protection settings. Fault clearing time (FCT) is selected as the primary performance metric and assessed under various fault conditions at both 33 kV and 11 kV voltage levels. The IEC 61850 based scheme results in lower FCT across all investigated scenarios, with an average reduction up to 14% approximately compared with conventional protection. The findings provide experimental evidence of the performance benefits offered by IEC 61850 based digital protection and establish a controlled reference for future evaluations of communication-based protection architectures in modern substations.

Keywords: IEC 61850, Digital Substation, Hardware-in-the-Loop (HIL), GOOSE Communication, Fault Clearing Time, Power System Protection

Theme 3: Paper 103

Experimental Investigation of Burr Size and Surface Quality in the End Milling Process of Al6082-T6 Alloy

Presentation time/location: 1 September 2026, 2:15 PM - 2:30 PM, OA7/02 (30)

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End milling is a fundamental part of the manufacturing industry and is often associated with high resource use and poor surface finish. This research experimentally investigates surface roughness, hardness, and burr size during end milling of Al6082-T6 alloy blocks. This study employed Taguchi's experimental design technique with three feed rates and three toolspeed levels at a depth of 0.4 mm. Surface roughness of the machined part was measured utilising a portable roughness tester. A hardness tester (model HM-200) was used to measure hardness, and an Olympus BX 53M Microscope was used to measure burr size. The experimental results were analysed, and the statistics showed that increasing tool speed increased machinedsurface hardness, whereas lower feed rates favoured better surface quality. Main effect plots showed how varying input cutting conditions affected the output responses (surface roughness, hardness, and burr size). Feed rate was the most influential factor, significantly affecting surface roughness, hardness, and burr size. The cutting condition of 500 rpm (353.4 mm/min) and a feed rate of 0.045 rev/min produced the best surface hardness and a good surface finish, with low surface roughness. Experiment 6 shows the lowest burr length for both up-and downmilling operations. However, Experiment 9 with a cutting speed of 1500 rpm shows the largest burr lengths of 768.1 µm and 645.1 µm.

Keywords: End milling, Al6082-T6 alloy, surface roughness, microhardness, Taguchi, burr size.

Theme 3: Paper 107

Green hydrogen production with AEM pressure electrolyser-using an advanced electrolyte management concept

Presentation time/location: 1 September 2026, 2:30 PM - 2:45 PM, OA7/26 (30)

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In the context of energy transition, fluctuating renewable energies from solar and wind require sophisticated storage systems. In addition to batteries, green hydrogen is unavoidable for seasonal storage and long-distance vehicles. Therefore, we developed a compact hydrogen supply unit with a high-pressure AEM electrolyser, supplying hydrogen at up to 80 bars – which is truly an innovation. This is combined with a hydrogen piston compressor for filling gas cylinders with to 700 bar gas pressure. The electrolyser is supplied with a continuous flow of tempered aqueous KOH at the anode with a concentration of 1.0 mol L-1. At the dry cathode, pressurized hydrogen is released with up to 80 bar. A major issue is the dislocation of hydroxide ions and water within the membrane-electrode-assembly. Reasonably, the liquid level in the electrolyte container is decreasing over time, since H2O is split within the process. Remarkably, the KOH concentration is decreasing as well. This is due to KOH leaking through the MEA and concentrated at the cathode. Separation of liquid takes place in a pressure cylinder, where KOH concentrations of >3.0 mol L-1 were measured. Controlling the

level of lye is provided with a non-invasive ultrasonic level detection. One objective of this development is fully automated and safe unit control for operations management and maintenance. Therefore, deeper knowledge of the MEA diffusion processes is preferable. Soon, a simulation model of the diffusive mass transport phenomena through the MEA will be developed and validated for enhanced flow management and remote maintenance of the system.

Keywords: Anion-exchange-membrane (AEM), Raney-nickel electrode, pressure electrolyser, hydrogen filling station, electrolyte management system

Theme 3: Paper 109

Durability and Mechanical Behaviour of Recycled PET-Modified Polyester Resin and GFRP Bars under Aggressive Environments

Presentation time/location: 1 September 2026, 4:00 PM - 4:15 PM, OA7/27 (40)

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The development and experimental evaluation of low environmental-impact Glass Fiber Reinforced Polymer (GFRP) bars manufactured using an orthophthalic polyester resin modified with 20% by weight recycled polyethylene terephthalate (rPET) are presented. The combination of conventional orthophthalic polyester with recycled PET offers a sustainable and effective alternative to traditional vinylester and epoxy systems for structural applications. The experimental programme comprised three complementary investigations. First, tensile tests were performed on resin dog-bone specimens after 1000 hours of conditioning in distilled water, alkaline solution, and saline solution to evaluate the residual mechanical properties of five thermosetting resin systems. Second, tensile tests were carried out on unconditioned pultruded GFRP bars to determine their mechanical properties. Finally, three-point bending tests were performed on reference and environmentally conditioned GFRP bars coated with orthophthalic polyester (OP) + rPET, vinylester, and epoxy resin systems to increase the environmental resistance of the modified polyester matrix. The OP+rPET resin achieved a tensile strength of 48.7 MPa, an elastic modulus of 3.4 GPa, and an ultimate strain of 2.86% in the unconditioned state. The corresponding GFRP bars exhibited a tensile strength of 689 MPa and an elastic modulus of 62.2 GPa, while the OP+rPETcoated bars showed reductions in flexural strength of 13.6% and 27.1% after alkaline and saline conditioning, respectively. These results confirm the potential of the OP+rPET system as a sustainable alternative for GFRP reinforcement in concrete structures.

Keywords: GFRP bar, sustainability, PET, ageing, saline and alkali solutions.

Theme 3: Paper 110

Computational Fluid Dynamics based Flow Diagnostics of Train-roof Mounted Vertical Axis Wind Turbines

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA7/26 (30)

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Vertical Axis Wind Turbines (VAWTs) are unconventional wind power harnessing devices popular for small-scale power generation especially in difficult terrains like rooftops due to their simple design, operation and maintenance. Normally operating in highly non-uniform wind conditions, a potential application of these turbines is to install them on train roofs where the wind speed is considerably higher. For proof-of-concept, a comprehensive Computational Fluid Dynamics (CFD) based investigation has been presented here for a 6-bladed drag-based Vertical Axis Wind Turbine having a diameter of 250 mm and an aspect ratio of 2.4. For protecting the turbine assembly from extreme wind loads, an inclined plate has been placed just upstream the turbine, with a rectangular slit opening in it for better flow control and maximizing power generation from the turbine. Unsteady Reynolds Averaged Navier-Stokes (URANS) equations have been iteratively solved on the three-dimensional spatially discretised flow domain. Eddy viscosity-based Shear Stress Transport k-ω turbulence model has been employed to predict flow turbulence. Transient flow diagnostics of the concept wind turbine have been carried out at a wide range of Tip Speed Ratios (TSRs) to map its complete power spectrum. Numerical flow fields obtained demonstrate the classical cyclic power generation from the wind turbine with the number of peaks equal to the number of blades, though interestingly, a cyclic asymmetry has been observed due to the complex interaction of the shielding plate and the turbine. The wind turbine has been demonstrated to produce > 2.5 kW of peak power at its optimal rotational velocity.

Keywords: Vertical Axis Wind Turbine (VAWT), Computational Fluid Dynamics (CFD), Unsteady Reynolds Averaged Navier-Stokes (URANS), Shear Stress Transport k-ω turbulence model, Tip Speed Ratio (TSR)

Theme 3: Paper 112

Comfort-Aware Predictive Heating Management for Smart Homes Using Edge AI and Multi-Zone Presence Detection

Presentation time/location: 3 September 2026, 2:00 PM - 2:15 PM, OA7/02 (30)

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Reducing heating energy in smart homes without compromising occupant comfort remains a challenging control problem, particularly in multi-zone domestic settings where room usage is dynamic and uneven. This paper presents AISHIELD (Artificial Intelligence Smart Home Integrated Edge Learning and Detection), a privacy-preserving, edgefirst platform for comfort-aware heating management. The novelty of the work lies in the integration of non-visual room-level presence detection, local edge intelligence, predictive weekly preheating plans and deployment-oriented validation within a unified smart-home framework. Unlike conventional reactive control, the proposed system combines current zone occupancy with short-term occupancy prediction to decide when heating should be reduced, maintained, or activated in advance of expected use. AISHIELD employs mmWave radar-based sensing for multi-zone presence inference, avoiding the privacy and acceptability concerns associated with camera-based monitoring. The time-critical sensing–inference–actuation loop is executed at the edge, while cloud services are limited to non-timecritical tasks such as model training, weekly plan generation, and signed plan release. For evaluation, the study combines multi-home occupancy traces with a digital-twin thermal simulation environment that supports repeatable testing under realistic operating conditions, including sensing faults such as dropout, occlusion and delayed events. Three heating strategies are compared: a fixed baseline without occupancy awareness, a presence-only reactive strategy and a predictive strategy using forecast-based preheating. Results show that presence-aware control reduced the simulated heat-input proxy by approximately 66% relative to the fixed baseline, while predictive preheating increased the saving to around 73% across the evaluated homes. In addition, predictive control reduced daily comfort violations to about 25 minutes, compared with more than 40 minutes for the simpler threshold-based method. The best presence inference results were obtained using a Random Forest model, achieving an F1-score of approximately 0.90 with practical edge latency below 300 ms.

Keywords: AISHIELD · Smart home · Energy management · Predictive heating · Occupant comfort · Edge AI · Multi-zone presence detection · mmWave radar · Random Forest model

Theme 3: Paper 128

Life cycle analysis of conventional turning of Aluminum and Stainless-Steel alloys

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA7/26 (30)

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This study conducts a life cycle analysis of the turning process that removes material from a 20 mm diameter round bar made of aluminium 6082T6 or stainless steel 304, each 50 mm long. Experiments were performed on a WARCO WM290V lathe at spindle speeds of 250, 500, and 750 rpm and feed rates of 0.21 mm/rev and 0.42 mm/rev. The data were input into SimaPro life cycle assessment (LCA) software to evaluate carbon emissions using the ReCiPe 2016 midpoint (H) method. Results showed that energy consumption and carbon emissions decreased significantly as spindle speed and feed rate increased. For example, when turning aluminium at a feed rate of 0.21 rev/mm, increasing spindle speed from 250 rpm to 750 rpm reduced emissions from 0.9644 to 0.9633 kg CO2 eq, a reduction of 0.1095 %. A similar trend was observed for stainless steel, lowering emissions by 0.0817% under the same parameters. However, stainless steel has a 40.56% higher baseline material emission rate than aluminium due to higher emissions from raw material extraction and greater density. Material removal rate (MRR) is the most significant factor in reducing emissions; increasing MRR removes more material faster, reducing machining time and energy consumption.

