

Verification of Optimization of Machining Process for Semi-Open Impeller Based on Siemens NX Platform [†]

Yurong Wang, Xu Zhang and Zhaowei Wang *

School of Intelligent Manufacturing, Shanghai Zhongqiao Vocational and Technical University, Shanghai 201514, China; wangyr@shzq.edu.cn (Y.W.); zhangxu@shzq.edu.cn (X.Z.)

* Correspondence: wangzhaowei@shzq.edu.cn; Tel.: +86-13671656238

[†] Presented at the 2024 Cross Strait Conference on Social Sciences and Intelligence Management, Shanghai, China, 13–15 December 2024.

Abstract

As the core component of high-performance mechanical transmission devices, semi-open impellers are widely used in aerospace, automobiles, and high-end industrial manufacturing. Their complex structures and variable blade shapes have extremely high requirements for machining accuracy and surface quality. However, at present, traditional manual programming for machining generally has problems of relatively low machining efficiency and machining accuracy. Therefore, we explored the application of the Siemens NX (UG NX12.0) software platform in modeling and process programming for machining semi-open impellers and designed an efficient machining strategy by combining rough machining, semi-finishing machining, and finishing machining in an optimized manner. By using the advanced functions of UG NX, the whole process from three-dimensional modeling and process planning to tool path generation was formulated, and machining verification was carried out on the Mikron Mill E500U five-axis machining center. The process plan significantly improved machining efficiency and optimized surface quality. After verification, the machining efficiency increased by more than 30%, and the machining accuracy was significantly improved, fully verifying the superiority and practicability of the UG NX platform in the machining of complex curved surface parts.

Keywords: UG NX; semi-open impeller; machining process; five-axis machining; surface quality



Academic Editors: Teen-Hang Meen, Jiazhen Huo and Cheng-Fu Yang

Published: 26 August 2025

Citation: Wang, Y.; Zhang, X.; Wang, Z. Verification of Optimization of Machining Process for Semi-Open Impeller Based on Siemens NX Platform. *Eng. Proc.* **2025**, *98*, 47. <https://doi.org/10.3390/engproc2025098047>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Semi-open impellers have been used extensively in the mechanical manufacturing industry due to their high efficiency and wide range of applications. However, their multi-axis machining involves complex tool path movements, which makes manual programming extremely difficult [1]. Therefore, automatic programming usually relies on computer-aided design/computer-aided manufacturing CAD software. The three-dimensional data model of the part was obtained by modeling with CAD or reverse engineering. The CAM functions of UG NX software were used to generate the cutter location source file, and the post-processing file was set according to the specific conditions of the processing equipment to generate numerical control (NC) code for numerical control machining.

2. UG NX Platform in Machining Semi-Open Impeller

2.1. Three-Dimensional (3D) Modeling

In the machining process of semi-open impellers, 3D modeling is crucial. The UG NX platform provides high-precision 3D modeling tools to accurately construct the geometric model of the impeller, including the complex twisted shapes of the blades and the precise dimensions of the rim. In this study, a semi-open integral impeller was explored, as shown in Figure 1. The impeller was made of aluminum alloy. The maximum outer diameter of the impeller was 195 mm. The outer shape was conical in part, with the outer diameter at the smallest part being 50 mm. The maximum height of the blades was 88 mm, and there were 12 sets of blades evenly distributed along the circumferential direction.

