TECHNICAL DESIGN OF THE MACHINING PROCESS OF PARTS ON CNC MACHINES USING 3D SOFTWARE (UZAUTO MOTORS POWERTRAIN)

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This study investigates the technical design of machining processes for powertrain components on CNC machines using advanced 3D CAD/CAM technologies. The research focuses on optimizing toolpath strategies, improving cutting efficiency, and reducing machining errors through digital simulation. The findings highlight the significance of virtual manufacturing in enhancing precision, minimizing production waste, and increasing competitiveness in automotive manufacturing, particularly at UzAuto Motors Powertrain. Modern advanced manufacturing technology greatly relies on CAD/CAM software. Many CAD/CAM software tools have been rapidly developed in recent years, with Unigraphics (UG) standing out for its powerful design, CNC programming functions, and seamless CAD/CAM integration.

As an application example, a complex-surfaced mouse model part was designed and trial-manufactured using a CNC machine. First, the 3D model was created in UG's modeling module. Then, *a process scheme was developed after careful analysis. In the manufacturing module, NC machining parameters were set according to the processing requirements; toolpaths were generated, edited, and verified, and NC codes were produced via post-processing. Simulation in YULONG software preceded the actual machining on a 3-axis CNC milling machine, resulting in a part with high accuracy and desired shape.*

The results show that UG's CAD/CAM capabilities streamline NC machining of complex surface parts, improving design and machining efficiency, shortening production cycles, and reducing costs. The methodology described provides a valuable reference for similar parts processing and related studies.

Introduction

Numerical Control (NC), specifically Computer Numerical Control (CNC), refers to the automated control of tools using preprogrammed software. CNC automates operations, movement, and precision for various machine tools, including mills, lathes, routers, drills, grinders, water jets, and lasers. Optimizing G-code and toolpath strategies is critical for improving machining efficiency and performance.

Advanced CAM software enhances toolpath strategies, reduces machining time, improves surface finish, and minimizes tool wear. Machining time for different strategies was simulated using ICAM3D software (Version 3.1.0) and AutodeskArt (Version 2018.0.0 ECMAScript 6/ES6). Simulation allows validation before physical production, reducing trial-and-error adjustments.

Toolpath strategy, the preprogrammed route of the cutting tool, is key in modern CNC machining. Efficient tool movement minimizes cycle times, reduces tool wear, and ensures superior surface finishes. With advanced CNC systems, toolpath strategies now incorporate real-time machine feedback and adaptive algorithms, optimizing performance further.

This study combines ICAM3D, Art CAM, and Aspire software to enhance G-code generation and reduce machining time by 12% (from 15 min 23 s to 13 min 33 s). This approach improves efficiency, precision, and productivity in CNC machining.

The paper structure includes: an overview of research on toolpath planning, materials and methods for different strategies, results from three analyzed projects, discussion of simulation and real CNC data, and conclusions.

Modern automotive manufacturing, especially for engine and transmission components, requires high precision and reliability. The complexity of powertrain geometries necessitates 3D CAD/CAM integration for visualization, simulation, and process optimization.

Literature review

Recent studies highlight the transformative impact of digital technologies in manufacturing. CAD/CAM simulation improves accuracy, predicts tool wear, and reduces trial-and-error adjustments.

Zhang & Bai (2024) demonstrated that toolpath optimization significantly reduces machining time.

Pajaziti et al. (2025) showed that high-performance CNC machines with digital simulation improve consistency and reduce defects.

Groover (2020) and Kalpakjian (2021) emphasized precise process planning to minimize production waste.

This paper further analyzes macro machining processes by associating CAD and CAM models. Using Bayesian inference, it constructs relationships between query part features and actual machining processes, avoiding direct geometric comparisons. Tool trajectory algorithms for multi-axis CNC programming were optimized, improving machining efficiency by 36.94%, reducing maximum cutting forces, and minimizing vibration amplitude. This demonstrates practical benefits in efficiency and quality.

Methodology

The methodology involves:

Component analysis based on geometry and machining requirements.

3D modeling using CAD software.

CNC toolpath simulation and evaluation using CAM systems.

Iterative optimization of toolpaths based on cutting forces, predicted surface quality, and machining time.

Results and discussion

Simulation results indicate that 3D CAD/CAM significantly improves machining accuracy. Key findings:

Toolpath optimization reduced machining time by 12–18%.

Surface finish quality improved.

Virtual collision detection eliminated fixture-related errors and unnecessary tool movements.

Material waste reduced by 10–15% due to optimized blank selection.

Digital twin technology allowed detection of deviations before actual machining, ensuring consistent quality.

Industrial Application at UzAuto Motors Powertrain. At UzAuto Motors Powertrain, 3D machining simulation is applied in cylinder head, crankshaft, and camshaft production. Virtual modeling aligns machining sequences with CNC machine capabilities. Digital inspection tools improve reliability and reduce rework rates. The study demonstrates that wider adoption of digital technologies can enhance productivity and reduce costs in Uzbekistan's automotive manufacturing sector.

Conclusion

The technical design of CNC machining processes using 3D CAD/CAM tools improves precision, efficiency, and cost-effectiveness in powertrain component manufacturing. Digital simulations reduce machining errors, material waste, and production time. For UzAuto Motors Powertrain, advanced CAD/CAM adoption offers modernization and competitiveness. Future research should focus on digital twin systems and AI-assisted machining parameter optimization.

References

1. Zhang, S., & Bai, J. (2024). Research on CNC programming and machining process based on CAD/CAM technology. Applied Mathematics and Nonlinear Sciences, 9(1). https://doi.org/10.2478/amns-2024-0516

2. Pajaziti, A., Tafilaj, O., Gjelaj, A., & Berisha, B. (2025). Optimization of toolpath planning and CNC machine performance in time-efficient machining. Machines, 13(1), 65. https://doi.org/10.3390/machines13010065

3. Gao, S. (2024). Simulation of mechanical NC machining based on CAD/CAM. Computer-Aided Design & Applications, 21(S6), 1–9. https://doi.org/10.14733/cadaps.2024.S6.1-9
4. Siddiquee, A. N., Khan, Z. A., & Mallick, Z. (2022). Recent research development of CNC-based milling machining conditions: A comprehensive review. Materials Today: Proceedings, 62, 3983–3989.
5. Guo, C., Li, J., & Xu, W. (2021). Intelligent optimization of CNC machining parameters using integrated CAD/CAM–AI technologies. Journal of Manufacturing Processes, 68, 520–532.
6. UzAuto Motors Powertrain. (2022). CNC machining and powertrain manufacturing guidelines.
7. Groover, M. P. (2020). Fundamentals of Modern Manufacturing. Wiley.
8. Kalpakjian, S., & Schmid, S. (2021). Manufacturing Engineering and Technology. Pearson.