REVOLUTIONIZING ENGINE MANUFACTURING WITH AI: FROM CONCEPT TO CUSTOMER

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Abstract

This essay explains how a company transforms its engine manufacturing process, starting with current problems in the global market. It outlines steps to analyze the situation, design a solution, build a simulation, assess the results, and plan the next steps. The essay combines IT and IS concepts such as Decision Support Systems, Business Process Change, and Engineering methods to explain the manufacturing process. It demonstrates the author's learning and problem-solving skills as an IT analyst. Overall, the essay highlights the importance of IT and IS in improving business and increasing productivity.

Keywords: Engine, Industry 4.0, Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), Smart Manufacturing (SM)

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1. Introduction

FIGURE 1. Introduction AI in Industry

Engine manufacturing has resulted in significant emissions of greenhouse gases and harmful waste for over 150 years. The original design of engines produced a substantial amount of waste that could not be utilized and was harmful to the environment. Efforts have been made to reduce the impact of engine emissions, but improvements to engine longevity, power, and efficiency have had adverse effects on the environment. Progress has yet to be made in creating an engine with a neutral or positive environmental effect.

1.1. Background of Engine Manufacturing

This article is written to explain the current state of engine manufacturing and illustrate the importance of AI and how it can be utilized appropriately to benefit the efficiency and profitability of the process. With the advent of AI and machine learning, it has become a popular topic of discussion about how these new technologies can help streamline methods and cut costs in current manufacturing. The consensus is that AI has much potential, but the theories must be effectively implemented. In today's engine manufacturing process, there are many stages, from concept to customer, and many methods have been employed to increase efficiency. Simulation is one method on the right track, but it still has a long way to go. This is a very elastic term, and simulation can mean anything from testing ideas using simple mathematical models to fully modeling complex real-world systems. It still needs to be perfected in an efficient, cost-effective, and informative way.

1.2. Importance of AI in Engine Manufacturing

Automation of complex manufacturing processes, like engine manufacturing, is hindered by a lack of successful AI applications that can be implemented throughout the process. While progress has been made in programming robot paths and monitoring machining processes, these systems are often separate and must communicate or have a common objective. A flexible and versatile system is needed to make implementation more accessible and cost-effective. AI systems have the potential to revolutionize manufacturing by providing solutions to problems and different options or learning the best course of action based on constraints.

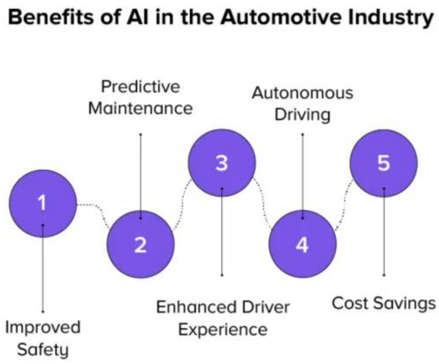

FIGURE 1.1. Benefits of AI in the Automotive Industry

The use of AI methods in engine control and design is increasing due to cheaper computing resources and the complexity of engine systems. Virtual testing environments are popular to decrease development time and cost before expensive hardware testing. For example, multi-body dynamic simulations can be used to develop control algorithms for different engine types, saving time and potential damages. AI-supervised learning can predict the best course of action. More complex AI methods can be implemented in virtual engine development environments as computing resources improve to assist various processes.

1.3. Purpose of the Research Article

This research article aims to build an intelligent engine designing model that will act as a decision support system for engine designers. The engine design process involves integrating various design tasks like conceptual design, analysis of the concept designs, and detailed design. The major activity in the detailed design phase is the design of components and the assemblies made from these components. The proposed intelligent model will carry out the critical task of designing components for the engine cylinder head. A methodology will be developed for the design of manufacturing assemblies. These will comprise groups of components designed for the same or similar function and the components to fix them to the engine. An intelligent decision-making model will guide the engine designer in choosing the component materials and the most suitable manufacturing process. This research will focus on components made from a material that can be cold-formed using a die. This is because cold forming increases the strength and hardness of the material and it can be a very cost-effective forming method. This makes it ideal for the design of components for an automotive engine. An example of such a component would be a connecting rod made from forged steel.