Keywords: Machining, life cycle assessment (LCA), spindle speed, feed rate, and carbon emissions.

Theme 3: Paper 155

An artificial neural network model for the spatial prediction of mould growth on indoor building surfaces

Presentation time/location: 2 September 2026, 3:15 PM - 3:30 PM, OA7/02 (30)

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The spatial distribution of mould across the built surfaces of 3D geometries is complex and non-uniform, driven by the coupled interactions between the geometrical and environmental features of the local indoor environment. Although empirical mould prediction models are widely applied at the surface-material level, their extension to whole-room geometries for spatial prediction remains challenging. This study investigates the feasibility of an artificial neural network (ANN) model to spatially predict mould growth risk across 3D building geometries. Using a dataset comprising 2086 spatial points from 145 hygrothermal simulations, an artificial neural network model was trained in rotated folds across five indoor geometries, using specifications of geometrical dimensions, ventilation, and heating, with relative spatial descriptors and material classes as input variables, through a 16-neuron hidden layer, to predict the spatial distribution of the mould index. The

results revealed a systematic failure in the extrapolation test (MAE = 1.251, RMSE = 1.349, R2 = -53.2793) due to the limited number and diversity in the training geometries. In corroboration of this finding, an extrapolation test using a linear regression model (MAE = 1.5391, RMSE = 1.6348, R2 = -78.661) on the same training dataset confirmed the generalisation failure was a result of the limitations in the dataset rather than the model, with the ANN performing marginally better than the linear baseline. Thus, it is recommended that training datasets for generalised spatial mould prediction span geometries drawn from multiple buildings rather than a single facility, with independent variation in storey height, room volume and proportions, and ventilation and heating placement, to support generalised and transferable representation across various geometries.

Keywords: Mould growth prediction, Spatial distribution, Artificial neural network, 3D building geometry, Indoor environment

Theme 3: Paper 156

Guidelines for reduction of infrastructure backlogs under the Regional Bulk Infrastructure Grant Port Elizabeth: A Water–Health Nexus Approach

Presentation time/location: 2 September 2026, 4:30 PM - 4:45 PM, OA7/31 (60) Hybrid

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The Regional Bulk Infrastructure Grant (RBIG) in South Africa aims to enhance the Water-Health nexus through funding provision for large-scale water and sanitation projects. The RBIG-funded projects tend to undergo delays which influence the reliability of infrastructure, thus posing a health risk to communities in need of water and sanitation services. The challenges encountered also carry financial implications and project-related delays. This research explored the factors leading to project failures and delays with a focus on a bulk water supply projects in the Eastern Cape Province, using a mixed-method approach. 8 key stakeholders were interviewed, and 40 questionnaires were distributed to determine the impact of the project delays on households. The findings reveal that inadequate planning and unclear project goals are critical contributors to delays. Additionally, governance and institutional difficulties have an adverse impact on project timelines, maintenance and reliability of infrastructure. The study proposes a practical guideline to improve project management, infrastructure management and service delivery in RBIG-funded initiatives. These aim to tackle service delivery backlogs and ensure that vulnerable communities in South Africa have equitable access to water resources, addressing critical health risks they face. Thus, contributing to the Water-Health nexus. The study addresses sustainable development goal 6, water and sanitation.

Keywords: Regional Bulk Infrastructure Grant, Infrastructure management, water-health nexus

Theme 3: Paper 157

Finite Element Analysis and Geometric Optimization of Torispherical Heads in Hydrogen Pressure Vessels

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA7/02 (30)

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Hydrogen storage is a key enabling technology for renewable energy systems; however, safe high-pressure containment requires pressure-vessel geometries that minimize stress concentration during operation and pressurization. This study presents a transient Abaqus/Explicit finite element investigation of stainless-steel pressure vessels with hemispherical, ellipsoidal, and torispherical heads subjected to rapid internal pressurization from 0 to 70 MPa. Attention is given to the influence of the external crown-diameter-to-head-height ratio, DC_o/H_o, on the stress response of torispherical heads. Thirteen torispherical configurations were analyzed while maintaining the same external vessel radius, head height, wall thickness, material properties, pressure history, element type, and mesh strategy. The hemispherical head produced the lowest stress response, followed by the ellipsoidal head, while the torispherical response depended strongly on DC_o/H_o. Reducing DC_o/H_o from 16.30 to 4.48 increased the maximum Von Mises stress from 92.5 MPa to 143.6 MPa and the maximum principal stress from 46.8 MPa to 94.1 MPa. Torispherical heads with DC_o/H_o values of approximately 6.06 and above produced lower or comparable stress levels relative to the ellipsoidal reference, whereas lower ratios produced rapid stress amplification near the crown-knuckle transition. The study further highlights the relevance of structural health monitoring (SHM) and acoustic emission (AE) sensing for safe operation, because FEA-predicted critical regions can guide future sensor placement and in-service damage detection.

Keywords: Hydrogen storage, Pressure vessel, Torispherical head geometry, Transient Stress Analysis, Structural Health Monitoring (SHM), Acoustic emission sensing.

Theme 3: Paper 163

Sustainable bricks reinforced with natural fiber: A performance study

Presentation time/location: 2 September 2026, 4:00 PM - 4:15 PM, OA7/31 (60) Hybrid

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Natural fibers are widely available in India and their uncontrolled disposal can lead to serious environmental problems such as waste accumulation, blockage of drainage system, air pollution due to open burning and

unhygienic conditions. However, fiber waste possesses significant potential for eco-friendly construction material applications. This study aims to present performance study of coconut fibrous waste material reinforced bricks. The bricks were prepared from cement-stone dust matrix reinforced with coconut fibers. During the brick moulding process, the bricks were compacted using compression testing machine under 3MPa pressure. Bricks were demoulded immediately after casting, thereafter subsequently kept 24 hours for final setting and then cured under water of 27°C temperature. To assess the quality and performance of the fiber reinforced bricks, various physical, mechanical and durability test were conducted while the crystalline phases, microstructural characteristics and elemental composition of bricks were investigated using X-ray diffraction (XRD), field emission scanning electron microscopy and scanning electron microscopy (FESEM-SEM) analysis, respectively. The experimental findings demonstrated that the fiber bricks achieved satisfactory results and exhibited average compressive strength of 9.27 MPa confirming its potential use as a sustainable building material. The findings reveal that bricks satisfy Indian Standard requirements (IS 3495 (Part 2): 1992), with all values of water absorption falling below the 15% limit permitted. Nil efflorescence was recorded on the bricks, indicating better durability against continuous moisture exposure and drying cycles. In addition, the XRD analysis confirmed the presence of crystalline phases in bricks i.e. quartz, portlandite and ettringite. Quartz has a high peak intensity located at 2-theta angle of 26.6 in all brick specimens, indicating the high volume of silica content that provides better particle packing and reducing voids within the matrix.

Keywords: Natural fibers, fiber reinforced bricks, eco-friendly, brick properties, XRF analysis, XRD analysis, FESEM-EDS analysis.

Theme 3: Paper 165

Mix Design of M30 Grade Fly Ash and Ground Granulated Blast Furnace Slag-Based Geopolymer Concrete

Presentation time/location: 3 September 2026, 2:15 PM - 2:30 PM, OA7/29 (58) Hybrid

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The major limitation of using Portland cement in concrete is that its production is energy-intensive and emits a huge amount of CO_2. To mitigate this environmental concern, the use of geopolymer concrete (GPC) is considered an effective solution. In absence of standard codes and guidelines for GPC, various challenges arise in design reliability and field implementation. This paper is an attempt to present a methodology for the mix design of M30 grade geopolymer concrete, which would help in developing future guidelines and standards for GPC. In this study, class F fly ash and microfine ground granulated blast furnace slag (µGGBS) are used as binders activated using alkaline activator solutions (AAS), namely sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions. Different NaOH molarities and aggregate grading in accordance with DIN standards are considered. Moreover, the influence of two different curing temperatures, i.e., 60°C and 90°C, is evaluated. Based on a trial-and-error approach, it is observed that using 8 M NaOH solution and DIN A grading standard for aggregates, the GPC samples cured at 60°C attained an average 28-day compressive strength of 42.92 MPa with a 130 mm slump flow. An integrated characterization was carried out using XRD, EDS, and FESEM analyses to evaluate the microstructural characteristics of the GPC matrix. The proposed design methodology for M30-grade geopolymer concrete has been provided systematically.

Keywords: Mix Design, Geopolymer Concrete, Fly Ash, Microfine Ground Granulated Blast Furnace Slag, Alkaline Activator Solution, Waste Material

Theme 3: Paper 176

Fenton-Assisted Nano-Remediation of Petroleum-Contaminated Soil using Magnetite Nanoparticles: A Full Factorial Design Study

Presentation time/location: 1 September 2026, 4:15 PM - 4:30 PM, OA7/02 (30)

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Petroleum hydrocarbon contamination in the Niger Delta region of Nigeria represents a persistent environmental challenge with severe consequences for soil quality, agricultural productivity, and ecosystem health. This bench-scale study evaluated the effectiveness of commercial magnetite nanoparticles (Fe_3O_4) in the Fenton-assisted nano-remediation of Bonny Light crude oil-polluted loamy soil through a full factorial experimental design. Three process variables were investigated i.e. remediation time (Factor A), soil-to-oil ratio (Factor B), and nanoparticle addition (Factor C). Commercial Fe_3O_4 nanoparticles were characterised by their cubic inverse spinel crystal structure, Fe-O stretching vibrations at 570 and 401 cm^{-1}, and particle size range of 20-60 nm. The loamy soil substrate exhibited a slightly acidic pH (5.8-6.2) and sandy loam texture consistent with published Niger Delta soil data. Total Petroleum Hydrocarbon (TPH) concentrations were determined by solvent extraction followed by Gas Chromatography-Flame Ionisation Detection (GC-FID) as per US EPA Method 8015D across 16 experimental runs over 28 days. All three main effects and all interaction terms were statistically significant ($p < 0.0001$; model $F = 53{,}317.87$). Nanoparticle addition exerted the dominant influence on TPH reduction ($SS = 3.741 \times 10^7$), producing a maximum reduction of 73.1% relative to unamended controls. TPH ranged from 2,192.64 mg/kg under the best performing tested condition (nanoparticle amended) to 8,146.24 mg/kg in the control. These findings establish Fe_3O_4 nanoparticles as a highly effective amendment for accelerating petroleum hydrocarbon degradation in contaminated tropical soils and provide a quantitative factorial basis for field-scale Nano-remediation design.