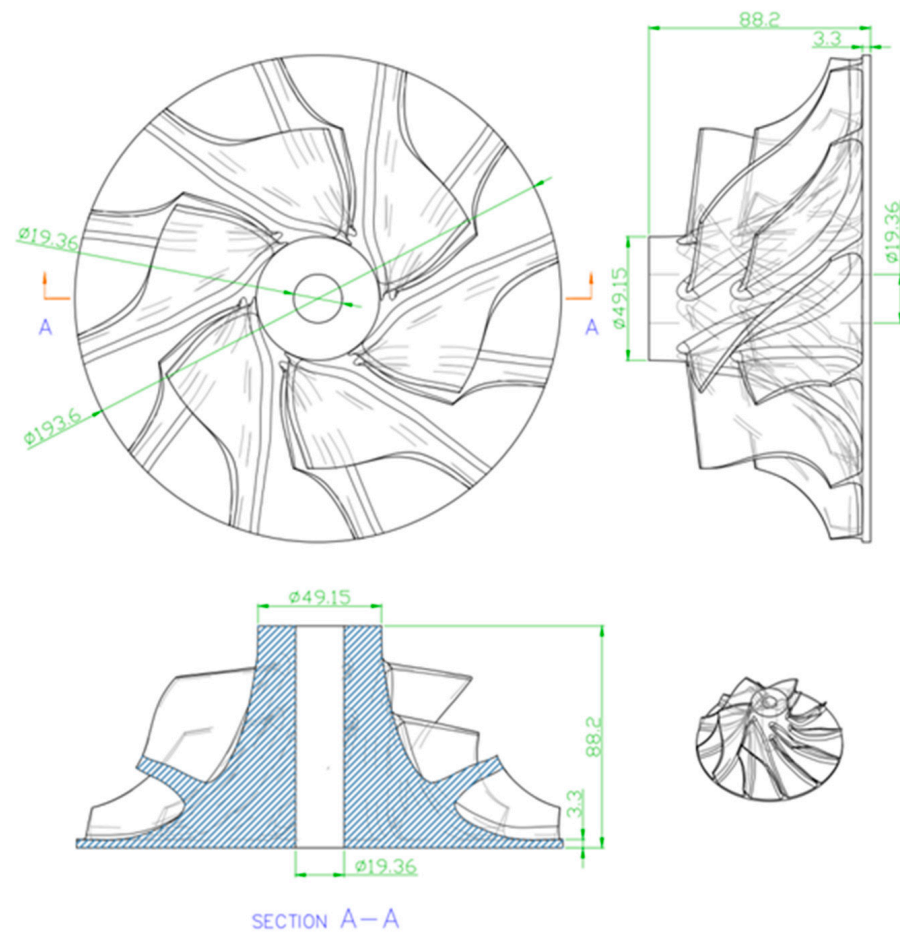


Figure 1. Structure of semi-open integral impeller.

2.2. Process Planning

Based on the precise 3D model, the UG NX platform was used to conduct detailed process planning. According to the geometric features and machining requirements of the impeller, an appropriate machining process route was selected. The geometric structural features and application requirements of the impeller are shown in Figure 2, which include removing a large amount of material in the rough machining stage, further approaching the final shape in the semi-finishing stage, and achieving the required surface quality and dimensional accuracy in the finishing stage.

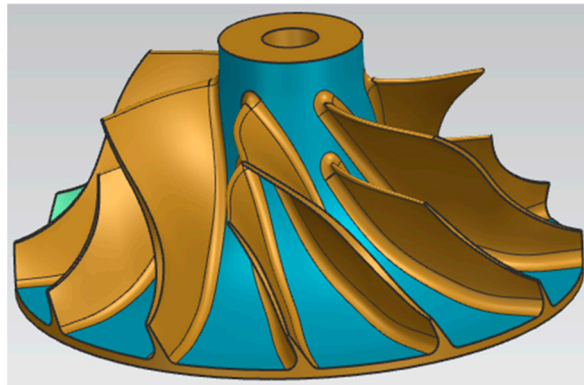


Figure 2. Geometric structural features of impeller.

2.3. Tool Path Generation

Based on process planning, the UG NX platform generated optimized tool paths considering the geometric features and machining requirements of the impeller, ensuring the smoothness and high efficiency of the machining process. UG NX offered multiple tool path generation strategies, such as contour machining, spiral machining, and five-axis simultaneous machining. Users can select appropriate tool path generation strategies according to specific machining requirements and equipment conditions to maximize machining quality and efficiency [2]. In addition, the UG NX platform also has powerful simulation and verification functions. After generating the tool paths, users can simulate the machining process through a simulation to check the feasibility and optimization potential of the tool paths. The tool paths of the impeller are shown in Figure 3.