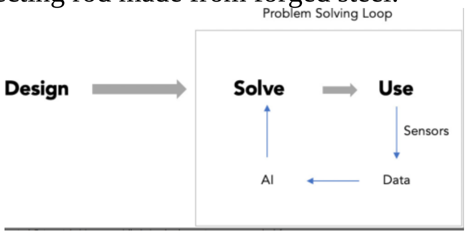

FIGURE 1.3. Problem solving loop with AI

2. Current Challenges in Engine Manufacturing

Currently, there are over 50 engine designs in production for vehicles. This variety has led to manufacturing companies avoiding ordering dies for certain engine parts. Instead, parts are made through investment, sand castings, or plastic moldings. However, transitioning back to die-casting these parts will be challenging, requiring communication with car companies and increased investment in dies to decrease costs. Material changes and cost-reduction designs will rely on information from car programs. Accurate design simulation is crucial to efficiently carrying out expected engine part tooling design changes. The EDS and NADCA project aims to achieve this through a prototype-based gating and venting design expert system. This system will guide part designers in meeting all die-cast part requirements.

2.1. Quality Control Issues

Engine components are inspected for deficiencies during production to prevent defects from reaching the customer. This process, though not perfect, involves monitoring part dimensions using techniques like CMM or Laser Scan. Other methods, like strain gauges, LVDTs, accelerometers, sensors, and cameras, can gather data for quality control. However, relying solely on part dimensions assumes correct design, which is only sometimes valid. The current method may need to be updated as technology and new methods advance.

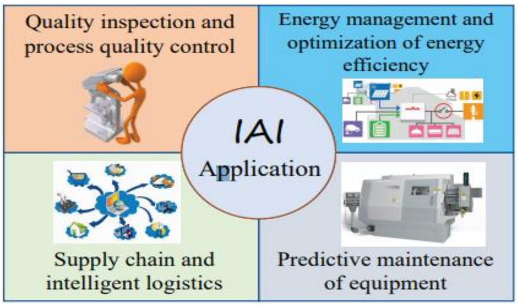

FIGURE 1. 2. Typical application scenarios of industrial artificial intelligence.

2.2. Efficiency and Productivity Concerns

Efficiency and productivity are critical for engine manufacturing, but there are challenges. Lack of process standardization, delays, and stoppages in production due to parts shortages and the complexity of engine design affect productivity. High competition leads to cost reduction and worker wage sacrifices. Engine production involves multiple suppliers, resulting in long storage periods and financial tie-ups. Poor communication between suppliers and manufacturers leads to quality issues and warranty claims.

2.3. Cost Optimization Challenges

Persuading customers to understand and implement proper costing is a difficult task. Common issues for cost reduction in engine manufacturing include historical cost calculations, lack of suitable cost data for new engines, purchasing not obtaining cost data from suppliers, and suppliers needing to be involved early enough in programs. Companies must address supplier, design, and manufacturing costs simultaneously.

2.4. Environmental Impact and Sustainability

Engine manufacturing lacks sustainability and environmental impact. While minimal improvements have been made in fuel efficiency and reducing emissions, little capital has been invested in improving the manufacturing processes. This results in engines becoming cleaner on the road but with minimal impact on global warming. A paradigm shift is necessary to achieve significant emission improvements. New engine designs should consider advanced manufacturing techniques to ensure improvements are maintained.

3. Role of AI in Engine Manufacturing

Due to extensive bookkeeping and complex production activities, the chemical industry needs to adopt manufacturing. However, technological advancements allow for the utilization of data from development projects to enhance current and future design projects. Computer-based modeling and simulation in the motor industry are still in their early stages, suggesting potential for further improvements. Traditional methods of designing experiments for motor part design are time-consuming and costly. Functional relationships can automate part design optimization and reduce the need for actual experimentation. Simulation of assembly and disassembly can identify possible assembly issues early on, preventing costly changes in tooling.

