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Editorial Corner

AI-Driven Digital Manufacturing and Sustainable Materials

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The manufacturing sector is undergoing an unprecedented transformation, driven by the convergence of digital technologies, advanced manufacturing processes, and sustainable materials. Sustainable and Smart Manufacturing has become a fundamental part of modern engineering as industries worldwide seek to boost productivity and minimise their environmental impact [1]. The integration of Artificial Intelligence (AI), Machine Learning (ML), digitalization, and advanced manufacturing technologies is reshaping traditional production systems, enabling industries to become more efficient, intelligent, and environmentally responsible.

The increasing awareness of sustainability and the stringency of environmental regulations have accelerated the adoption of greener manufacturing practices. Sustainable materials such as bio-based polymers, recycled plastics, natural fibre-reinforced composites, biochar and waste-derived functional fillers are increasingly replacing conventional materials in sectors such as automotive, aerospace, construction, energy, healthcare and consumer products [2]. These novel materials help to reduce the dependency on limited natural resources and support the principles of circular economy by converting waste into value-added engineering products. The development of these technologies is a big step towards carbon neutral and resource efficient manufacturing.

Digitalisation is equally revolutionising manufacturing by enabling seamless communication between machines, production systems and decision makers. Modern manufacturing facilities generate a huge amount of operational data, and this offers opportunities for process optimisation, product quality improvement, and supply chain efficiency improvement [3]. These datasets are being analysed increasingly using AI and ML algorithms, enabling predictive maintenance, intelligent quality inspection, defect detection, process optimisation and real-time decision-making [4]. These data-driven approaches are helping to reduce material waste, energy consumption and operating costs while improving manufacturing reliability. Advanced digital technologies such as cyber-physical systems, cloud computing, digital simulation, digital twin, and virtual process optimisation are also driving the shift from conventional manufacturing to intelligent manufacturing [5]. With digitalisation, complex production processes can be modelled, various design scenarios can be evaluated, and potential problems can be identified before physical implementation. These capabilities decrease product development cycle, experimental cost, and manufacturing precision, while facilitating sustainable production goals.

The digital innovations are complemented by advanced manufacturing technologies. Additive manufacturing, automated fibre placement, robot processing, advanced compression moulding, laser-assisted fabrication and hybrid manufacturing systems are providing unprecedented flexibility in the design and production of components [6]. The technologies enable near-net-shape manufacturing, material efficiency, energy efficiency and rapid prototyping and are essential tools for next generation engineering product development. Furthermore, the combination of intelligent monitoring systems with sophisticated manufacturing equipment facilitates ongoing process control and dynamic optimisation, guaranteeing uniform product quality and enhancing resource efficiency. Despite significant technological advancements, several challenges must still be addressed before fully autonomous and sustainable manufacturing systems can be widely adopted. Areas such as data interoperability, cybersecurity, workforce training, system integration, lifecycle assessment and economic feasibility still require much research and industrial attention [7]. Simultaneously, the responsible use of AI and digital technologies should be based on transparency, reliability and ethical considerations to foster trust and long-term sustainability.

The future of manufacturing will depend on the cooperation of different specialists in materials science, manufacturing engineering, computer science, data analysis, and industry experts. The ability to combine sustainable materials and intelligent manufacturing systems can bring great benefits in developing light, multifunctional, and high-performance materials with minimal environmental impacts. It will help solve many problems associated with climate change, resource scarcity, and sustainable industrial development.

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