Keywords: Magnetite nanoparticles, Fenton oxidation, Nano-remediation, Petroleum hydrocarbons, Full factorial design.

Theme 3: Paper 180

Electrochemical Recycling of Carbon Fibre for High-Strength Polypropylene Filaments in Additive Manufacturing

Presentation time/location: 1 September 2026, 4:30 PM - 4:45 PM, OA7/02 (30)

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The recycling of carbon fibre (CF) is increasingly important for reducing the environmental impact and cost of composite manufacturing. This paper presents a condensed experimental investigation into electrically driven heterogeneous catalytic decomposition (EHD) as a route for reclaiming semi-long and long recycled carbon fibres (rCFs) from dry fibre wastes and cured composite scraps. The reclaimed fibres were characterised by scanning electron microscopy and single-fibre tensile testing, and then incorporated into polypropylene (PP) to produce composite filaments for additive manufacturing. The EHD process preserved fibre integrity effectively: rCFs from dry wastes and cured composites retained tensile strengths of 4065 MPa and 3928 MPa, respectively, compared with 4184 MPa for virgin CF. When incorporated into PP, rCFs significantly increased filament tensile strength. Neat PP showed a tensile strength of 11.36 MPa, whereas PP reinforced with 26 wt% rCF from dry wastes reached 148 MPa, exceeding the performance of virgin CF reinforced PP. The results demonstrate that EHD-derived rCFs can provide a sustainable and mechanically efficient feedstock for high-performance extrusion-based additive manufacturing.

Keywords: Additive manufacturing; recycled carbon fibre; polypropylene; composite filament; EHD recycling; tensile strength.

Theme 3: Paper 181

The Catalytic Effect of ESG on Green Bond Issuance: A Panel Threshold Analysis

Presentation time/location: 2 September 2026, 4:30 PM - 4:45 PM, OA7/02 (30)

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Green bonds have emerged as a key financial instrument supporting the transition toward low-carbon and climate-resilient economies. Despite growing interest, empirical evidence on how sovereign Environmental, Social, and Governance (ESG) performance influences green bond issuance remains mixed and insufficiently understood, particularly across different stages of sustainable development. This study examines the catalytic role of sovereign ESG performance in shaping green bond issuance across 32 countries over the period 2012–2023. To better capture sustainability commitment, we construct a composite Sovereign ESG Index using the Entropy Weight Method, offering an objective and data-driven measure of cross-country ESG performance. The empirical strategy begins with a dynamic panel data model, which yields limited explanatory power and diagnostic inconsistencies, suggesting the presence of non-linear dynamics. To address this, the analysis employs a more flexible econometric framework, including Panel Threshold Regression, Panel Quantile Regression, and Panel Vector Autoregression techniques, allowing for heterogeneity and regime-dependent effects. Results reveal a statistically significant non-linear relationship between sovereign ESG performance and green bond issuance. In particular, ESG impacts are conditional on a country's level of sustainable development, with a clear threshold effect identified. Below the threshold, improvements in ESG performance have a strong catalytic effect in stimulating green bond markets, particularly in less developed economies. However, beyond a certain level of ESG maturity, the marginal impact diminishes, indicating decreasing returns to ESG improvements in more advanced systems. These findings highlight the importance of stage-specific policy design in sustainable finance and challenge the effectiveness of uniform policy approaches across heterogeneous economies.

Keywords: Green Finance · Sovereign ESG · Green Bonds · Panel Threshold Regression · Sustainable Development · Transition Finance · Sustainable Investment

Theme 3: Paper 183

Chip Morphology and Cutting Force in Milling of Additively Manufactured Ti-6Al-4V: Statistical and SEM-Based Analysis

Presentation time/location: 1 September 2026, 2:00 PM - 2:15 PM, OA7/02 (30)

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Additively manufactured (AM) components require special attention during machining to achieve the desired machining performance and surface quality. This research investigates cutting forces and chip morphology under varying cutting conditions during slot milling of Ti6Al4V alloy manufactured by selective laser melting (SLM). Experiments were performed under dry conditions using a full factorial design of experiments (DoE), and responses were recorded. Chips were examined after cutting. A scanning electron microscope (SEM) was employed to study chip morphology. The Analysis of variance (ANOVA) results indicate that cutting forces increase with cutting speed, feed rate, and axial depth of cut. Chip thickness also varied with feed rate and axial depth of cut. ANOVA results show that both feed rate and axial depth of cut were significant factors affecting deformed chip thickness. Additionally, all three factors affected cutting force; according to the ANOVA, cutting speed contributed 41%, feed rate 30%, and axial depth of cut 19%. SEM analysis shows a

chip deformed thickness of 1190 µm under high cutting conditions of 180 m/min, 0.2 mm/rev, and 0.75 mm. This analysis provided a comprehensive insight into the integration of cutting force, chip morphology, and SEM analysis in slot milling of SLM-Ti-6Al-4V alloy. Likewise, the study identifies cutting parameters that improve slot accuracy, unlike previous studies, which evaluated individual responses of AM parts.

Keywords: Ti6Al4V alloy, selective laser melting, additive manufacturing, cutting force, chip deformed thickness, SEM

Theme 3: Paper 184

CFD Simulation of a Bubbling Fluidized Bed Regenerator for K2CO3 Sorbent Production in CO2 Capture Applications

Presentation time/location: 1 September 2026, 3:15 PM - 3:30 PM, OA7/02 (30)

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This study presents a CFD investigation of a bubbling fluidized bed regenerator for producing K2CO3 sorbent via thermal decomposition of KHCO3 for CO2 capture applications. The Eulerian-Eulerian two-fluid model coupled with the kinetic theory of granular flow (KTGF) was developed to resolve gas-solid hydrodynamics, bubble formation, and their interaction with decomposition kinetics. A rigorous gridindependence test confirmed numerical stability and mesh-insensitive predictions. The model was validated against experimental results of CO2 concentration at the regenerator outlet, demonstrating good agreement and confirming the fidelity of the hydrodynamic and reactive sub-models. Simulation results indicate that temperature strongly enhances CO2 release, which increases regeneration efficiency. Hydrodynamic analysis shows effective gas-solid mixing, progressive sorbent conversion, and spatial variation of species and temperature within the reactor. The findings demonstrate the capability of CFD in predicting reactor performance and provide insights for optimizing operating conditions in carbonate-looping CO2 capture systems.

Theme 3: Paper 187

Architecting Real-Time Environmental Accounting in Digital Commerce: A System Topology for Transaction-Linked Carbon Analytics and Micro-Donation Orchestration

Presentation time/location: 3 September 2026, 3:15 PM - 3:30 PM, OA7/02 (30)

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The rapid scaling of international real-time payment rails has optimized transaction velocity, but it has simultaneously decoupled consumer spending behavior from environmental impact metrics. While market solutions exist that offer near-real-time or retrospective post-transaction carbon tracking via external application programming interfaces (APIs), widespread commercial and institutional adoption remains limited due to downstream processing latency and a lack of point-of-sale integration. This paper introduces an upstream Carbon Footprint System Topology designed for high-throughput real-time payment networks. By parsing rich transactional data payloads at the exact point of ingestion, the proposed framework dynamically correlates ISO 20022 messaging schemas, Merchant Category Codes (MCC), cross-border transactional location deltas, SKU-level itemization, and device telemetry with localized carbon emission indices. Furthermore, this architecture natively integrates Card-Not-Present (CNP) e-commerce processing channels by parsing 3-D Secure (3DS) authentication strings and structured shipping logistics payloads. Crucially, the architecture incorporates an automated, low-latency micro-donation routing mechanism that leverages real-time fiscal incentives—specifically, point-of-sale tax credits—allowing payment networks to facilitate direct capital flows to sustainable agriculture ecosystems without compromising network settlement velocity. This framework is validated via a trace-driven simulation of 10,000 synthetic transaction payloads spanning High-Fidelity (65%) and Low-Fidelity (35%) metadata streams. Experimental results demonstrate full compliance with strict real-time payment constraints, achieving an average core pathway latency of 142 ms (well below the 200 ms threshold) and an asynchronous analytics execution overhead of under 18 ms. This study demonstrates how digital payment infrastructures can be re-architected to transform passive financial networks into active, automated engines for fiscal and environmental accountability.

Keywords: Payments Architecture, ISO 20022, 3-D Secure, Green FinTech, Real-Time Payments, Tax Incentives, Transactional Carbon Accounting, Sustainable Asset Management

Theme 3: Paper 204

Beyond Chemical Inhibition: A Thermodynamic Reassessment of Pressure–Temperature Optimisation for Water Vapour Removal in the Aje Field Three-Phase Separator

Presentation time/location: 3 September 2026, 2:30 PM - 2:45 PM, OA7/29 (58) Hybrid

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Horizontal three-phase separation of the Aje gas–condensate stream (offshore Nigeria, OML 113) has previously been shown to leave approximately 1% water vapour in the gas outlet, a residual that published work has addressed exclusively through downstream chemical hydrateinhibitor injection. A subsequent reconstruction of the separator in Aspen HYSYS V14 reported that raising the separator inlet pressure above 260 kPa while lowering the feed temperature below 15 °C can substantially reduce vapour-phase water carryover without any chemical treatment. Neither study, however, checked whether the pressure–temperature conditions needed for this reduction are themselves compatible with hydrate-free operation. This paper is a thermodynamic screening study that closes that gap; it is a reassessment of the published Aje case study, not a

field-validated hydrate model. Using the well-characterised upper quadruple point of propane – one of the strongest common hydrate promoters, and therefore a conservative bounding reference for this feed – we screen the tested operating envelope (200–300 kPa, 13–20 °C) and find it lies outside the hydrate-stable region, with an indicative thermodynamic margin exceeding 8 °C. We further show that standard gasgravity hydrate correlations are not valid for this unusually heavy feed composition, and that the flow-assurance risk is not removed but relocated downstream, to the higher-pressure export pipeline, where the residual water fraction still requires separate verification. The result is a more cautious, hydrate-aware operating recommendation than either of the two prior studies on this field, together with an explicit account of where rigorous equation-of-state-based confirmation is still needed.

