

# Trends and Applications of Artificial Intelligence in Mechanical Engineering: A Review

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## Abstract

*Artificial Intelligence (AI) has become a revolutionary force across various fields, including mechanical engineering, where it is redefining traditional approaches to design, manufacturing, maintenance, and overall system optimization. This review aims to provide a comprehensive introduction to AI and explore its diverse applications within the domain of mechanical engineering. The study begins with a foundational overview of AI, including key concepts such as machine learning, neural networks, deep learning, and natural language processing. These technologies enable machines to learn from data, recognize patterns, and make decisions with minimal human intervention in mechanical engineering, AI is being increasingly integrated to solve complex problems, enhance accuracy, and improve efficiency. One significant application is in design and simulation, where AI-driven tools are used to generate optimized designs, reduce development time, and simulate real-world conditions with high precision. In smart manufacturing, AI is utilized to monitor production lines, predict equipment failures, and control robotic systems, leading to higher productivity and reduced downtime. AI-powered predictive maintenance is another critical area, where data from sensors and historical performance is analyzed to forecast failures before they occur, thereby saving costs and improving safety. Furthermore, AI contributes to quality control and inspection processes by automating defect detection using computer vision and machine learning algorithms. It also plays a crucial role in energy management and thermal systems, optimizing energy consumption in manufacturing systems and other industrial processes. The review also discusses the implementation of intelligent control systems in robotics and automation, enabling adaptive and responsive mechanical systems. Overall, this study provides a detailed insight into how AI is not just an emerging trend but a vital tool in advancing the future of mechanical engineering. It serves as a guide for researchers, engineers, and students seeking to understand the impact and opportunities AI brings to this dynamic and evolving field.*

**Keywords:** AI in mechanical engineering, artificial intelligence, machine learning

## INTRODUCTION

In recent years, Artificial Intelligence (AI) has emerged as one of the most transformative technologies across various industries, fundamentally reshaping how systems operate, learn, and adapt.

Initially rooted in computer science, AI has steadily expanded its influence into engineering disciplines, particularly mechanical engineering. As the demand for smarter, faster, and more efficient systems continues to grow, the integration of AI into mechanical processes has become both a necessity and an opportunity for innovation.

Mechanical engineering traditionally relies on established principles of physics and mathematics to design, analyze, and manufacture mechanical systems. However, with the increasing complexity of modern engineering challenges, conventional

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methods often fall short in terms of speed, adaptability, and precision. AI bridges this gap by introducing intelligent algorithms capable of learning from data, recognizing patterns, and making informed decisions without explicit programming. This has opened new avenues for solving engineering problems that were previously time-consuming or difficult to address using classical approaches.

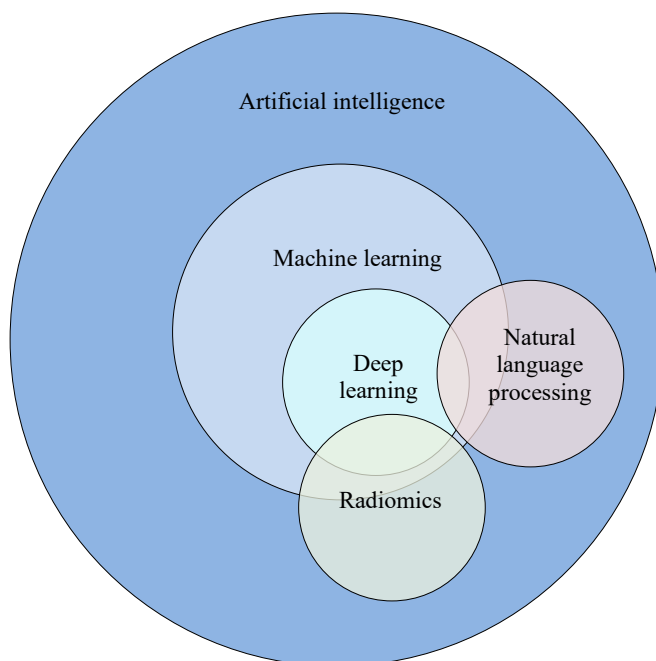
The application of AI in mechanical engineering spans a broad spectrum. From optimizing design and simulation workflows to enabling predictive maintenance, AI technologies like machine learning, neural networks, and computer vision are enhancing productivity, reducing operational costs, and improving the reliability of systems. For example, AI-driven tools can now analyze vast amounts of data from sensors in real-time to predict equipment failures, ensuring minimal downtime and better asset management. Similarly, generative design algorithms allow engineers to explore thousands of design alternatives rapidly, resulting in more innovative and efficient solutions [1].

Moreover, AI contributes significantly to advancements in robotics, automation, thermal systems, and smart manufacturing. With the adoption of Industry 4.0, the synergy between AI and mechanical engineering is becoming increasingly critical in developing intelligent, autonomous systems capable of self-monitoring and continuous improvement.

