

Research on the Application of Computer-Aided Technology in NC Machining Manufacturing

Qiming Rao¹, Donglai Luan²

University of Shanghai for Science and Technology, Shanghai 200093, China

Copyright: © 2026 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), permitting distribution and reproduction in any medium, provided the original work is cited.

Abstract: As the transformation speed of the manufacturing industry from industrialization to digitalization and intelligence accelerates, computer-aided technology has become the main driving force for the development of the modern manufacturing industry. For NC machining manufacturing, the application effect of computer-aided technology is remarkable and outstanding achievements have been made. From the perspective of integrating theory with practice, this paper conducts a detailed analysis of the application of Computer-Aided Design (CAD), Computer-Aided Engineering (CAE), Computer-Aided Manufacturing (CAM), and emerging intelligent auxiliary technologies in the whole process of NC machining. Aiming at the risks existing in the technology application process, practical guarantee measures such as establishing unified data standards, strengthening process simulation verification and building compound talent echelons are put forward. It is expected to provide technical support for the efficient, precise, and intelligent development of NC machining and boost the high-quality development of the modern manufacturing industry.

Keywords: Computer-aided technology; NC machining manufacturing; Application

Online publication: September 10, 2026

1. Introduction

NC machining manufacturing is one of the pillar industries of modern industry, which plays a key role in improving production efficiency and ensuring product quality. However, traditional NC machining may restrict its development space due to complex processes, excessive labor costs and inability to realize precision control. In recent years, with the rapid development of computer-aided technology, the pace of technological innovation and mode transformation in the field of NC machining manufacturing has been accelerating. At present, computer-aided technology is widely used in various fields such as CAD, CAM and CAE, and is gradually forming a highly integrated system ^[1]. Relying on advanced computer-aided technology, the operation procedures of NC machining are simplified, while the machining precision and production speed are greatly improved, and labor input is reduced step by step. Therefore, researching the application of computer-aided technology in NC machining manufacturing is of great significance for promoting the development of the manufacturing industry towards intelligence and digitalization and accelerating the process of industrial modernization.

2. Characteristics of computer-aided NC machining manufacturing

2.1. High precision and high stability

Computer-aided technology possesses powerful computing capacity. When applied to NC machining manufacturing, it can realize intelligent management of machining processes. CAD software is adopted in design to build 3D geometric models and accurately define key dimensional parameters to meet strict tolerance requirements and improve product design precision. CAM systems are used for machining programming to provide a basis for precise positioning and path planning of NC machine tools, so as to improve the design efficiency and operation stability of tool paths ^[2,3]. As we all know, aero-engine blades feature complex shapes and extremely high precision requirements in the machining process. The introduction of computer-aided technology can not only greatly reduce blade machining errors, but also guarantee their aerodynamic performance, and realize mass production of products with consistent precision, lowering potential risks brought by manual intervention. Compared with traditional manual operation and semi-automatic process flow, computer-aided NC machining has obvious technical advantages and promising development prospects.

2.2. High efficiency and high productivity

Computer-aided technology can greatly improve product development efficiency. With the help of CAD software, designers can rapidly complete the design and optimization of 3D models. Compared with previous manual drawing and revision, it takes less time and achieves higher efficiency. CAE software can conduct pre-simulation analysis of machining processes and evaluate the suitability of machining parameters in advance, effectively avoiding production suspension or rework caused by improper configuration ^[4].

CAM systems have the function of automatically generating NC programs, which enables highly automatic machine tool processing and maintains efficient operation without manual supervision. For example, when computer-aided technology is applied to the mass production of auto parts, supported by CAM technology, production efficiency and economic benefits are greatly improved, which can better meet the requirements of mass and rapid production in the automobile industry and further enhance the operational efficiency of the whole manufacturing link.

2.3. High automation and flexibility

Computer-aided NC machining can promote the whole process of product design and machining to develop towards automation. The whole process of importing CAD design data, automatic programming by CAM and automatic machining by NC machine tools hardly requires a large amount of manual operation, which can effectively reduce operation errors caused by human mistakes and improve production efficiency. Moreover, NC machining systems feature good flexibility and adaptability. By changing relevant data programs, the same equipment can efficiently process multiple types of products ^[5,6]. For instance, to meet customers' personalized demands, mold manufacturing enterprises can adjust machining processes in a targeted manner with computer-aided technology and optimize production procedures, so as to speed up the development of special-function molds and the machining of supporting parts and satisfy market demands.

3. Specific application of computer-aided technology in NC machining manufacturing

3.1. CAD technology: Digital foundation from concept to precise models

Design is the foundation of manufacturing. CAD technology can convert designers' ideas into accurate 3D

digital models on computers. It is not merely graphic drawing, but the precise definition of product geometric information, topological relations and engineering attributes.