Keywords: Three-phase separation · Gas hydrates · Aje field · Aspen HYSYS · Process optimisation · Flow assurance

Theme 4: Paper 66

Advancements in Multi-Hazard Risk Assessment at the Urban Scale

Presentation time/location: 1 September 2026, 2:15 PM - 2:30 PM, OA7/26 (30)

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Urban areas increasingly exposed to multiple hazards that may occur independently, simultaneously, or in cascading sequences, including pluvial flooding, heatwaves, extreme weather events, earthquakes, and infrastructure failures. The growing complexity of urban systems has highlighted the need for integrated multi-hazard risk assessment approaches capable of capturing interactions between hazards, exposure, vulnerability, and resilience. This paper presents a state-of-the-art review of multi-hazard risk assessment methodologies applied in urban environments. A structured review methodology adopted, based on the thematic and methodological classification of peer-reviewed studies, technical reports, and international guidelines. Emphasis placed on GIS-based hazard mapping, remote-sensing indicators, multi-criteria decision-making methods, infrastructure accessibility analysis, and emerging digital technologies for risk assessment and emergency support planning. The review indicates that considerable progress achieved in hazard characterization, exposure modelling, and the integration of vulnerability assessment within multi-hazard frameworks. Recent developments in simulation-based modelling, artificial intelligence, machine learning, and digital-twin technologies have further enhanced the capability to evaluate complex urban risk scenarios. However, challenges remain in representing cascading hazard interactions, temporal dynamics, infrastructure interdependencies, recovery processes, and emergency accessibility within operational decision-support frameworks. The analysis identifies GIS-integrated network modelling and combined AHP-TOPSIS approaches as promising tools for supporting risk-informed planning and emergency management. The paper contributes a critical synthesis of current knowledge and outlines future research directions for developing more dynamic and integrated multi-hazard assessment frameworks to strengthen urban resilience and emergency support planning.

Keywords: Multi-hazard risk assessment, Urban resilience, Emergency accessibility, GIS-based risk mapping, AHP-TOPSIS, Digital-twin frameworks.

Theme 4: Paper 79

Risk-Aware Trust-Weighted Federated Learning for Resilient Healthcare Monitoring under Byzantine Clients

Presentation time/location: 1 September 2026, 3:15 PM - 3:30 PM, OA7/26 (30)

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Federated learning (FL) is attractive for healthcare monitoring because hospitals, clinics, and edge devices can train shared models without centralising sensitive patient records. Practical deployments, remain vulnerable to Byzantine clients that submit poisoned, low quality, stale, or strategically delayed updates. This paper presents a risk-aware trust-weighted FL framework for resilient healthcare monitoring under Byzantine participation. The server computes a dynamic trust score from validation performance, payload quality, and temporal consistency. This score controls both adaptive update routing and trust-weighted aggregation. High-trust updates use a fast path, uncertain updates use a warm path, and suspicious updates use a higher-scrutiny path that reduces operational priority and aggregation influence. Across 240 runs with 50, 100, and 150 clients, Byzantine ratios up to 40%, and realistic and adversarial network profiles, the proposed method achieves 0.8401 mean final accuracy, close to FLTrust at 0.8419 and above FedAvg at 0.8350. It also reduces mean backdoor attack success rate from 0.1398 under FedAvg to 0.0897, and maintained 26.33–33.02 transactions/s under realistic networks and 20.61–25.08 transactions/s under adversarial networks. The results support a practical claim that risk-aware routing and trustweighted optimisation provide a useful resilience layer for distributed healthcare monitoring, although specialised robust aggregators remain stronger in some backdoor regimes.

Keywords: Federated learning · Byzantine robustness · Healthcare monitoring · Trustworthy AI · Risk-aware routing · Trust-weighted aggregation

Theme 4: Paper 88

AISHIELD: An Edge-First, Privacy-Preserving Platform for Multi-Zone Presence Detection and Predictive Thermal Preheating in Smart Homes

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA7/26 (30)

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Accurate room-level occupancy awareness remains a persistent challenge in occupant-centric smart-home energy management. Widely used sensing modalities, including Passive Infrared (PIR) and ultrasonic sensors, often show limited robustness in multi-zone residential environments, especially under low-motion behaviour, inter-room transitions, and prolonged stationary presence. Although vision-based methods can improve spatial awareness, their use in domestic settings remains constrained by privacy, acceptability, and data-governance concerns. This paper presents AISHIELD (Artificial Intelligence Smart-Home Integrated Edge Learning and Detection), an edge-first and privacy-preserving platform for multi-zone presence detection and predictive thermal preheating in smart homes. The architecture keeps runtime authority at the edge by executing the

time-critical sensing–inference–actuation loop locally, while delegating non-time-critical functions, including model training, evaluation, signed artefact release, and fleet-level monitoring, to the cloud. To support rigorous assessment beyond a single testbed, the work also introduces a digital-twin simulation framework that replays datasetinformed occupancy traces, simulates sensing faults such as dropout, occlusion and delayed events, and evaluates thermal-control behaviour using a per-zone thermal model under repeatable operating conditions. Comparative evaluation is carried out across rule-based, sequential probabilistic and supervised approaches to presence inference together with three control strategies: reactive operation without preheating, fixed scheduling and AI-generated weekly planning with real-time edge overrides. Across five case-study homes, presence-aware control achieved average energy savings of 66.5%, while predictive preheating increased this to 72.8%, consistently outperforming the reactive baseline. In addition, predictive control improved comfort readiness by bringing zones closer to target conditions before expected occupancy, thereby reducing delayed comfort and improving the practical user experience without compromising privacy, resilience or edge autonomy.

Keywords: Smart home · multi-zone · edge computing · privacy-preserving sensing · predictive preheating

Theme 4: Paper 91

Adaptive Hybrid Physical-Layer Authentication for Low-Power LoRaWAN IoT Nodes: Four Stress Conditions and a Lightweight Decision Framework

Presentation time/location: 1 September 2026, 2:00 PM - 2:15 PM, OA7/26 (30)

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LoRaWAN deployments authenticate end devices by proving possession of pre-shared symmetric keys, which verifies knowledge of a secret but does not bind identity to the hardware on which that secret was provisioned. This paper characterises how two physical-layer identity primitives—SRAM Physical Unclonable Functions (PUFs) and Carrier Frequency Offset (CFO) radio-frequency fingerprinting—fail on real LoRaWAN hardware, and uses those measurements to motivate a reliability-aware fusion policy for industrial asset-monitoring nodes. Four stress conditions are applied to a 2 × 2 factorial testbed: host-platform substitution, supply-voltage variation across the rated range, same-batch procurement, and elevated temperature. Two defeat authentication, and in opposite modalities. Moving an enrolled chip to a different host raises its Hamming distance from 4.18% to 13.94%—3.2× the error-correction budget a helper-data scheme is dimensioned for, and within 1.1 pp of the 15% acceptance threshold—while leaving CFO untouched. Conversely, on 45 same-model LoPy4 transmitters CFO within-batch false acceptance reaches 17.0% at a 95% genuine-accept point, while same-batch SRAM-PUF impersonation does not occur (different-chip Hamming distance 45.93%, FAR 0%). Supply variation and heating to 56◦C are reported as nulls. The two modalities therefore fail under disjoint conditions, which is what licenses a fallback design rather than an assumption of independence. A depth-4 CART tree, deployed as a fixed 380-byte artefact, maps [HDPUF, zCFO, zRSSI] to three operating states that set the fusion weights, entirely at the gateway and with no end-device firmware change. System-level error rates are not reported: four instances built from two SRAM chips cannot support a population estimate.

Keywords: LoRaWAN security · SRAM Physical Unclonable Function · RF fingerprinting · Carrier Frequency Offset · IoT authentication · adaptive authentication

Theme 4: Paper 101

Privacy-Aware YOLOv11n-Based Multi-Posture Fall Detection on Jetson Orin Nano with TensorRT Deployment and Smart-Home Dashboard Integration

Presentation time/location: 2 September 2026, 3:00 PM - 3:15 PM, OA7/26 (30)

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Falls are a leading cause of injury and loss of independence among older adults. Vision-based detection systems offer rich contextual information for indoor monitoring, yet most prior work reports only offline accuracy and omits the end-to-end deployment characteristics essential for real-world use. This paper presents a complete, privacy-aware fall detection framework combining the Huddersfield Indoor Multi-Posture (HIMP) dataset – 8,627 annotated source frames across five posture classes and two indoor environments, expanded through data augmentation to 15,528 images – a YOLOv11n detector exported as a TensorRT FP16 engine, and a fully integrated edge application on an NVIDIA Jetson Orin Nano (15 W). On a held-out frame-level test split of 431 images the model achieves precision 0.910, recall 0.895, and mAP@0.5 of 0.947. On-device, the system sustains 19–35 FPS at a mean power draw of 6.9 W. Raw video is processed entirely on-device; only a timestamped alert thumbnail is transmitted to a caregiver. Multi-stage temporal confirmation, automated email alerting, SQLite logging, and a Flask web dashboard complete the system. Full throughput, power, memory, GPU utilisation, and thermal measurements are reported, addressing a reproducibility gap in the edgedeployment literature.

Keywords: Fall detection · Smart home · YOLOv11 · Edge AI · Jetson Orin Nano · TensorRT · Privacy-aware

Theme 4: Paper 106

Digital Behavioural Monitoring Systems: A Trustworthy Hybrid Neural-Symbolic Pipeline for the Longitudinal Profiling of Coercive Control

Presentation time/location: 2 September 2026, 3:00 PM - 3:15 PM, OA7/31 (60) Hybrid

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Traditional industrial maintenance relies upon physical sensors to monitor functional safety and detect mechanical irregularities. In contrast, identifying behavioural risks within digital ecosystems, specifically the longitudinal patterns of coercive control, requires the development of digital “soft sensors” capable of processing high-volume text streams. This paper proposes a hybrid neural-symbolic pipeline engineered for the continuous profiling of coercive behaviour, shifting the academic focus from psychological classification accuracy towards systems engineering, fault tolerance and practical reliability. The architecture functions as a reliable soft sensor, integrating Explainable AI (XAI) and Human-in-the-Loop (HITL) verification to ensure safe deployment in active forensic environments. We resolve the practical limitations of autonomous, black-box machine learning models by enforcing symbolic logic constraints over neural outputs, thereby guaranteeing deterministic transparency. The system design focuses on low-latency execution and high resilience against data corruption, which are essential requirements for real-time monitoring infrastructure. By structuring the pipeline for direct integration into standard Security Operations Centres (SOC), this work applies natural language processing for high-stakes threat detection, providing a synthetic proof-of-concept for an efficient and auditable solution for digital forensics.

Keywords: Behavioural Monitoring · Explainable AI (XAI) · Threat Detection · Digital Forensics · Neuro-Symbolic AI.