Additionally, simulating motor operation can contribute to developing durability and strength requirements. AI techniques like machine learning and expert systems are ideal for these computer-based modeling and simulation activities. The complex thinking and mathematical optimization involved in modeling may be complicated. However, the advancement of AI technology holds the potential for substituting a human designer with AI optimization for complex systems.

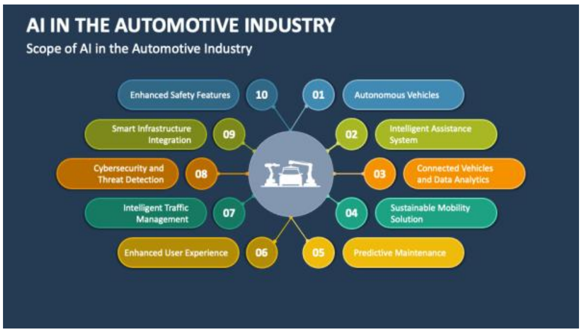

FIGURE 3. AI in the Automotive Industry

3.1. AI Applications in Design and Development

AI has the potential to increase engine development teams' productivity by automating the most computationally intensive aspects of design or by intelligently searching and classifying existing designs. AI techniques such as evolutionary computation, genetic algorithms, simulated annealing, and neural networks can automate the design process or search through many possibilities to find the best design. AI has been successfully applied to optimize processes in many industries, and there is no reason why the complex processes involved in engine development cannot be optimized similarly.

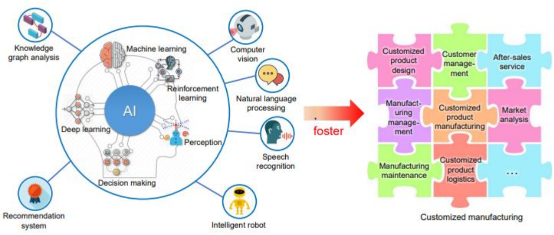

FIGURE 2. The AI and customized manufacturing.

Automotive engine design and development is a challenging process involving many interrelated tasks and a substantial degree of uncertainty. The trends in modern engine development are characterized by shorter development times, faster time to market, and pressure to reduce costs. These trends have led to the increased use of computational techniques and modeling combined with extensive testing and validation. However, the complexity of the tasks involved and the degree of uncertainty often mean that the design process is more about searching for a good design than optimizing an existing concept. The most significant advances in AI are likely to occur through AI techniques to aid design and support development decisions.

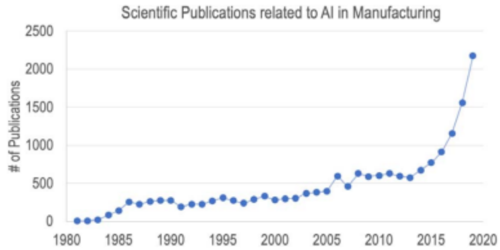

FIGURE 2.1. Growing scientific publications for AI in manufacturing

3.2. AI-Enabled Predictive Maintenance

Considering the significant operational cost savings that predictive maintenance can yield, it is becoming a high-priority research area for Rolls-Royce, with AI and machine learning offering a way to deliver new insights from data. Rolls-Royce has been at the forefront of engine health monitoring since the 1980s. We are now exploring the potential of deep learning methodologies to classify time series sensor data from engines to learn more precisely when maintenance interventions are needed. This helps avoid unnecessary removals and reduces the inspection burden on engineers during maintenance. The ultimate aim is to fully understand an engine's current and future headline and a prescriptive plan to optimize its service throughout its life. This work is being conducted both in-house and through academics and other partnerships. An example of a recent academic partnership in this area is the extensive data lab collaboration with the University of Nottingham in the UK, looking at various aspects of data analytics on engines.