For NC machining, the core value of CAD lies in its powerful geometric modeling capability. Software such as Siemens NX and Pro/E can carry out parametric and feature modeling for complex free-form surfaces of aero-engine blades and precise structures of automobile molds ^[7]. Designers can adopt methods including extrusion, scanning, and lofting to construct arbitrary complex solid models, providing a reliable data basis for subsequent engineering analysis and manufacturing.

Modern CAD systems based on single-database technology can instantly reflect every modification in the design process to the whole product data model and automatically update all views and assemblies. Such associative design can well eliminate conflicts between versions and lay an accurate geometric foundation for subsequent CAM programming, ensuring consistency between design intentions and final products.

3.2. CAE technology: Performance preview and process optimization in virtual environment

If CAD constructs the “body” of products, CAE technology endows them with “soul”. Before formal machining, relevant personnel can carry out simulation analysis with CAE technology, which is an indispensable link to guarantee performance, optimize processes and avoid risks.

The essence of CAE technology is to carry out digital twin tests in virtual environments. Engineers can adopt methods such as Finite Element Analysis (FEA) to simulate models from multiple dimensions, including structural strength and thermodynamics. Taking the machining of high-load parts as an example, engineers can use the above methods to simulate stress distribution diagrams of parts under limit working conditions, discover design deficiencies in advance, and provide a basis for material layout optimization, finally realizing the consistency of lightweight design and high strength ^[8,9].

In particular, CAE technology has gradually penetrated deep into manufacturing processes. In cutting processes, cutting force, heat and workpiece deformation are key factors affecting smooth operation. Advanced CAE software can simulate cutting processes and predict the magnitude of cutting force and temperature changes. On this basis, process personnel can adjust cutting parameters in advance and select appropriate cutting tools and fixtures to minimize risks and guarantee machining stability and precision.

3.3. CAM technology: Intelligent conversion from digital models to machining instructions

CAM technology builds a bridge between digital and physical worlds and serves as the core link for the application of computer-aided technology in NC machining. The key tasks of CAM technology are to plan tool paths based on CAD models and generate NC programs (G codes executable by machine tools). The biggest advantage of CAM technology is liberating programmers from cumbersome and complicated work. Manual programming for complex curved surfaces and multi-axis linkage machining features low efficiency and high error probability. CAM software such as Mastercam and UG possesses powerful automatic programming capabilities. Programmers only need to define blanks and cutting tools, set coordinate systems and select machining strategies such as cavity milling and surface contour milling through graphical interfaces, and the software will automatically calculate efficient and interference-free tool paths ^[10].

Modern CAM systems feature prominent intelligent characteristics: first, they can automatically identify machining features such as holes and grooves and provide highly operable processing schemes; second, accurate collision detection can be completed while generating tool paths; third, the whole cutting process is

simulated in the form of 3D animation to intuitively display material removal and facilitate early detection of over-cutting or under-cutting problems. Finally, optimized tool paths are converted into G codes through post-processing, and detailed process sheets are generated to provide accurate guidance for on-site operation.

3.4. Emerging intelligent auxiliary technology: Toward adaptive and autonomous machining

In recent years, artificial intelligence, big data and other technologies have developed rapidly. Empowered by computer-aided technology, NC machining is accelerating toward adaptation and intelligence. These technologies are no longer merely assisting human work, but starting to make decisions instead of humans. The most typical application is AI-driven one-click automatic programming. Traditional CAM basically realizes automation yet sometimes relies on manual parameter setting. Emerging intelligent software can automatically identify CAD model features after learning a large number of expert cases, intelligently select optimal processes and cutting tools as well as parameters, and generate complete programs with one click, thus greatly improving programming efficiency and reducing dependence on traditional staff^[11,12].

Furthermore, the in-depth application of computer-aided technology is mainly reflected in real-time adaptive control of machining processes. Intelligent systems can accurately collect signals such as spindle load and vibration through sensors, and fully grasp tool wear and cutting stability online. If signs of chatter are detected, the system will immediately adjust feed speed or spindle speed to protect cutting tools and guarantee quality. Such a closed-loop control system composed of perception, analysis, decision-making and execution truly transforms NC machine tools from passive executors into intelligent agents capable of adapting to the environment autonomously.

4. Safeguard measures for the application of computer-aided technology in NC machining manufacturing

4.1. Establish unified data standards and interface specifications

Accident-free data circulation serves as the foundation of digital manufacturing. In practical application, design terminals (CAD) and manufacturing terminals (CAM) usually adopt different software platforms, so it is necessary to guarantee data compatibility among various platforms. Enterprises need to formulate unified data exchange standards and standardize the use of general interfaces such as STEP and IGES to ensure no loss or distortion of geometric models and topological information after multiple conversions^[13]. Moreover, enterprises shall implement single data source management to ensure timely synchronization of design changes to manufacturing links and avoid machining errors caused by version confusion, thus guaranteeing the continuity of design and manufacturing chains from the source.