Theme 4: Paper 133

Hazard Assessment of Digital Twin Implementation in Wind Turbine Operations and Maintenance

Presentation time/location: 2 September 2026, 4:00 PM - 4:15 PM, OA6/07 (30)

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In recent years, Digital Twin (DT) technology has emerged as a promising solution by integrating real-time sensor data with predictive models to monitor asset health, predict future behaviour, and support operation & maintenance decisions. However, despite significant investment, many wind farm operators remain reluctant to rely fully on Digital Twins because the hazards affecting their reliability and dependability have not been systematically studied. This study addresses this gap through a Systematic Literature Review (SLR) conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. A total of 44 peer-reviewed publications were analysed to identify hazards associated with the implementation of Digital Twins for wind turbine O&M. The review identified ten core hazards (H1–H10), grouped into three categories: Technological (accuracy–latency trade-off, reduced-order model bias, Model-Reality gap, sensor drift, computational bottlenecks, communication latency, and data silo fragmentation), Governance (cyber-physical security threats), and Socio-Technical (operator over-reliance and lack of multidisciplinary skills). The study further identifies key hazard interactions and cascade pathways that contribute to the degradation of Digital Twin performance. The findings show that reliable Digital Twin deployment depends not only on accurate predictive models but also on workforce capability, data governance, and system integration. The identified hazard taxonomy, together with the associated hazard interactions and cascade pathways, provides a structured foundation for understanding and mitigating the factors that influence the reliability and dependability of Digital Twins for wind turbine operation and maintenance.

Keywords: Digital Twin; Wind Turbine; Hazard Assessment; Hazard Classification; Systematic Literature Review.

Theme 4: Paper 152

Displaced risk: how front-end decisions in renewable energy projects shape operational and safety risk years before the operator arrives

Presentation time/location: 1 September 2026, 4:30 PM - 4:45 PM, OA7/26 (30)

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Industry safety efforts in renewable energy concentrate on the construction phase, yet incident data locate the greater operational-phase risk. SafetyOn records 89% of all incidents and 93% of high-potential incidents in UK onshore wind on operational sites in 2024, a pattern confirmed in 2025 data. G+ offshore data show a per-hour Lost Time Injury Frequency (LTIF) of 2.79 on operational sites against 0.94 on construction sites in 2024, with operational site injury volumes rising 46% in 2025 as more sites transitioned from construction to operations. Working at height, lifting operations, and working with electrical systems are identified as high-severity work processes by both bodies; G+ additionally identifies grouting in offshore operations as high-severity. Each has a risk envelope fixed at the design stage. This paper argues that operational and safety risk in renewable energy is substantially determined during front-end project development, and distinguishes two phases of risk envelope creation: the design risk envelope, fixed by development-phase decisions before operators arrive, and the work risk envelope, within which asset management and O&M personnel plan and

execute service activity within the conditions they inherit. Drawing on a 2024 cross-functional survey of 33 renewable-energy professionals, it evidences limited operational voice in front-end governance and a design-risk process that is weakest in downstream lifecycle factors. The paper frames the problem through ISO 55001 whole-life asset management and resilience engineering theory, and proposes a decision-support layer that operates across both envelopes, treating knowledge-seeking behaviour as a leading indicator of operational risk at each phase. Prior deployment evidence from an APAC offshore wind context is cited alongside a formal evaluation design and the limits of generalisation beyond the studied context.

Keywords: Front-end decision-making, Operational safety, Whole-life asset management, Renewable energy O&M, ISO 55001, Design risk assessment.

Theme 4: Paper 162

Factors Influencing Crash Severity of Road Crashes Involving Speeding: Insights from Police-Reported Crashes in India

Presentation time/location: 2 September 2026, 2:00 PM - 2:15 PM, OA7/31 (60) Hybrid

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Road traffic crashes are emerging as a major public health concern worldwide, accounting for approximately 1.2 million fatalities annually. India accounts for nearly 11.6% of these fatalities, the highest among all countries. Speeding is a leading contributor to road traffic fatalities and accounts for approximately 70% of crashes and fatalities in India. While previous studies have examined factors influencing crash severity, they have not specifically focused on crashes in which speeding is recorded as a violation. Moreover, most existing studies focus on a particular vehicle type, although the impact of speeding depends heavily on interaction between two vehicles or vehicle with pedestrians. With this background, the study aims to identify the factors influencing crash severity where speeding is reported as a violation. Subsequently, cooccurrence patterns of these factors in speeding-related crash outcomes are also investigated. For the analysis, police reported crash data were used, and a Multinomial Logit (MNL) model was employed to identify factors that contributed to different severity levels. Additionally, Association Rule Mining (ARM) was applied to identify the frequent combinations of factors associated with different crash severities. The MNL results indicate that crashes occurring during post-midnight hours, near bus stops, and involving pedestrians or fixed objects are more likely to result in fatal outcomes. ARM further revealed differences in the co-occurrence patterns of different crash severities. Findings from the study provide evidences that could be useful for developing targeted road safety interventions and formulating speed management-related policies.

Keywords: Speeding, Crash Severity, Crash Data Analysis, Association Rule Mining, Multinomial Logit, Road Safety.

Theme 4: Paper 168

Enhancing Safety in Lithium-Ion Battery Repurposing: A System-Theoretic Process Analysis (STPA) Approach

Presentation time/location: 2 September 2026, 2:45 PM - 3:00 PM, OA7/31 (60) Hybrid

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The rapid adoption and shift towards electrification of various market ecosystems, such as automotive, grid storage and consumer electronics have triggered an increase in demand for lithium-ion batteries. The subsequent increase in lithium-ion battery (LIB) production, in combination with LIB waste and finite global lithium reserves emphasises the essential need for sustainable end-of-life (EOL) management of these batteries, which includes the need for refining the LIB repurposing and recycling processes. Particularly, the lithium-ion batteries used in electric vehicles are retired at 70-80% of their original State of Health (SoH). These batteries can still be repurposed towards less demanding second-life applications, thus lowering production pressure and reducing e-waste. The review analyses the risk and hazard present in the process of repurposing EV batteries within a circular economy framework, for which it uses the System-Theoretic Process Analysis (STPA) framework. The STPA framework is the preferred method for this review for its ability to address systemic and control-related failures that conventional tools such as FMEA and HAZOP do not completely capture in complex, multi-stakeholder processes. The assessment identifies potential hazards, including chemical exposure, thermal runaway, and unstandardised processes at each stage of lithium-ion battery handling like, collection, testing, disassembly, reassembly and second-life integration. Leveraging STPA, the review proposes safety controls improvements, process efficiency enhancements, and crossstakeholder collaboration frameworks, integrating safety feedback loops and regulatory compliance to connect theoretical hazard assessment with practical implementation, thus offering a comprehensive framework for the safer repurposing of LIBs with significant implications for manufacturers, policymakers, and researchers.

Keywords: Lithium-ion batteries, repurposing, System-Theoretic Process Analysis, risk and hazard, circular economy, EV batteries.

Theme 4: Paper 172

Addressing Key Safety Hazards through Proactive Risk Control System in an Integrated Steel Plant

Presentation time/location: 1 September 2026, 3:00 PM - 3:15 PM, OA7/26 (30)

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Integrated steel plants are complex, highly interconnected industrial facilities where diverse metallurgical, logistical, and material handling processes present severe operational safety risks. This study critically examines five critical hazards namely Fall of Object, Heavy Vehicle & Mobile Equipment, Moving Machinery & Human-Machine Interface, Hot Substances, and Fall from Height, which historically accounted for 63% of red-risk incidents between April 2022 and October 2024 across the Pan-India locations of an integrated steel plant under study. Globally, data from the World Steel Association indicates consistent incident patterns tied to these critical safety hazards. To mitigate these key hazards, this research establishes a three-fold objective: i) compiling a comprehensive inventory of risk barriers for the top five safety hazards ii) evaluating the efficacy of the systematic barrier deployment framework, and iii) developing a methodology to prescribe safety related intervention for sustainable risk control in an integrated steel plant. Statistical and risk modeling techniques including Pareto analysis, control charts, fuzzy Analytical Hierarchy Process-Failure Mode and Effects Analysis (AHP-FMEA) were deployed to evaluate safety performance improvements during a targeted safety campaign against pre-campaign baseline data. The empirical results reveal strong inverse correlations between barrier implementation and incident rates, validating overall barrier effectiveness. This paper exemplifies how a rigorous Hazard Identification and Risk Assessment (HIRA) framework, paired with continuous barrier management and robust leadership engagement, can systematically control workplace risks and accelerate toward a sustainable journey of zero harm in steel plants.

Keywords: Integrated Steel Plant, Hazards, Risk, Safety, Barrier Management

Theme 4: Paper 174

A Risk-Informed Contractor HSE Performance Framework: A Case Study of Kuwait Oil Company for Proactive Safety Engineering in Oil and Gas Asset Management

Presentation time/location: 2 September 2026, 4:45 PM - 5:00 PM, OA7/29 (58) Hybrid

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The oil and gas industry depends on a multinational contractor workforce for its high-risk activities. Contractor-related incidents/non-conformances (NCs) remain a concern, underscoring the need for an improved, more proactive HSE governance framework. Despite significant progress in implementing HSE management systems, current practices remain fragmented in addressing new HSE interface issues with contractors. This study develops a risk-informed framework for contractor HSE performance tailored for Kuwait Oil Company (KOC) to improve oversight of contractor performance. The framework integrates operational data, performance measurement, barrier management, and risk-based decisionmaking within contractor HSE systems to support a more proactive governance approach. A mixed-methods research design was adopted, combining data from KOC field operations with structured analytical techniques for performance evaluation and system safety analysis using the electronic reporting platform viz. MyHSSE. The framework is organized around eleven key pillars, including contractor compliance, performance monitoring, competency assurance, emergency preparedness, assessment and verification, journey management, equipment integrity, and the potential use of digital tools. These pillars create measurable connections among leading indicators, safety culture, operational risks, and monitoring activities, helping KOC to identify/address NCs early rather than responding only after incidents occur. The proposed framework will further improve HSE performance through the assessment of various indicators. It offers KOC a scalable governance model, which will enable proactive practices and risk-based management. As the first-year results are preliminary, the paper presents practical evidence of implementation maturity and early performance improvement. The framework provides a scalable governance model for riskbased contractor HSE management in high-hazard oil and gas operations.

Keywords: risk-based approach, safety engineering, contractor HSE, barrier management, oil and gas.