Types of Artificial Intelligence	Characteristics
Strong Artificial Intelligence	It Mimics the human level of intelligence
Weak Artificial Intelligence	It is Artificial Narrow intelligence that works on specific criteria
Super intelligent Artificial Intelligence	It exceeds human-level intelligence and also has the capabilities of creative and specific thinking

Table 1. Types of AI with Characteristics

3.3. AI-Driven Quality Control and Inspection

Quality control and inspection are critical for ensuring the final engine meets performance and life requirements. AI-driven systems use models to verify part geometry and neural networks for pattern recognition. New research explores modelfree learning systems to learn feature descriptors. Prospects will use AI to diagnose quality problems and implement corrective actions using knowledge-based systems. Expert systems evaluate the effectiveness of corrective actions.

3.4. AI-Enhanced Supply Chain Management

AI is a powerful tool for supply chain management and has potential applications in engine manufacturing. It can improve inventory control, optimize transportation routes and storage decisions, reduce production costs, and detect counterfeit products. AI techniques like fuzzy logic can improve forecasting and inventory optimization. AI can also detect counterfeits by analyzing data from suppliers. AI-enhanced supply chain management is essential for manufacturers to consider.

4. Implementation of AI in Engine Manufacturing

The most progressive AI application is integrating AI systems to automate machine operations. It involves automating existing CNC machinery and adopting robotics and new AI systems to transform factory layouts and machinery. This requires high capital investment but provides cost savings, efficiency, and product quality. Decision-making systems can replace human knowledge in certain areas, minimizing human error. For example, an engine remanufacturer can decide to repair a used engine component instead of replacing it to be cost-effective. AI applications debate the development of products with solid assembly and reliability, benefiting high-tech and performance engine manufacturers.

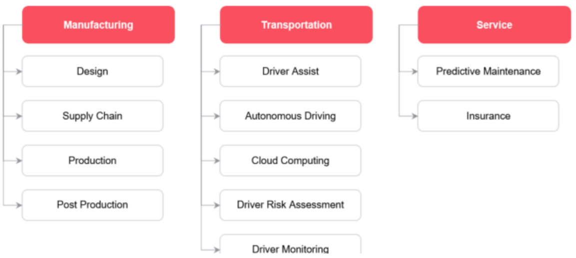

FIGURE 3.1. Implementation of AI Manufacturing

AI implementation can be divided into four areas: data collection and analysis, AI algorithm integration, training and skill development, and overcoming resistance. Data is crucial for AI intelligence, and accurate, reliable data is needed. Machine learning requires quality datasets for effective decision-making. AI technology can analyze big data faster and more effectively than humans. Engine manufacturers can access a wealth of data, which is ideal for AI analysis. The limitation may be the availability of digitized data. Digital twin technologies enable virtual experimentation and can have both benefits and risks.

4.1. Data Collection and Analysis

The faster data is transformed into information, the faster decisions can be made. Storage in a digital format allows for the leap from data to information. AI relies on data and can make complex decisions by learning trends. Driverless cars can replicate human decisions with minimal error. Collecting more and better data is crucial for AI development. In engines, valuable data still needs to be collected. This data could be used to design future engines and predict failures. A digital representation of an engine requires data on each component.

4.2. Integration of AI Algorithms and Systems

The AI algorithm integrates expert knowledge into a computational model, which assists experts in their activities. AI systems use formal and embedded knowledge for decision support in complex and unpredictable environments. This is common in manufacturing and assembly processes. Engine assembly systems using AI must handle various engines, which can be costly to develop and implement. However, high development costs can be justified in a high-volume production environment with frequent design changeovers to improve productivity and quality. Engine manufacturers with low variability in their production will not benefit from AI assembly systems.

