

The role of mechanical engineering in the era of industry 4.0 and society 5.0

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Abstract

The article delves into the contrasting impacts and roles of Industry 4.0 and Society 5.0 in technological and societal advancement. While Industry 4.0 promises enhanced efficiency and income but raises concerns about automation-driven inequality, mechanical engineering has evolved from traditional to digital realms. Society 5.0, emerging as a response to societal issues, envisions a human-centric society bridging physical and virtual worlds, emphasizing technology for inclusive and sustainable progress. This transformative shift amalgamates human intellect and technology, advocating preparedness and lifelong learning amidst the ongoing industrial revolution. Mechanical engineering's pivotal role spans both paradigms, optimizing Industry 4.0's manufacturing systems and spearheading sustainable solutions and user-centric technologies in Society 5.0, emphasizing a holistic approach to societal and industrial challenges.

Keywords: Mechanical engineering, Industry 4.0, Society 5.0, Digital transformation

1. Introduction

In our previous article [1], we discussed the impact of new technologies such as AI, 3D printing, and robotics in industrial and economic society. While IR 4.0 promises increased revenues and global efficiencies characterized by the convergence of physical, digital, and biological disciplines, it also raises concerns about increasing inequality due to automation. Industry 4.0 impacts all disciplines, including mechanical engineering and production systems, such as the application of IoT, robotic workforce, augmented reality training, cloud-based design simulation, remotely controlled maintenance, and data-driven production optimization. Experts and policymakers agree on the need for comprehensive solutions involving stakeholders across global sectors to overcome the challenges of this ongoing revolution [2]–[5]. Therefore, it is important to recognize human intelligence along with AI, advocate preparedness, harness digital potential, and encourage lifelong learning to adapt to the industrial revolution, as well as emphasize the role of mechanical engineering in solving societal and industrial challenges for a sustainable future.

However, when not all mechanical engineering stakeholders were able to adapt to Industry 4.0, a new concept emerged regarding Society 5.0 which was introduced in Japan around 2016 as part of the government's vision for the future [6]. It is officially articulated and promoted by the Japanese government, particularly by the Ministry of Economy, Trade, and Industry (METI) in the "Fifth Basic Plan of Science and Technology" released in 2016. Society 5.0 refers to the evolution of human society through technological progress [7]. This emerged as a response to societal challenges and aims to create a human-centered society that integrates the physical world (reality) and the virtual world (cyberspace) through various technological innovations. Several factors contributing to the emergence of Society 5.0 include technological advances, societal problems, physical and digital integration, a human-centered approach, and economic and industrial transformation. Overall, the emergence of Society 5.0 reflects a vision of the future where technology is leveraged to address societal challenges, enhance human capabilities, and create a more inclusive and sustainable society [8].

2. Main Characteristics of Industry 4.0 and Society 5.0

Although both discuss technology and digitalization, Industry 4.0 and Society 5.0 are concepts that represent different paradigms in the evolution of technology and society. Industry 4.0 focuses on technological advances in manufacturing and Society 5.0 focuses on the evolution of society through technology, encompassing broader societal transformation, emphasizing a more holistic



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integration of technology to improve quality of life and address social challenges [9]. Therefore, the main characteristics of both are described in **Table 1**.

Table 1.
Main characteristics of Industry 4.0 and Society 5.0 (summarized from ChatGPT)

Term	Industry 4.0	Society 5.0
Technology Integration	Integrating cyber-physical systems, IoT, AI, big data and automation in manufacturing and production.	Envision the integration of similar technologies to improve the functioning of society and human well-being.
Interconnectivity	Emphasizes interconnectivity between machines, systems, and processes in manufacturing.	Envisions a connected environment where technology integrates various aspects of daily life and societal functioning.
Data Utilization	Data is used to optimize production processes and make informed decisions.	Data helps overcome social challenges by providing solutions in the fields of health, transportation, environmental problems, and others.
Automation and AI	Enables machines to perform tasks autonomously and make decisions.	Empowering solutions to societal challenges, improving quality of life, and creating more efficient and accessible services.
Transformational Impact	Transforming manufacturing and production processes.	Addressing issues beyond industry, such as healthcare, aging populations, sustainability, and inclusion.
Emphasis on Innovation	Encouraging innovation in manufacturing processes and industrial systems.	Encouraging innovation in overcoming societal challenges and improving the quality of life through technological advances.