Theme 4: Paper 208

Risk and Cybersecurity Challenges in AI-Enabled Decentralised Asset Trading Platforms: A Structured Review and Layered Classification Framework

Presentation time/location: 2 September 2026,5:00 PM - 5:15 PM, OA7/31 (60)

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Artificial intelligence is being embedded into decentralised finance (DeFi) trading platforms as both a mechanism-design component and a security control, while these platforms increasingly perform the functions of critical financial infrastructure. Research on the resulting risks remains divided between financial-economics, software-security and machine-learning communities, and is rarely expressed in the reliability and asset-management terms used by infrastructure operators. This paper reports a targeted structured review of fourteen anchor works comprising twelve peerreviewed studies and two clearly labelled preprints, selected to span market mechanisms, smart contracts and oracles, blockchain execution, and AI components. The review is deliberately not presented as an exhaustive systematic review. Evidence is synthesised into a four-layer classification that maps risk classes to the analytical methods and controls currently available at each layer and identifies the cross-layer paths along which failures propagate. The synthesis shows that design-time

analysis is comparatively mature, runtime detection is emerging, and preventive protocol-level control remains sparse, while the AI layer is presently studied as a control mechanism rather than as a source of assurance risk. The classification provides a vocabulary in which DeFi trading platforms can be discussed as reliability-critical socio-technical systems, and identifies where reliability, availability and maintainability metrics could be defined.

Keywords: Decentralised Finance, Cybersecurity, Reliability Engineering, Smart Contracts, Risk Classification, Large Language Models

Theme 5: Paper 4

Deposition-Informed Airway Inflammation: A Systematic Review of CFD, Machine Learning, and Multiscale Modelling Toward Respiratory Digital Twins

Presentation time/location: 1 September 2026, 2:30 PM - 2:45 PM, OA7/27 (40)

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Airway inflammation is central to asthma, chronic obstructive pulmonary disease (COPD), and cystic fibrosis, yet links between inhaled particle deposition and localised biological responses remain unclear. This systematic review synthesises evidence on computational fluid dynamics (CFD), machine learning (ML), validation methods, and multiscale modelling connecting aerosol deposition with airway inflammation. Using a PRISMA-guided approach, Scopus and Web of Science were searched, with the search updated in April 2026. From 3156 records, 49 studies were included. The review examines CT-based airway reconstruction, idealised and patientspecific geometries, mesh and turbulence modelling, particle tracking, imaging validation, ML surrogate models, and biological linkage. Evidence shows that deposition is heterogeneous and governed by airway anatomy, disease-related obstruction, breathing conditions, flow regime, and particle properties. Local deposition hotspots, wall shear stress, particle flux, and residence time plausibly link deposition to epithelial stress, oxidative burden, cytokine release, immune-cell recruitment, mucus dysfunction, and exacerbation risk. However, most studies focus on physical deposition endpoints and lack biological or clinical validation. ML can accelerate CFD-based prediction but remains constrained by CFD-generated datasets and limited training domains. This review proposes a patient-specific CFD–ML– biology framework integrating CT reconstruction, validated deposition modelling, biomarker assays, and clinical feedback to support deposition-informed airwayinflammation prediction and personalised respiratory medicine. This positions the framework as a respiratory digital twin for intelligent health-asset management and clinical decision support.

Keywords: Particle deposition; Airway inflammation; Computational fluid dynamics; Machine learning; Intelligent health asset management; Clinical decision support.

Theme 5: Paper 28

Enhancing telecommunications testing environments with network digital twins

Presentation time/location: 2 September 2026, 4:30 PM – 4:45 PM, OA7/29 (58)

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Most telecommunications organizations use physical laboratories and traditional methods of testing to test and validate their network products. These traditional methods have become inefficient as networks grow complex and technology is evolving. This has led to high testing error rates, longer deployment times and inaccuracies in the network, due to the laboratories' failure to reflect real-life network in testing. Network digital twins are proposed as a solution to this, to enhance the testing environments. A digital twin is a virtual replica of an object or system intended to accurately mirror a physical object. It covers the object's entire lifecycle, receives updates from real-time data, and employs simulation. The qualitative research employed in this study through semi-structured interviews with individuals in the field has provided some insights into how a network digital twin could potentially improve testing environments. Findings in the study have demonstrated that lack of realistic testing environments and limited automation are some of the leading challenges, moreover, results show that using network digital twin needs advanced telemetry. It is concluded that the network digital twin technology is seen as a viable solution to enhance testing environments within the telecommunications industry in the near future, taking into consideration all the requirements, technical and organizational.

Keywords: Network digital twins; telecommunications; virtual replica; testing environments

Theme 5: Paper 34

PVP oil lubricated thermo-hybrid textured circular thrust pad bearing

Presentation time/location: 2 September 2026, 4:45 PM - 5:00 PM, OA7/26 (30)

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The performance of thrust pad bearing (TPB) primarily relies on the rheological characteristics of the lubricant. Various additives, viz. VI improvers, detergents, corrosion inhibitors, anti-wear and anti-oxidants etc. are added in the base oil to improve the rheological characteristics of the lubricants. Viscosity modifier additives having long chain structure attain polarity due to the presence of couple stresses. Polar lubricants may depict pressure-dependent viscosity at high pressure and are characterized as piezo-viscous-polar lubricants. During bearing operation, the temperature of the lubricant starts increasing due to viscous heat dissipation, which affect the viscosity of PVP lubricant. Moreover, to enhance the performance characteristics of the hybrid circular thrust pad bearing. The textures are employed at the surface of the thrust pad in the form of multiple micro-geometries. This article investigates the effect of texture on the performance of thermo-hybrid circular thrust pad bearing operating with piezo-viscous-polar lubricant. To model the flow behaviour of the PVP oil in the clearance space of the bearing, Stokes' micro-continuum theory concurrently used with Barus' and Reynolds' law yields modified Reynolds' equation. To solve modified Reynolds' equation finite element method is employed. The results show that the friction power loss significantly decreased, whereas a

remarkable enhancement is achieved in the load carrying capacity compared to the plain pad bearing due to texturing. PVP lubricant provides an enhanced value of damping coefficient compared to Newtonian lubricant.

Keywords: Piezo-viscous-polar lubricant, finite element method, Thrust bearing, Texture, Hybrid thrust.

Theme 5: Paper 38

Design and Simulation of a UWB Circular U-Slot Microstrip Patch Antenna for Future Microwave Breast Phantom Sensing

Presentation time/location: 1 September 2026, 2:45 PM - 3:00 PM, OA7/27 (40)

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Breast cancer remains a major health challenge, and early detection is essential for improving treatment outcomes. Microwave breast sensing has gained attention as a non-ionising and low-cost technique because malignant tissue exhibits different dielectric properties compared with healthy breast tissue. This paper presents the design and simulation of a compact ultra-wideband (UWB) circular U-slot microstrip patch antenna for microwave breast phantom sensing applications. The proposed antenna is designed on Rogers RT/Duroid 5880 substrate with relative permittivity εr = 2.2 and thickness of 1.575 mm. A circular radiating patch, U-shaped slot, microstrip feedline, and partial ground plane are used to improve impedance matching and support wideband operation over the 3.1–10.6 GHz UWB range. The antenna is simulated in Ansys HFSS and evaluated using reflection coefficient, VSWR, gain, radiation pattern, and electric-field distribution. The simulated results show that S11 remains below −10 dB across the complete UWB band, with a minimum return loss of approximately −30.94 dB. The VSWR remains below 2, with a maximum value of approximately 1.58, confirming good impedance matching. The antenna achieves a maximum gain of approximately 3.2 dB, and the radiation patterns confirm effective radiation at 3.1 GHz, 7 GHz, and 10 GHz. The electric-field results show strong field concentration around the patch and U-slot region. These results indicate that the proposed antenna is a suitable candidate for future microwave breast phantom sensing studies. This study is limited to free-space antenna simulation, while breast phantom modelling with healthy and tumour-loaded cases is planned as future work.

Keywords: UWB antenna· circular patch antenna· U-slot antenna · microstrip antenna · Rogers RT/Duroid 5880 · S-parameters · VSWR · HFSS.

Theme 5: Paper 42

Machine Learning-Enhanced UWB Radio SLAM: NLOS Mitigation and Optimal Tag Placement for Accurate Indoor Robotic Localization

Presentation time/location: 3 September 2026, 2:15 PM - 2:30 PM, OA7/26 (30)

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Ultra-Wideband (UWB) radio simultaneous localization and mapping (RSLAM) offers centimeter-level accuracy for indoor navigation, yet its real-world performance is degraded by non-line-of-sight (NLOS) biases, multipath propagation, and dynamic human body occlusions. To address these challenges, this paper proposes a machine learning (ML)-enhanced UWB framework that combines classical time difference of arrival (TDoA) multilateration with an ensemble of ML models. By extracting channel impulse response (CIR) features, the system performs reliable NLOS classification, residual error compensation, and the optimal selection of body-worn tag positions. Real-world experiments, utilizing 23 anchors and Qualisys motion capture (MoCap) ground truth (GT), demonstrate a 94–97% reduction in localization error compared to raw UWB TDoA. This framework achieves 97–100% accuracy in identifying the tag placement across different participants and activities.

Keywords: UWB, RSLAM, Indoor Localization, Channel Impulse Response, Machine Learning, LSTM, Optimal Tag Placement.

Theme 5: Paper 43

Development of Blind / Partially Sighted Assisted Living Aid: Smart Canes with Integrated Depth Detection

Presentation time/location: 3 September 2026, 2:45 PM - 3:00 PM, OA7/26 (30)

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This paper presents the design and development of a smart cane that combines an ESP32-CAM vision module with a Raspberry Pi 4 processing unit, with the aim of giving visually impaired users real-time awareness of obstacles in their path: what an obstacle is, how far away it is, and its approximate size. The YOLOv8 object detection model identifies obstacles and their position within the camera's image plane, while an HC-SR04 ultrasonic sensor supplies the distance that is spoken to the user for each detection; building on this, the system also estimates each object's approximate width, height, and depth, and uses these to choose between several spoken instructions, such as moving away from a full-sized obstacle, stepping over a low one, or continuing once the path is reported clear. Cross-checks against manually measured objects showed the system's distance and dimension estimates agreeing closely with the true values, with a mean absolute error under 3 cm across the objects tested so far. These results are based on a small number of test objects, and a larger, formally quantified accuracy evaluation has not yet been carried out. Even at this early stage, the system shows that a low-cost camera and ultrasonic setup can give a visually impaired user more actionable

guidance than a raw distance reading alone, with a broader set of trials and testing involving visually impaired users remaining the main priority going forward.

Keywords: Assistive Technology, Smart Cane, Visually Impaired, YOLOv8, ESP32-CAM, Sensor Fusion.

