INTERNATIONAL MULTI DISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
eISSN 2394-6334 Impact factor: 8.854 Volume 13, issue 04 (2026)

MODERN MACHINE-BUILDING TECHNOLOGY: THE ROLE OF CAD SYSTEMS IN THE MANUFACTURING OF PARTS ON CNC MACHINE TOOLS

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Abstract: This paper analyzes the role and importance of CAD (Computer-Aided Design) systems in the process of manufacturing parts using CNC machine tools in modern machine-building technology. The implementation of digital design technologies is considered a key factor in increasing production efficiency, ensuring accuracy, and reducing human-related errors. In addition, the integration of CAD systems with CAM systems and its potential for automating the manufacturing process are discussed.

Keywords: CNC machine tools, CAD systems, CAM systems, machine-building technology, digital design, G-code, 3D modeling, automation, production efficiency, 5-axis machining.

Introduction

In modern machine-building industry, the automation and digitalization of production processes are among the main priority directions. The widespread implementation of CNC machine tools has enabled high accuracy and stability in the manufacturing of parts. However, achieving high efficiency requires not only CNC technologies but also the effective use of CAD systems. CAD systems make it possible to design parts, define their geometric parameters, and prepare them for production. Therefore, the integration of CAD and CNC technologies is considered a fundamental pillar of modern machine-building.

Traditional design and manufacturing processes

Traditional design and manufacturing processes have long served as the main approach in machine-building. In this system, parts are first designed manually using drafting tools (pencil, ruler, tracing paper) in the form of 2D drawings. The designer manually defines all dimensions, sections, and tolerances, which slows down the process and increases the likelihood of human errors.

In the manufacturing stage, technological processes are planned based on these drawings, and machining is carried out manually or on semi-automatic machines. Cutting parameters are often selected based on experience, which may lead to unstable results. Manufacturing complex parts requires multiple setups and repeated measurements, increasing time and resource consumption.

In addition, in the traditional approach, there is insufficient integration between design and manufacturing stages. As a result:

- production cycle is extended
- probability of errors increases
- product cost rises

In general, traditional systems are sufficient for simple parts, but their efficiency is limited for modern requirements such as high precision, complex geometries, and fast production.

Problems in traditional design and manufacturing

The following problems are observed in traditional systems:

- slow and manual design process
- high level of human-related errors
- insufficient accuracy in manufacturing complex parts
- need for manual CNC programming
- increased production costs and time consumption

These problems become more critical when manufacturing complex geometric parts.
Modern design and manufacturing processes
Modern design and manufacturing processes are fully based on digital technologies and automated systems. The main roles in this process are played by CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), and CNC technologies.
In the design stage, parts are created in a computer environment using 2D and 3D modeling. CAD systems allow precise definition of geometric shapes, dimensions, material properties, and technical requirements. This significantly reduces human errors and speeds up the design process. In addition, modern CAD software enables simulation of parts, allowing potential problems to be detected before production.

Solution

The key solution for efficient manufacturing on CNC machine tools is the full integration of CAD systems into a digital production chain. This integration operates as a "digital thread," where all stages from concept to final product are managed within a unified data environment.

Firstly, CAD systems enable parametric and associative modeling. This means that any change in dimensions or shape automatically updates the entire model. This significantly reduces design time and minimizes errors, especially in complex geometries and free-form surfaces.

Secondly, CAD systems provide digital simulation and analysis before production. Structural strength, deformation, and thermal effects can be evaluated in a virtual environment. This helps identify and eliminate defects before actual manufacturing, reducing material waste and production costs.

Thirdly, CAD systems are integrated with CAM systems to automatically generate CNC control programs (G-code). Cutting paths, tool selection, and machining parameters such as speed, feed rate, and depth of cut are automatically calculated. This reduces the need for manual programming and minimizes human errors while improving speed and accuracy.
Fourthly, modern CAD systems support multi-axis machining, especially 5-axis CNC operations. Such systems allow complex parts to be machined in a single setup, which:

- reduces machining time
- increases accuracy
- eliminates repositioning errors

Fifthly, CAD systems enable manufacturing based on the Digital Twin concept. A virtual replica of the real part is created, and the production process is monitored through this model in real time. This is a key component of Industry 4.0, enabling monitoring and optimization.

CAD systems also automate standardization and documentation processes by generating drawings, specifications, and technological sheets automatically.
Another important aspect is optimization of manufacturing processes, including:

- maximum material utilization (nesting)
- optimization of tool paths
- reduction of energy consumption

As a result, production costs decrease and competitiveness increases.

Conclusion

In conclusion, CAD systems play a fundamental role in CNC-based manufacturing within modern machine-building technology. They integrate all stages from design to production into a unified digital environment, ensuring accuracy, speed, and efficiency. The use of CAD systems significantly improves product quality, reduces costs, and expands the capabilities for producing complex and innovative components.

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