Despite its vast potential, the implementation of AI in mechanical engineering also presents several challenges. These include the need for high-quality and large-scale datasets, integration with existing systems, ethical considerations, and the requirement for interdisciplinary expertise. Addressing these challenges is essential to fully unlock the benefits AI offers to the field.

This study aims to provide a comprehensive overview of AI, its core concepts, and its applications in mechanical engineering. By reviewing current trends, technologies, and real-world implementations, the study seeks to highlight the evolving role of AI in shaping the future of mechanical engineering [2, 3].

Artificial intelligence (AI) is a branch of computer science that aims to duplicate human intelligence in order to complete tasks. Deep learning (DL) and machine learning (ML) are two of its many subfields. Figure 1 summarizes the basic concepts of AI and related techniques.



**Figure 1.** Terminology related to AI [1].

## LITERATURE REVIEW

- Wallsberger *et al.* had introduced a new synthetic dataset for failure mode analysis in drilling that is generated with real-world applicability in mind [3]. It was optimized for XAI purposes and can be used to evaluate explanations of such methods.
- Chen proposed an optimized ant colony algorithm path planning method [2]. Through experiments and data analysis, it was verified that the algorithm in his paper was closer to the original ant colony algorithm, and the convergence speed of the algorithm was slower. Therefore the improved ant colony algorithm converged more quickly as a result.
- Adediran *et al.* concluded in their paper that with AI, CAD in mechanical engineering appears to have a bright future [4]. By offering creative ideas and streaming design procedures CAD software will be essential in determining the direction of engineering in the future.
- Ahanaf *et al.* indicated in their paper that the utilization of AI technology can enhance the operational effectiveness of mechanical manufacturers, while concurrently minimizing resource wastage, thereby exerting a significant influence on the expeditious advancement of mechanical manufacturing [5].
- Bisht *et al.* concluded that the AI generated prediction closely resembles the experiment value [6]. The orthogonal array used in the test trials produced good results, resulting in little tool wear, making it more appropriate for use in chemical, marine, and aerospace applications.
- Sreeja *et al.* discussed Adaptive Defect Net (ADN), Reinforce Optimize (RO), and Predictive AI-Maintain (PAM) [7]. They concluded that these technologies enable smart business applications that are more precise, versatile, and cost-effective. ADN, RO, and PAM have the potential to transform enterprises, ensure product quality, and significantly reduce costs through the use of AI.
- Bargiela *et al.* discussed that Artificial Intelligence (AI) has seen exponential growth in recent decades, with its applications extending into various engineering domains, including mechanical engineering [8]. Several studies have explored the integration of AI in design, manufacturing, maintenance, and system control, indicating its transformative impact on traditional mechanical processes.
- In the field of predictive maintenance, AI has played a crucial role in identifying patterns in machine behavior to forecast potential failures. According to Lei *et al.*, deep learning and data-driven approaches significantly outperform traditional methods in predicting machinery faults and remaining useful life (RUL) [9]. The use of sensor data and real-time analytics has enabled industries to reduce downtime, lower maintenance costs, and enhance equipment reliability.
- Smart manufacturing, often associated with Industry 4.0, is another area where AI has made substantial contributions. Zhang *et al.* discussed the role of AI in enabling intelligent process control and decision-making in manufacturing environments [10]. Their work emphasized how AI technologies like reinforcement learning and digital twins contribute to the automation and self-optimization of production systems.

## APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN MECHANICAL FIELD

AI is revolutionizing mechanical engineering by refining design processes, advancing manufacturing techniques, streamlining operations, and powering intelligent systems. Here is a look at how AI is being applied across different mechanical areas of field:

### Design and Simulation

- *Generative design*: AI algorithms are used to create optimized designs based on specific input parameters (material, weight, strength, etc.), allowing engineers to explore unconventional and highly efficient design solutions.
- *Finite element analysis (FEA)*: AI-based techniques can optimize simulations to predict how parts or assemblies will perform under different conditions. Machine learning can improve accuracy and reduce the time required for simulation.
- *Topology optimization*: AI can assist in determining the best material distribution within a part, ensuring the most efficient use of resources while maintaining strength and durability.

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**Manufacturing**

- *Predictive maintenance*: AI algorithms can analyze data from sensors embedded in machines and predict when a machine part might fail, allowing engineers to perform maintenance before a breakdown occurs. This minimizes downtime and reduces operational costs.
- *Smart manufacturing*: AI is integrated into the manufacturing process to optimize production lines, reduce waste, and enhance quality control. Machine learning can adjust the manufacturing process in real-time to adapt to changes and improve product quality.
- *Automation and robotics*: Assembly, material handling, inspection, and packaging are among the jobs performed by AI powered robots. These robots can interact with their surroundings and make judgments based on data in real time since they are outfitted with sensors and visual systems.

