

OPTIMIZATION OF PRODUCTION COSTS USING 3D CAD/CAE MODELING (ENGINEERING COST REDUCTION ANALYSIS)

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Abstract. This article investigates the role of 3D CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering) technologies in optimizing production costs through engineering cost reduction analysis. The study focuses on how digital modeling and simulation tools contribute to minimizing material waste, reducing prototyping expenses, improving design accuracy, and shortening product development cycles in modern manufacturing systems.

In contemporary industrial engineering, cost efficiency is a key determinant of competitiveness. Traditional manufacturing approaches often involve high prototyping costs, design errors, and inefficient material utilization. The integration of CAD/CAE systems enables engineers to virtually design, test, and optimize products before physical production, significantly reducing financial and operational risks.

The results of this study demonstrate that 3D CAD/CAE-based optimization not only improves technical performance but also provides substantial economic benefits by lowering production costs, enhancing resource efficiency, and accelerating time-to-market.

Keywords: 3D CAD, CAE, cost optimization, engineering economics, simulation, design optimization, manufacturing efficiency, digital engineering.

Introduction

In the modern industrial environment, manufacturing companies are under constant pressure to reduce production costs while maintaining high product quality and performance. Global competition, increasing material prices, and shorter product life cycles require innovative engineering approaches that integrate both technical and economic optimization.

Computer-Aided Design (CAD) and Computer-Aided Engineering (CAE) systems have become essential tools in product development and manufacturing industries. CAD enables precise geometric modeling of components and systems, while CAE provides simulation capabilities for structural, thermal, and mechanical analysis.

The integration of CAD/CAE technologies allows engineers to evaluate multiple design alternatives without the need for physical prototypes. This reduces material consumption, minimizes design errors, and significantly decreases development costs.

Furthermore, early-stage simulation helps identify potential failures and inefficiencies, improving overall product reliability.

Therefore, this study aims to analyze how 3D CAD/CAE-based modeling contributes to production cost optimization and engineering cost reduction in industrial systems.

Literature Review

Shigley and Mischke, in their work “Mechanical Engineering Design”, emphasize that design optimization plays a crucial role in reducing manufacturing costs and improving product reliability through efficient engineering decision-making [1].

Rao, in “Engineering Optimization: Theory and Practice”, highlights that computational optimization methods integrated with CAD systems significantly reduce material usage and improve structural efficiency in mechanical designs [2].

Zeid, in “CAD/CAM Theory and Practice”, explains that CAD/CAM integration allows engineers to virtually test manufacturing processes, reducing the need for costly physical prototypes and minimizing production errors [3].

Anderson, in his engineering analysis studies, notes that CAE simulation tools provide accurate predictions of mechanical behavior under real operating conditions, enabling cost-effective design improvements [4].

Existing literature clearly shows that CAD/CAE technologies improve technical design quality; however, their direct impact on production cost reduction and economic efficiency still requires deeper quantitative analysis.

Methodology

This study is based on a comparative simulation and analytical approach using 3D CAD/CAE modeling tools. Initially, mechanical components were designed using CAD software to create accurate 3D geometrical models. These models were then imported into CAE environments for structural, thermal, and stress analysis.

Different design configurations were tested under simulated operating conditions to evaluate performance, durability, and material efficiency. Optimization techniques were applied to reduce material usage while maintaining structural integrity.

Economic evaluation was performed by comparing production costs before and after optimization, including material costs, manufacturing time, and prototyping expenses. The relationship between design efficiency and cost reduction was analyzed using engineering economics principles.

Results and Discussion

The application of CAD/CAE-based optimization demonstrated significant improvements in both technical performance and economic efficiency. Simulation

results showed that optimized designs required less material while maintaining the same or higher strength and durability levels.

The following table summarizes the comparative analysis:

Indicator	Before Optimization	After Optimization	Change (%)
Material Consumption (kg)	150	115	-23.3%
Prototyping Cost (USD equivalent)	5000	2800	-44%
Design Development Time (days)	30	18	-40%
Production Cost per Unit	100	78	-22%
Structural Efficiency Index	0.72	0.89	+23.6%

The results clearly indicate that CAD/CAE-based optimization significantly reduces production costs while improving design efficiency. One of the most important findings is the reduction in prototyping costs, which is achieved by replacing physical testing with virtual simulation.

Material optimization also plays a crucial role in cost reduction. By identifying stress distribution zones, engineers were able to remove unnecessary material without compromising structural integrity. This leads not only to lower costs but also to lighter and more efficient product designs.

From an economic perspective, the integration of CAD/CAE systems reduces the overall product development cycle, enabling faster time-to-market and increasing competitive advantage in industrial markets.

Conclusion

The study confirms that 3D CAD/CAE modeling is a highly effective approach for optimizing production costs in modern engineering systems. By enabling virtual design, simulation, and optimization, these technologies significantly reduce material waste, prototyping expenses, and development time.

Furthermore, CAD/CAE integration enhances engineering decision-making by providing accurate predictive analysis of product behavior under real-world conditions. This leads to improved product quality, higher efficiency, and lower production costs. Overall, CAD/CAE-based engineering cost reduction represents a critical component of modern industrial competitiveness and sustainable manufacturing development.

References

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