Theme 5: Paper 62

Adaptive Frequency-Informed Magnetic Control of von Kármán Vortex Shedding Behind a Confined Bluff Body

Presentation time/location: 1 September 2026, 3:00 PM - 3:15 PM, OA7/27 (40)

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Magnetohydrodynamic forcing provides a non-contact method for modifying electrically conducting flows and can be used to attenuate bluff-body wake unsteadiness. This paper numerically investigates magnetic control of vortex shedding behind a square bluff body in a confined two-dimensional channel at Re = 100. The uncontrolled wake is first simulated to identify the natural shedding frequency from the lift-coefficient spectrum. Steady transverse magnetic fields are then applied to quantify the attenuation of lift oscillations and the associated drag penalty. Openloop sinusoidal forcing and a windowed frequency-updated strategy are subsequently examined using the shedding frequency as the reference actuation scale. The results show that increasing the steady magnetic-field amplitude progressively weakens the alternating vortex street. Strong fields almost suppress the unsteady lift response, but produce a substantial increase in mean drag. A weak steady field of B = 0.1 provides moderate lift-amplitude reduction with a small drag penalty. Open-loop modulation at the same mean field gives a further modest reduction, while the adaptive strategy gives the lowest lift amplitude among the investigated weak-field cases. The adaptive case reduces CL,amp by approximately 21% relative to the uncontrolled wake and by about 6% relative to the equivalent steady weak-field case, with negligible additional mean-drag penalty. The results indicate that frequency-informed magnetic forcing is most useful as a low-intensity strategy for reducing unsteady wake loading, rather than as a maximum-suppression method.

Keywords: Magnetohydrodynamics · Active flow control · Vortex shedding · Bluff-body wake · Adaptive forcing

Theme 5: Paper 72

Enhancing Safety and Efficiency of LPG Fractionation Fired Heaters through Advanced Automated Control: A Case Study of Zueitina Oil Company, Libya

Presentation time/location: 1 September 2026, 4:15 PM - 4:30 PM, OA7/27 (40)

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Fired heaters are critical units in LPG fractionation plants, but their operation at Zueitina Oil Company, Libya, still depends largely on manual air regulation and visual flame observation. This practice can cause unstable combustion, delayed response to rich-burning conditions and unnecessary operator exposure near the furnace. This paper presents an automated control approach for improving fired heater safety and combustion performance in a legacy LPG plant. The main contribution is the integration of Aspen Plus V14 combustion modelling, MATLAB air–fuel ratio (AFR) analysis and LabVIEW-based control prototyping into one closed-loop design for AFR regulation, flame-colour monitoring, alarm handling and shutdown logic. Aspen Plus was used to model stoichiometric and air-deficient combustion cases, while MATLAB was used to study how AFR variation affects combustion behaviour and emission trends. The LabVIEW prototype was then used to test the real-time control response. The results show that the proposed controller maintains the AFR close to the stoichiometric target of 15.6:1 and stabilises tray temperature within ±1◦F of the setpoint. Compared with manual operation, the automated case gives more stable combustion behaviour, earlier detection of unsafe rich-combustion conditions and lower simulated pollutant formation trends. Safety is also improved by reducing routine manual furnace inspection and enabling automatic alarm and shutdown responses. Although the work is validated through simulation and calibrated plant data rather than full industrial deployment, it provides a realistic step towards PLC/SCADA implementation in Libyan LPG facilities. Future work will focus on plant trials, quantified emission reduction, efficiency validation and predictive control integration.

Keywords: LPG fractionation · Fired heaters · Air–fuel ratio control · Combustion monitoring · Industrial automation · Process safety

Theme 5: Paper 94

Towards Smart Railway Maintenance: Real-Time Robotic Fault Detection in Pantographs

Presentation time/location: 3 September 2026, 2:00 PM - 2:15 PM, OA7/26 (30)

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Pantographs are critical components of electric trains, responsible for drawing electrical power from overhead lines. Maintaining them in optimal condition is essential to ensure efficient current collection, minimize service disruptions, and enhance safety. Traditional defect detection methods, such as manual inspections or static contact force measurements, suffer from inconsistent human judgment, oversimplified analysis that

neglects dynamic behaviors, and susceptibility to environmental interference. These limitations hinder early fault detection and predictive maintenance efforts. In this study, we propose a novel approach that leverages dynamic and kinematic measurements from a robotic manipulator to detect pantograph faults. Initially, a fault-free pantograph was tested as a baseline, followed by experiments introducing controlled defects (e.g., high pressure faults). A machine learning model was then trained exclusively on robotic arm data for defect prediction and deployed for real-time fault detection. The results demonstrate that this method achieves an 95.8% accuracy rate, significantly improving fault detection reliability in real-time conditions.

Keywords: Pantograph · Fault Detection · Robotic Manipulator · Machine Learning · Railway Maintenance

Theme 5: Paper 100

Edge-Ready YOLO-Based Multi-Posture Fall Detection for Smart Homes with Confidence Calibration Error Analysis and Real-Time Validation

Presentation time/location: 3 September 2026, 1:45 PM - 2:00 PM, OA7/26 (30)

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Falls are a leading cause of injury-related hospitalisation in adults over 65, yet most vision-based detection systems reduce the problem to binary classification, ignore the transitional Pre-Falling phase that enables proactive intervention, and leave model confidence scores entirely uncharacterised — a critical gap for safety-critical deployment. This paper presents an attention-enhanced YOLOv11 framework incorporating a novel Spatial-Domain Interaction Attention (SDIA) module and CBAM for six-class multi-posture recognition, including the clinically important Pre-Falling transitional class, deployed as a TensorRT FP16 engine on an NVIDIA Jetson Orin Nano edge device. We present — to the best of the authors' knowledge, among the first systematic per-class Expected Calibration Error (ECE) analyses for YOLO-based fall detection — reliability diagrams for all six posture classes, revealing well-calibrated confidence scores throughout. Trained on 1,847 annotated frames, the model achieves mAP@0.5 of 92.85 %, with Pre-Falling reaching AP@0.5 of 91.1 % and Bending achieving 99.2 % — performance absent from all compared baselines. On-device throughput is 20–31 FPS at ≈45 ms end-to-end latency. ECE analysis shows Falling is best-calibrated (ECE = 0.0375) while Walking exhibits the highest underconfidence (ECE = 0.1069), directly informing confidence threshold selection for live alert systems.

Keywords: Fall detection · Pre-fall detection · Confidence calibration · ECE · YOLOv11 · CBAM · SDIA · Edge AI · Jetson Orin Nano · Smart home · Attention mechanism

Theme 5: Paper 145

Coupled Tribo-Dynamic Modelling of a Textured Gas Foil Journal Bearing with Graded Bump Support

Presentation time/location: 2 September 2026, 5:00 PM - 5:15 PM, OA7/29 (58)

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Falls Gas foil bearings offer oil-free support for high-speed turbomachinery, but their performance is limited by low gas-film viscosity, restricted load capacity, weak damping, start-stop rubbing, foil wear, and nonlinear rotor instability. Conventional bump supports also involve a stiffness trade-off: high stiffness improves load support but reduces compliance, whereas excessive compliance promotes foil collapse and reduces the minimum film thickness. To overcome these limitations, this work proposes a gas foil journal bearing that combines a graded, progressive dual-stiffness bump support with shallow bionic micro-grooves on the top foil. The primary bump stage improves compliance during lift-off, while the secondary stiffness stage limits excessive foil deformation under high load. The micro-grooves modify the local film thickness, redistributing gas-film pressure. A coupled rotor-gas-film-foil model is developed. The gas film is governed by the unsteady isothermal compressible Reynolds equation and discretised using a conservative finite-volume formulation over the circumferential-axial domain. The foil structure includes foil inertia, load-dependent bump stiffness, contact separation, and velocity-dependent interfacial friction. Linearised stiffness and damping coefficients are obtained through compliance-aware perturbation, and start-up behaviour is evaluated using rarefaction correction, asperity contact, rubbing friction, and Archard wear. Comparative simulations of rigid smooth, conventional bump-foil, graded bump-foil, textured bump-foil, and combined designs show that the combined architecture improves minimum film thickness, load support, start-up contact behaviour, and selected dynamic coefficients when bump stiffness and groove geometry are properly matched. Excessive groove depth or poor placement increases leakage and shear loss.

Keywords: Gas foil bearing; compressible Reynolds equation; graded progressive bump foil; bionic micro-grooves; rotor dynamics; nonlinear stability; start-up mixed lubrication.

Theme 5: Paper 146

Wear-Aware Compressible Lubrication of Pneumatic Rod Seals

Presentation time/location: 2 September 2026, 5:00 PM - 5:15 PM, OA7/29 (58)

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Pneumatic reciprocating rod seals operate with thin, compressible gas films, low lubricant viscosity, pressure-dependent density, and intermittent asperity contact. Their leakage and friction are highly sensitive to minor

changes in film thickness, lip deformation, surface roughness, and wear. Current lubrication models for rod seals are primarily developed for liquid-lubricated hydraulic seals and typically utilize one-dimensional structured discretizations. These models can be restrictive when the surfaces of pneumatic seals wear or include engineered textures. This work introduces a wear-aware compressible mixed-lubrication framework for pneumatic reciprocating rod seals, employing an element-based finite volume method. The gas film is governed by a conservative compressible Reynolds equation, with gas density evaluated based on the local pressure and temperature, along with optional rarefaction or slip corrections applicable for small film thicknesses. Finite-element contact analysis provides the contact pressure between the dry seal and rod, while asperity interaction is modeled using a Greenwood-Williamson-type contact model. The framework couples gas-film pressure, asperity contact, seal deformation, and wear evolution through an iterative update of film thickness. The element-based finite volume method allows for worn and textured sealing interfaces to be effectively resolved on irregular meshes. Surface texture is introduced as a design variable and optimized using a surrogate-assisted strategy. The optimization objective is based on several performance measures specific to pneumatic seals, including gas mass leakage, friction, minimum film thickness, asperity-load fraction, and wear. This proposed framework offers a consistent and physically sound approach for designing pneumatic rod seals that are low in leakage, friction, and wear resistance.

Keywords: Pneumatic rod seals; compressible lubrication; gas leakage; surface texturing; asperity contact; wear modelling; rarefaction effects; surrogate optimization.

Theme 5: Paper 158

Data-Driven System Identification and Embedded State Estimation for a Tracked Mobile Robot

Presentation time/location: 3 September 2026, 2:30 PM - 2:45 PM, OA7/26 (30)

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Autonomous navigation of mobile robots requires accurate vehicle models. Tracked vehicles are particularly difficult to model due to track slip, asymmetric friction, and the absence of direct drive sensors. For the ARES tracked rover of the Frankfurt Robotics and Science Team (FRoST), no powertrain model existed prior to this work, and first-principles modelling was infeasible given the limited onboard sensing. We develop a data-driven identification pipeline combining subspace identification (n4sid) with prediction error minimisation (ssest). Left and right tracks are identified independently to capture asymmetric dynamics, and the model order is selected over n = 2 . . . 10 using the Akaike and Bayesian information criteria across four configurations. The identified models form an augmented nonlinear state-space model (Nx = 10) coupling track dynamics with differential-drive kinematics. An Extended Kalman Filter with Mahalanobis-gated outlier attenuation fuses encoder and IMU measurements for real-time state estimation. Embedded C++ code is generated from Simulink via the ert.tlc target and deployed as a ROS 2 node on a Raspberry Pi 5. Both track models reach R2> 0.98 on identification data; on independent validation data the RMSE stays at 0.027 and 0.030 m/s for the left and right tracks. The trajectory closing error is 0.216 m, with real-time operation at 20 Hz confirmed on the embedded hardware. The pipeline yields a validated predictive model suitable as a foundation for Nonlinear Model Predictive Control, and its modular structure transfers directly to other tracked platforms.