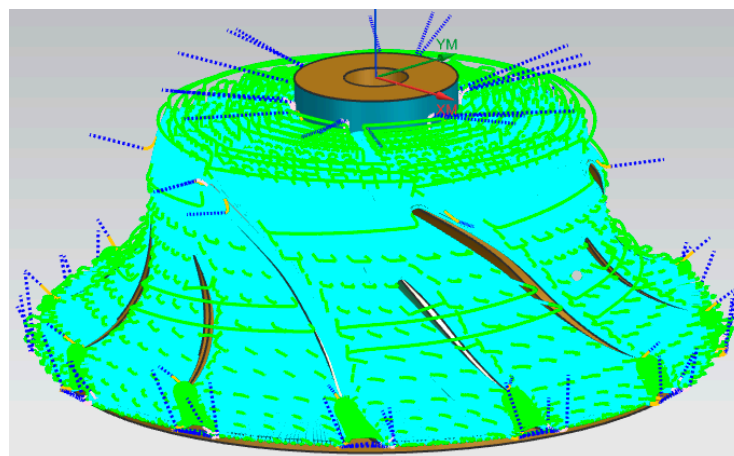


Figure 3. Tool paths of impeller.

3. Design of Machining Strategy for Semi-Open Impeller

In response to the complex and intricate geometric features of semi-open impellers, we designed machining strategies for rough machining, semi-precision machining, and precision machining to ensure machining quality and efficiency.

3.1. Rough Machining Strategy

Rough machining aims to quickly and effectively remove most of the material and the burden for subsequent processing. We chose large-diameter cutting tools for machining, which have higher cutting efficiency and stronger material removal ability, quickly reducing the volume of the impeller in a short period. By reasonable tool path planning and cutting parameter settings, the smooth progress of the rough machining process is ensured, and

unnecessary damage to the impeller is avoided. The overall rough machining tool path is shown in Figure 4.

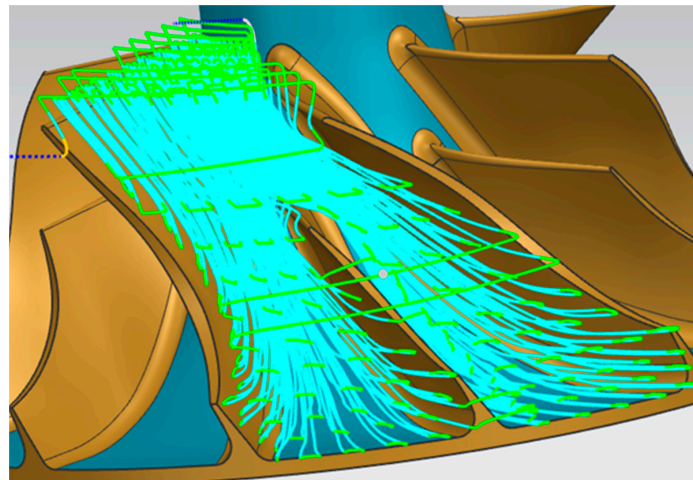


Figure 4. Overall rough machining path.

3.2. Semi-Finishing Machining Strategy

After rough machining, the shape of the impeller was initially formed, but there was still a relatively large allowance on the surfaces of the blades and the hub. Semi-finishing machining must be carried out to prepare for the subsequent finishing machining. At this stage, a small-diameter ball-end mill (such as R2-6-D10) was selected to further process the blades. Semi-finishing machining ensures that the surface allowances of the blades and the hub are uniform, providing a good foundation for the subsequent finishing machining. Meanwhile, semi-finishing machining is used to further correct the shape errors and surface defects that may have occurred during the rough machining process. The semi-finishing machining tool path is shown in Figure 5.

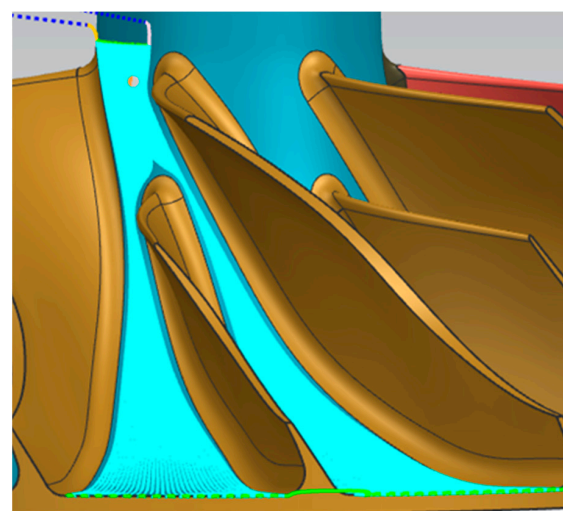


Figure 5. Semi-finishing machining path.