4.2. Strengthen process simulation and virtual verification mechanisms

Tool path codes generated by CAM directly control machine tools, and any logical error may lead to machine collision or waste products. Therefore, establishing a strict and effective virtual verification system is particularly necessary. Before releasing codes, relevant personnel can dynamically simulate the whole machining process with simulation software, focusing on checking interference and collision, over-cutting and under-cutting between cutting tools, workpieces, fixtures and machine spindles^[14]. In case of complex multi-axis machining, the kinematic feasibility of machine tools also needs to be verified. Compared with traditional

physical trial cutting, virtual trial cutting can better avoid physical risks and continuously optimize cutting parameters to guarantee the safety and efficiency of machining processes.

4.3. Build compound talent echelons and training systems

Human resources are the key factor determining the solid implementation of technologies. The application of computer-aided technology in NC machining manufacturing requires engineers to master both software operation and comprehensive in-depth knowledge of mechanical machining processes. Therefore, enterprises shall implement regular training systems. Apart from introducing various advanced software functions to participants, it is more important to impart relevant process knowledge such as cutting principles and fixture design ^[15]. Enterprises shall encourage programmers to go to workshops regularly to understand actual machine performance and clamping restrictions, and cultivate more compound talents with knowledge of design, machining and software, so as to provide strong intellectual support for technology implementation.

5. Conclusion

This paper systematically discusses the characteristics, application approaches and supporting measures of computer-aided technology in CNC machining and manufacturing. With the development of artificial intelligence and digital twin technology, CNC machining will advance toward a higher level of intelligent manufacturing. Therefore, only by relying on continuous technological upgrading and collaborative innovation in the construction of management systems to seize the initiative amid the trend of high-quality development in the manufacturing industry can the manufacturing sector achieve sound and steady progress.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Chen W, 2024, Application of Computer-Aided Technology in NC Machining Manufacturing. *Electronic Technology*, 53(2): 180–181.
- [2] Ning D, Xia Q, Wang H, et al., 2021, Analysis on the Application of Computer-Aided Technology in NC Machining Manufacturing. *Computer Knowledge and Technology*, 17(29): 138–139.
- [3] Huang S, 2021, Research on the Application of CAD/CAM Technology in NC Machining. *Modern Manufacturing Technology and Equipment*, 57(12): 37–39.
- [4] Zhao T, 2023, Research on NC Machining Process Based on CAD/CAM Technology. *Agricultural Machinery Use and Maintenance*, (8): 59–61.
- [5] Li X, 2025, Research on the Application of NC Machining Technology in Mechanical Processing. *Engineering Construction and Technology*, 3(2).
- [6] Han C, 2025, Research on the Application of Mechanical Automation Technology in Mold Manufacturing. *Mold Manufacturing*, 25(12): 53–55.
- [7] Li N, 2025, Application of Digital Intelligent Technology in Denture Processing Industry. *Communication World*, 32(3): 163–165.

- [8] Li S, 2024, Improved Design of Dovetail Tenon Structure Based on Computer-Aided Technology, thesis, Nanjing Forestry University.
- [9] Ma Y, 2025, Research on Innovative Application of Digital Manufacturing Technology in Bench Work. *Machinery and Electronic Control Engineering*, 7(6): 10.
- [10] Chen R, 2025, Research on the Application of Mechanical Automation Technology in Machinery Manufacturing. *China Equipment Engineering*, (12): 212–214.
- [11] Gao J, 2021, Application of NC Technology and Computer-Aided Design in NC Machine Tools. *Shihezi Science and Technology*, (4): 13–14.
- [12] Xu C, Huang R, Zhang S, et al., 2025, Adaptive NC Process Design Method for Mold Cavity Driven by CAD/CAM Model. *Journal of Beijing University of Aeronautics and Astronautics*, 51(10): 3374–3384.
- [13] Ma K, Chen H, Ye H, et al., 2021, Research Progress of CAD/CAM for Removable Partial Dentures. *Chinese Journal of Stomatology*, 56(5): 485–490.
- [14] Wang X, Qiu L, 2021, Five-Axis NC Milling Tool Path Optimization Assisted by Machine Learning. *Modular Machine Tool & Automatic Manufacturing Technique*, (2): 110–113.
- [15] Li J, Wu B, Lu B, 2024, Analysis of NC Programming and Machining Process Simulation Based on UG. *Paper Making Equipment and Materials*, 53(2): 79–81.

Publisher's note

Bio-Byword Scientific Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.