**Optimized Supply Chain Management System**

- *Demand forecasting*: Artificial Intelligence plays a vital role in improving demand forecasting within the supply chain. By processing historical sales data along with external variables such as weather conditions, market dynamics, and seasonal trends, AI algorithms can generate accurate predictions of future product demand. This level of foresight helps mechanical engineers and production managers make informed decisions about manufacturing schedules, resource allocation, and inventory control. As a result, businesses can minimize overproduction, reduce storage costs, and enhance overall operational efficiency.
- *Logistics and inventory management*: AI-driven algorithms help optimize supply chains by providing real-time data about inventory levels, shipping routes, and production status, ensuring more efficient and cost-effective operations.

**Product Testing and Quality Control**

- *Automated inspection*: AI-powered vision systems can identify defects in products or components, such as scratches, dents, or irregular shapes, during the manufacturing process.
- Machine learning algorithms are capable of accurately identifying and differentiating between quality-compliant and defective products by learning from labeled data and patterns in previous inspections.
- *Real-time quality monitoring*: AI can analyze real-time data from sensors and systems during production to identify any deviations from the quality standards, triggering corrective actions before faulty products are created.

**Optimization of Energy Systems**

- *Energy efficiency*: AI algorithms are being used to optimize energy consumption in mechanical systems, such as HVAC (heating, ventilation, and air conditioning) systems, or in manufacturing plants, to reduce energy waste and improve sustainability.
- *Smart grids*: AI is applied to manage and optimize energy distribution in power grids. It helps predict power demand, identify inefficiencies, and control energy flow in real time, ensuring a stable supply and reduced energy loss.

**Robotic Process Automation (RPA)**

- *Collaborative robots (cobots)*: AI enables robots to work alongside human operators in manufacturing and assembly processes. These robots are programmed to learn from their environment and human interactions, making them flexible and adaptable to different tasks.
- *Autonomous mobile robots (AMRs)*: These robots can navigate a factory floor independently, carrying materials, products, and tools to workers or other stations, reducing the need for manual labor.

**Additive Manufacturing (3D Printing)**

- *Optimized print design*: AI algorithms can optimize the design of 3D printed parts, considering factors such as material efficiency, printing time, and strength requirements.

- *Process control*: AI can monitor and control additive manufacturing processes in real time, ensuring that parameters such as temperature, speed, and material flow are optimal to create high-quality parts.

### **Artificial Intelligence in Vehicle Engineering**

- *Autonomous vehicles*: AI is at the core of self-driving vehicles, where it processes data from sensors (cameras, LIDAR, radar) to make real-time driving decisions. In mechanical engineering, AI is used to design vehicle systems that allow for autonomous control.
- *Electric and hybrid vehicle optimization*: AI can be used to optimize powertrains in electric and hybrid vehicles, improving energy efficiency and range prediction based on driving behavior, road conditions, and other variables.

### **Structural Health Monitoring (SHM)**

- *AI in structural analysis*: In large-scale mechanical structures such as bridges, buildings, and aircraft, AI systems can analyze sensor data from these structures to predict and monitor their health. This allows engineers to detect early signs of potential failures and take preventative measures.

### **Human-Machine Interaction**

- *AI-powered user interfaces*: In mechanical systems with complex user interfaces (e.g., CNC machines), AI-based systems can make interaction easier and more intuitive. By learning from users' behavior, AI can adapt the system to suit the user's preferences and improve overall efficiency.
- *Assistive AI in robotics*: AI can enable robots to respond dynamically to human operators in industrial settings, ensuring smooth collaboration between machines and workers.

### **CONCLUSION**

Artificial Intelligence has become a pivotal force in transforming the landscape of mechanical engineering. By integrating intelligent systems capable of learning, reasoning, and adapting, AI enhances the efficiency, accuracy, and innovation of mechanical processes. From design optimization and predictive maintenance to automation and quality control, AI technologies are enabling engineers to tackle complex challenges with greater precision and effectiveness.

This review has outlined the foundational concepts of AI and explored its diverse applications within mechanical engineering. It is evident that AI is not merely a supplementary tool but a fundamental enabler of the next generation of intelligent engineering systems.

However, the successful implementation of AI also depends on addressing key challenges such as data availability, system integration, ethical concerns, and the development of interdisciplinary skills. As research and innovation continue to evolve, collaboration between AI specialists and mechanical engineers will be crucial in maximizing the potential of this technology.

In conclusion, AI holds immense promise in redefining the future of mechanical engineering. As industries move toward automation and digitalization, embracing AI-driven solutions will not only improve performance and sustainability but also pave the way for groundbreaking advancements in engineering design, manufacturing, and maintenance.

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