3.3. Finishing Machining Strategy

Finishing machining is the most crucial stage in the processing of semi-open impellers. During the finishing machining stage, it is necessary to ensure that the quality of the blade surfaces meets the design requirements [3]. To achieve this goal, a ball-end mill (such as R2-6-D10) was used for machining. The ball-end mill has good adaptability and flexibility and can accurately machine the complex shapes of the blades. Through reasonable tool

selection and cutting parameter settings, the blade surfaces reached the required roughness and shape accuracy. The finishing machining tool path is shown in Figure 6. During the finishing process, the rigidity and stability of the cutting tools are ensured to avoid vibration and deformation during machining. Secondly, reasonable control over the cutting depth and feed rate is set to prevent excessive cutting force and heat generation. Finally, it is necessary to clean the cutting fluid and debris promptly to keep the machining environment clean and tidy.

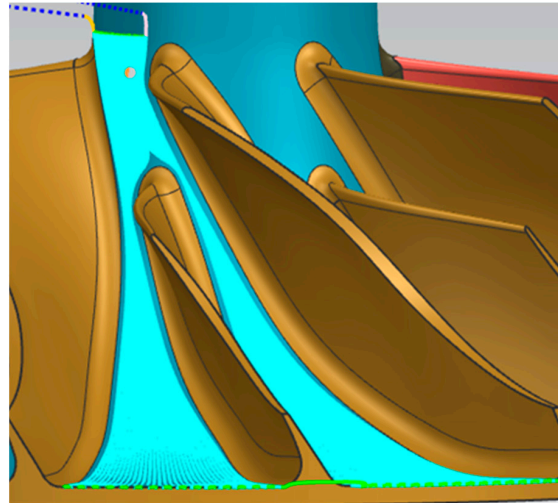


Figure 6. Finishing machining path.

4. Five-Axis Machining Verification

4.1. Machine Tool Selection

To verify the effectiveness and reliability of the machining strategies generated by the UG NX platform in practical applications, the Switzerland GF Mikron Mill E500U five-axis machining center was selected as the experimental platform. The Mill E500U is a vertical five-axis simultaneous CNC machining center introduced by Mikron in Boudry, Switzerland, adopting a rotary structure for the *B* and *C* axes of the worktable. The travel parameters are as follows: the *X*-axis was ≥ 500 mm, the *Y*-axis was ≥ 450 mm, the *Z*-axis was ≥ 400 mm, the *B*-axis (swing) ranged from -65° to $+110^\circ$, and the *C*-axis (rotation) was 360° . This machine tool has a high rotational speed, high stability of the simultaneous motion structure, and mature five-axis simultaneous motion technology. The machine tool control system was the HEIDENHAIN iTNC 640 system, and UG NX 12.0/Post Builder software was used to build the post-processing specific to the Mill E500U machine tool.

4.2. Tool Selection

To improve machining efficiency, during the roughing and semi-finishing of the flow channels, ball-end milling cutters with large diameters must be selected. However, the diameter of the cutting tools must be smaller than the minimum distance between two blades. During the finishing of the blades, on the premise of ensuring no overcutting, ball-end cutters with large diameters need to be selected as much as possible, that is, to ensure that the radius of the cutting tools is larger than the maximum fillet radius at the junction of the flow channels and the blades. When performing root cleaning on the junction of the flow channels and the adjacent blades, the radius of the selected cutting tools must be smaller than the minimum fillet radius at the junction of the flow channels and the blades [4]. The cutting tools used in this paper are shown in Table 1.

Table 1. Tool list used in this study.