Keywords: System identification · Tracked vehicle · Extended Kalman Filter · State estimation · Embedded deployment · ROS 2 · Model predictive control.

Theme 5: Paper 169

Design of a Predictive Sustainable Resource Allocation Dashboard: A Data-Driven Approach

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA7/26 (30)

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Tourism destinations often face inefficient resource allocation because demand forecasting relies on historical trends rather than real-time conditions. To address this challenge, this study proposes a predictive resource-demand framework using a Gradient Boosting Regression model trained on 1,001 hours of sensor data collected from three tourism sites. A regression-first approach with percentile-based classification was adopted to overcome the imbalanced demand distribution. The model achieved excellent performance (R^2 = 0.9968, prediction error = 0.0075), with visitor count and resource consumption identified as the most influential predictors. Deployed with FastAPI and Streamlit, the framework provides realtime demand forecasts, eco-stress assessments, and actionable recommendations for resource allocation, serving as an effective decision-support tool for proactive, sustainable tourism resource management.

Keywords: Sustainable Tourism Management, Resource Allocation, Gradient Boosting Regression, Eco-Stress Index, Machine Learning, Decision Support System.

Theme 5: Paper 179

Mechanical Performance of Epoxy Resin Infilled Vat-Polymerized 3D Printed Parts

Presentation time/location: 1 September 2026, 4:30 PM - 4:45 PM, OA7/27 (40)

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Vat polymerisation is widely used to manufacture polymer components with fine geometrical detail; however, post-curing time, resin cost and strain-rate sensitivity remain important limitations for functional applications. This short paper presents an experimental comparison between conventional solid vat-polymerised specimens and hollow 3D printed shells infilled with epoxy resin. Dog-bone and cylindrical specimens were manufactured using a LCD-based printer and tested under tensile and compressive loading after different UV post-curing durations and strain rates. The results show that epoxy resin infilling substantially reduces the time required to reach stable mechanical properties. While solid printed specimens required up to 180 min of UV post-curing, infilled specimens reached near-stable properties after approximately 60 min, corresponding to a 66.7% reduction in postcuring time. The resin infilled specimens also achieved higher strength and stiffness under both quasi-static and dynamic loading. In addition, the method reduced consumable material cost because epoxy resin replaced a significant proportion of the more expensive photopolymer resin. The approach therefore provides a practical route for improving the mechanical and economic performance of vat-polymerised parts.

Keywords: Additive manufacturing, Vat polymerisation, Epoxy resin, 3D printing, UV post-curing, Mechanical testing, Strain rate.

Theme 5: Paper 182

Aerodynamic Data Reconstruction of a 2D Aerofoil Using Proper Orthogonal Decomposition and Potential Concept for Inverse Design

Presentation time/location: 1 September 2026, 2:00 PM - 2:15 PM, OA7/27 (40)

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This research investigates the use of Proper Orthogonal Decomposition (POD) method to reconstruct pressure distribution around a 2D Aerofoil with emphasis on its potential extension toward inverse aerodynamic design. A NACA 2412 Aerofoil was analysed using Computational Fluid Dynamics (CFD) across 32 angles of attack (AOAs) at a constant free stream velocity. The resulting pressure field formed the snapshot matrix used to extract the dominant POD modes whilst constructing a reduced-order representation of the flow. The trained POD basis was then employed to reconstruct the pressure distribution of an Aerofoil at an unseen AOA which was not included in the training set. The reconstructed pressure values showed strong agreement with the reference CFD solution confirming the capability of POD method in capturing the aerodynamic behavior whilst reducing computational cost significantly. While the current implementation focuses on forward pressure field reconstruction, the demonstrated accuracy provides a baseline for prospective aerofoil shape optimization from target pressure distributions. Overall, this study establishes a robust POD-based pressure field reconstruction methodology and outlines a conceptual prospective framework for future data-driven inverse aerodynamic design.

Keywords: Proper Orthogonal Decomposition, Computational Fluid Dynamics, Reduced Order Modelling, Data-Driven Aerodynamics, Flowfield Reconstruction.

Theme 5: Paper 199

Numerical Assessment of RANS Turbulence Modelling on Ice-Roughened Slat Gap Flow Under Varying Liquid Water Content

Presentation time/location: 1 September 2026, 2:15 PM - 2:30 PM, OA7/27 (40)

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Aircraft icing continues to pose a serious threat to aviation safety, particularly during take-off and landing when high-lift configurations are deployed. While leading-edge slats enhance maximum lift, they are the primary accretion sites for early-stage ice roughness, which thickens the boundary layer and disrupts critical multi-element gap flows. Although Computational Fluid Dynamics (CFD) is routinely used to evaluate icing penalties, standard Reynolds-Averaged Navier-Stokes (RANS) models frequently exhibit predictive inconsistencies in these highly constrained, separated regimes. This study investigates the sensitivity of high-lift aerodynamic performance to early-stage icing using a NASA 30P30N multi-element airfoil, systematically evaluating the predictive variance between the Spalart-Allmaras, k-ω SST model, and Transition SST models. Steady-state simulations were conducted across varying angles of attack (α), slat deployment kinematics, and prescribed equivalent sand-grain roughness heights (ks) derived from atmospheric Liquid Water Content (LWC)via standard icing correlations. The results quantitatively demonstrate that for the baseline configuration at α=16°, the k-ω SST formulation predicts a progressive aerodynamic penalty, culminating in a 9.14% reduction in aerodynamic efficiency (L/D) under severe icing (ks = 1.5 mm). Moderating the slat deployment kinematics (δ slat -10°, denoted as Configuration X) was shown to increase aerodynamic resilience, effectively restricting this severe icing penalty to just 4.75%. Conversely, the extreme kinematic deflection of Configuration Y (δ slat-15°, denoted as Configuration Y) where this configuration triggers a

massive leading-edge stall, geometrically obstructing the gap flow (L/D ~ 3.1) and entirely overriding microscopic icing penalties (Δ L/D < 0.5 %). Crucially, the study isolates severe numerical anomalies: the default implementation of the Transition SST model fundamentally fails to resolve forced macroscopic roughness (as it lacks empirical roughness amplification corrections for the transition-onset correlations), erroneously predicting negligible efficiency responses (Δ L/D < 2 %), while the Spalart-Allmaras model over-predicts momentum retention in attached flow regions and consequently fails to capture the full severity of multi-element separation. Ultimately, this research provides critical insights into the limitations of standard RANS approaches when predicting high-lift aerodynamic safety margins under icing conditions.

Keywords: Aircraft Icing, Computational Fluid Dynamics, High-Lift Devices, Turbulence Modelling, Surface Roughness, Liquid Water Content.

Theme 5: Paper 203

Investigation of Thermal Radiation Effects on Electrical MHD Jeffrey fluid Flow over a Stretching Sheet through Porous Media via Optimal Homotopy Asymptotic Method

Presentation time/location: 2 September 2026, 3:00 PM - 3:15 PM, OA7/29 (58) Hybrid

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The flow of viscous fluid through different structures in porous medium has been discussed by many mathematicians. In this problem, the effects of thermal radiations on electrical MHD Jeffrey fluid flow over a stretching sheet through porous media method have been discussed. The approximate analytical solution of non-linear differential equations is obtained using the optimal homotopy asymptotic method (OHAM). The comparison of results has been made with the numerical output from the literature, and a very good agreement has been obtained. The effects of the governing parameters of the velocity, temperature and concentration profiles are presented graphically. Keywords Viscous fluids, Thermal radiation, Porous medium, Jeffry fluids, Temperature parameters, MHD Flow of fluids

Keywords: Viscous fluids, Thermal radiation, Porous medium, Jeffry fluids, Temperature parameters, MHD Flow of fluids

Theme 5: Paper 211

Dual-Nozzle Electrospun PVA/PLA Nanofibrous Mats Functionalised with Polygonum bistorta Extract for Wound Dressing Applications

Presentation time/location: 3 September 2026, 3:00 PM - 3:15 PM, OA7/29 (58) Hybrid

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Electrospun nanofibrous biomaterials are promising platforms for potential wound dressing applications because their extracellular matrix-like architecture, high surfacearea-to-volume ratio, and capacity to incorporate bioactive compounds enable the development of multifunctional dressings. In this study, dual-nozzle electrospinning was used to fabricate poly(vinyl alcohol)/poly(lactic acid) (PVA/PLA) nanofibrous mats incorporating Polygonum bistorta extract at concentrations of 2.5, 5, 10, and 20 mg mL^{-1}. Before its incorporation into the nanofibrous mats, the intrinsic antimicrobial activity of the free P. bistorta extract was evaluated against Staphylococcus aureus, Escherichia coli, and Candida albicans using an agar well-diffusion assay. The free extract showed concentration-dependent antimicrobial activity, with the greatest inhibition observed against C. albicans. Scanning electron microscopy revealed continuous, interconnected nanofibres, with mean fibre diameter increasing from 610 ± 110 to 760 ± 150 nm as the extract concentration increased. Localised fibre fusion and membrane-like regions were most evident at 20 mg mL^{-1}. Fourier-transform infrared spectroscopy confirmed retention of the characteristic PVA and PLA functional groups, indicating predominantly physical incorporation of the extract through non-covalent interactions. Contact-angle measurements showed differences in surface wettability among the extract-containing formulations, with the 10 mg mL^{-1} formulation exhibiting the lowest contact angle and highest apparent hydrophilicity. Overall, the 10 mg mL^{-1} formulation provided the most favourable balance between nanofibrous morphology and wettability, while the free extract exhibited concentration-dependent antimicrobial activity. These findings support the further investigation of P. bistorta-containing PVA/PLA nanofibrous mats for potential wound dressing applications, including direct evaluation of the antimicrobial activity of the fabricated mats.

Keywords: Dual-nozzle electrospinning; PVA/PLA nanofibres; Polygonum bistorta extract; antimicrobial activity; surface wettability; wound dressing.

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