3. The Role of Mechanical Engineering

As it is known, mechanical engineering is a branch of engineering science that combines the principles of physics and engineering mathematics with materials science to design, analyze, manufacture, and maintain mechanical systems (mechanics, energy, materials, manufacturing) in solving complex engineering problems [10]. During its development, mechanical engineering has played an important role in the industrial revolution 1.0 to 4.0. More specifically, it started with the commercial steam engine and the mechanical era (the 1700s), which was followed by electricity and mass production in the early 20th century which was applied to production lines. Then, its contribution continued to develop into the era of computerization in the 1970s where manufacturing elements shifted to automation and robotics [1]. The role of mechanical engineering did not diminish until Industry 4.0 was introduced, which was the beginning of digital supply chains, digital products and services, and data-based decision-making. Now, the implementation of Industry 4.0 must be combined with the concept of Society 5.0, to provide recognition of humans as social creatures. Therefore, the role of mechanical engineering in Industry 4.0 and Society 5.0 are presented in **Table 2**.

Table 2.
The role of mechanical engineering in the era Industry 4.0 and Society 5.0 (summarized from ChatGPT)

Industry 4.0	Society 5.0
<ul style="list-style-type: none"> • Designing and optimizing automated systems, robotics and machines used in manufacturing plants, aimed at increasing efficiency, reducing downtime, and increasing productivity. • Involved in the creation of cyber-physical systems that integrate machines with digital technology (designing sensors, actuators, and devices that enable machines to communicate, collect data, and make decisions), thereby improving overall system performance. • Employing additive manufacturing (3D printing), advanced materials, precision machining, and adaptive manufacturing processes, enables more flexible and customizable production methods. • Develop algorithms and systems that optimize manufacturing operations, predictive maintenance schedules, and resource utilization. 	<ul style="list-style-type: none"> • Develop sustainable technologies and solutions that align with Society 5.0's emphasis on sustainability (designing environmentally friendly products, energy-efficient systems, and renewable energy technologies to address environmental problems). • Develops medical devices, assistive technology, and rehabilitation equipment to contribute to advances in healthcare by designing innovative devices that improve patient care and improve quality of life. • Developing efficient and sustainable transportation systems, such as designing electric vehicles, autonomous transportation technology, and smart infrastructure to improve mobility while minimizing environmental impact. • Creating products and technologies that prioritize user experience, safety, and accessibility, aligning with Society 5.0's goal of empowering individuals and communities.

4. Conclusion

The link between Industry 4.0 and Society 5.0 marks a transformative shift in technological progress and societal evolution. Industry 4.0, which marks the convergence of digital technology in manufacturing, promises increased efficiency and global progress. However, this raises concerns about increasing inequality due to automation, requiring a comprehensive solution involving global stakeholders. Mechanical engineering, a discipline that was indispensable during the Industrial Revolution, continues to develop, from the era of steam engines to computerization and now to the digital era. Its role is critical in developing automated systems, cyber-physical integration, innovative manufacturing methods, and optimizing production operations during Industry 4.0. However, with the emergence of Society 5.0, which focuses on human-centered technology fusion, the significance of mechanical engineering extends beyond traditional manufacturing to encompass sustainable technology solutions, healthcare innovation, transportation advancements, and user-centered design. The combination of the technological sophistication of Industry 4.0 with the human-oriented approach of Society 5.0 underscores the important role of mechanical engineering in this paradigm. By harnessing digital potential, advocating preparedness, encouraging lifelong learning, and emphasizing human aspects alongside technological advances, mechanical engineering is poised to solve societal challenges and drive sustainable progress in the future.

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