Serial Number	Processing Method	Tool Type	Tool Diameter	Tool Corner Radius	Tool Blade Length
1	rough machining	ball-end cutter	D12.0	R6.0	40
2	rough machining	flat-bottomed blade	D10.0	R0.0	50
3	semi-finishing	ball-end cutter	R2-6-D10	R2.0	40
4	fine machining	ball-end cutter	R2-6-D10	R2.0	50
5	clean-up machining	ball-end cutter	R2-6-D10	R2.0	50

4.3. Parameter Setting

Before the start of machining, the tool path files generated by the UG NX platform were imported into the control system of the Mikron Mill E500U five-axis machining center. Subsequently, according to the material, size, and machining requirements of the impeller, appropriate machining parameters were set. In the rough machining stage, the spindle speed was set to 11,000 r/min and the feed rate was 3000 mm/min; in the finishing stage, the spindle speed was 15,000 r/min and the feed rate was 4500 mm/min to ensure the smooth progress of the machining process.

4.4. Machining Process

The machining process was carried out strictly following the process routes and tool paths generated by the UG NX platform. Meanwhile, close attention had to be paid to various parameters in the machining process, such as cutting force, vibration conditions, and cutting temperature, to ensure the safety and stability of the machining process. In addition, the machining time and surface quality data were recorded for further optimization and adjustment of the machining strategies in the follow-up.

4.5. Machining Results

By adopting the machining strategies generated by the UG NX platform to machine the semi-open impeller on the Mikron Mill E500U five-axis machining center, the machining efficiency was significantly improved, and the surface quality of the machined impeller met the design requirements. Specifically, the machining time was shortened by nearly 30% compared with the traditional machining methods, and the surface roughness reached Ra of below 0.8 μm , fully meeting the requirements of high-precision machining. The finished machined product is shown in Figure 7. The experimental results demonstrated the strength and broad application prospects of the UG NX platform in the machining of semi-open impellers. It helps engineers optimize machining strategies quickly and accurately and achieves seamless docking with advanced five-axis machining centers to develop and innovate semi-open impeller machining technology.

**Figure 7.** Machining effect of finished product.

5. Conclusions

The 3D modeling, process planning, and tool path generation of the UG NX platform reduce unnecessary machining steps and repeated machining, thereby greatly improving machining efficiency. Using the strategies generated by the UG NX platform, the machining of semi-open impellers enabled a reduction in the machining time by 30% compared with traditional machining methods. Through meticulous process planning and tool path optimization, the UG NX platform ensured the effective control of parameters such as cutting force, cutting temperature, and vibration during the machining process. The surface quality of the machined impeller was excellent and fully met the design requirements. The blade surfaces were flat and smooth without obvious defects such as scratches and pits. This process scheme significantly improves the machining efficiency and surface quality, verifying the superiority and practicability of the UG NX platform in machining complex curved surface parts. Such results provide a new technical path and theoretical basis for the precision manufacturing of semi-open impellers, which is of important theoretical and practical significance.

Author Contributions: Conceptualization, Y.W.; methodology, Y.W.; investigation, Z.W.; writing—original draft preparation, Y.W.; formal analysis, Y.W.; data curation, Y.W.; visualization, Y.W.; validation, X.Z.; writing—review and editing, X.Z. All authors have read and agreed to the published version of the manuscript.

Funding: Natural Science Foundation of Shanghai Zhongqiao Vocational and Technical University (No. ZQZR202416).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data supporting this study are not publicly available due to commercial restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Chen, X.; Fan, L. Process Analysis and Application of High-Efficiency Machining Technology Based on Titanium Alloy Impellers. *N. Technol. N. Prod. China*. **2022**, *3*, 41–44. [[CrossRef](#)]
2. Ma, Y.; Zhang, Y. Research on Multi-axis Machining Technology of Precision Small Impellers. *Mod. Manuf. Eng.* **2021**, *5*, 111–115. [[CrossRef](#)]
3. Xiong, Y.; Fan, Y.; Zhang, X.; Gao, Y.; Yuan, Z.; Feng, J. Design of Intelligent Manufacturing Production Line Based on Complex Components such as Impellers. *Mach. Tool Hydraul.* **2024**, *4*, 106–111.
4. Xu, C.; Wang, J.; Wang, T. Research on the Machining Process of Axial-flow Integral Impellers Based on UG NX. *Tool Eng.* **2023**, *11*, 107–110.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.