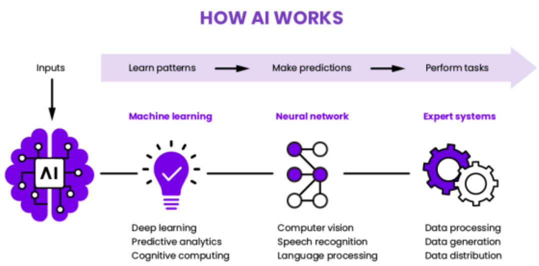

FIGURE 4. HOW AI WORKS

4.3. Training and Skill Development

The training plan bridges the gap between current and future competence levels. It is based on individual skill gaps and employee roles. The plan focuses on upskilling data analysts in tools, techniques, and domain knowledge. A knowledge base tool supports it, providing filtered, relevant information and easy access to training activities.

Job Mapping and Skill Set Definition: AI-based job mapping will define future job roles based on future business requirements, while skill set definition will identify the exact skill requirements for each job role using a knowledge-based tool.

Competence Analysis: Competence analysis will use AI-based tools to identify individual employees' current level of competence and better accurately rate their potential for different roles. The system will collect individual employee data and simulate their potential and performance for the future role.

4.4. Overcoming Resistance to Change

Resistance to change is expected when implementing revolutionary systems like the proposed AI solution. The traditional workforce, especially the older generation, unfamiliar with AI, may oppose job replacement. Teaching the basics of AI and mechatronics is necessary for better understanding and job security.

5. Future Scope

Future Scope is about the various items of future work and recommendations for future research that will contribute to current work. AI is at the stage of early research and development in the aerospace industry. Although the concept of AI has been around for several decades, it is only recently that significant developments have been made in both the technology itself and its applications. Furthermore, automation, a technology closely related to AI, has been employed to a large extent in the aerospace manufacturing and design industry. This is especially true in the automotive and lower-tech aerospace manufacturing industries, where many current products and AI technologies were developed. As such, the advancement of AI technology in today's environment can drastically influence how systems are designed and manufactured.

This creates a compelling case for further research, with a current environment conducive to implementing AI technologies. Much of AI research for aerospace research focuses on technology to design autonomous vehicles and systems. One such study at Stanford University conducted by Ilge Akkaya, Duncan Abbot, and Mykel Kochenderfer has aimed to create a system capable of designing and testing potential UAVs quickly and cost-effectively. This is achieved by utilizing a discrete event system and Markov decision processes to model system failure and make decisions based on risk and uncertainty. Although further development of AI design systems is not the main focus of this paper, new technologies resulting from studies such as this will be fundamental in the progression from the design and analysis methods explained in this paper to a state of fully autonomous system design.

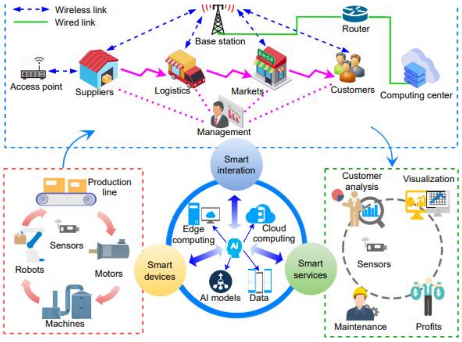

FIGURE 5. Smart Devices interaction with AI

6. Conclusion

This paper focuses on reducing engine manufacturing costs while maintaining flexibility. It argues that increased automation does not lead to cost reduction; a better manufacturing system is needed. The paper describes a system that uses evolutionary search and indirect encoding to generate and evaluate engine designs and synthesize a manufacturing system. This approach significantly advances AI-based design and manufacturing systems for complex artifacts. It can be applied to the general design problem for X and manufacturing system synthesis. The internal combustion engine design domain is used as a case study due to its high-cost pressure and existing research in candidate design representation and evaluation. This study serves as a model for applying AI to complex artifact design and manufacture, showcasing the challenges and opportunities in system synthesis.

7. References

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Biography

Vishwanadham Mandala is an Enterprise Data Integration Architect in Data Engineering, Data Integration, and Data Science areas. He holds bachelor's and master's degrees in computer science & engineering.