International Journal of Multidisciplinary Research and Literature
IJOMRAL
Vol. 5, No. 2, March 2026 pp. 293-306
Journal Page is available at http://ijomral.esc-id.org/index.php/home

IMPLEMENTATION OF NANJING SWANSOFT-BASED CNC MILLING SIMULATION IN THE MANUFACTURE OF UMSB BRAND GRAVIS PRODUCT

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Abstract

Development of engraved products featuring institutional identity at Mechanical Engineering Department, Universitas Muhammadiyah Sumatera Barat offers promotional opportunities and commercialization potential. Manufacturing plaques, keychains, and name tags through CNC Milling technology demands precision in design formulation, toolpath optimization, and determination of cutting parameters that align with material properties. This research implements Nanjing Swansoft-based CNC Milling simulation for producing UMSB-branded gravis products, analyzing toolpath prediction accuracy, machining duration, and evaluating contributions toward production efficiency. The study applies descriptive-analytical approach with case study method conducted at Faculty of Engineering during November 2025 to January 2026. Research stages encompass comprehensive literature review on CNC milling technology and parameter optimization, two-dimensional and three-dimensional design creation using SolidWorks software for aluminum material sized 240×60×40 mm, G-code programming employing single tool strategy with Ø10mm end mill designated as T01, configuration of FANUC 0i-M controller with G54 work coordinate system, and execution of four machining phases: facing, roughing, semi-finishing, and finishing operations targeting 20 mm engraving depth. Dimensional validation demonstrates accuracy within ±0.1 mm tolerance on critical dimensions with maximum deviation of ±1.5% in engraving zones, maintaining compliance with manufacturing tolerance limits for institutional souvenir applications. Actual simulation cycle time recorded 68 minutes 50 seconds with deviation below 5% from initial programming calculations. Cutting force monitoring revealed optimal range between 90-140 N without collision detection warnings. Surface quality assessment indicates superior finishing profiles with uniform stepover ridge formation and sharp edge definition on UMSB typography elements without excessive burr formation. Integration of CAD/CAM systems through simulation validates feasibility of CNC instructions for actual machine implementation, confirming Nanjing Swansoft simulator effectiveness as cost-efficient tool for programming verification and material waste reduction supporting manufacturing digitalization within Industry 4.0 framework.

Keywords: CNC Milling, Nanjing Swansoft Simulation, Gravis Product, Digital Manufacturing, CNC Programming

INTRODUCTION

Universitas Muhammadiyah Sumatera Barat's Mechanical Engineering Department demonstrates considerable capacity to create engraved merchandise featuring institutional branding, which functions both as marketing instruments and revenue-generating ventures. Production workflows for items such as commemorative plaques, keychain accessories, and identification badges utilizing CNC Milling machinery necessitate exactness in conceptual planning, cutting trajectory enhancement, and specification of machining variables aligned with substrate characteristics (Arsenal et al., 2025; Kalpakjian & Schmid, 2014). Achieving successful machining outcomes relies heavily on deliberate choices regarding operational settings and suitable material removal conditions (Kalpakjian & Schmid, 2014)

Deployment of CNC Milling simulation platforms, specifically Nanjing Swansoft, delivers protective measures against coding mistakes while simultaneously advancing operator proficiency through digital validation processes conducted before implementation on actual manufacturing equipment (Burhanudin et al., 2023). These virtual environments enable detailed examination of tool trajectories, forecasting of manufacturing durations, and assessment of technical viability while eliminating exposure to material wastage or machinery deterioration. Evidence indicates that instructional approaches incorporating simulation components can elevate CNC instruction effectiveness by 40-60 percent by establishing protected and flexible training conditions (Suryono & Burhanudin, 2022). Incorporating simulation tools within CNC coding instruction has demonstrated success in strengthening learners' theoretical comprehension of equipment functionality.

Utilizing simulation frameworks in engraving manufacturing accomplishes several objectives: decreasing programming mistakes in G-code sequences, limiting raw material losses, and expediting product development timelines. Contemporary digital production methodologies make substantial contributions toward elevating precision levels and operational effectiveness in current manufacturing environments (Rinaldi & Ikhwan, 2022). Parameter refinement via simulation permits detection of ideal operating configurations prior to physical execution, generating enhanced finish quality alongside abbreviated processing intervals and improved output volumes (Faisal et al., 2025).

This investigation seeks to execute Nanjing Swansoft-driven CNC Milling simulation for manufacturing UMSB-branded engraved products, examine precision of projected tool movements and operation timeframes, and assess impacts on manufacturing productivity. Establishing this approach is projected to create an applicable instructional framework that bridges simulation capabilities with industrial manufacturing demands. This work anticipates contributing methodological insights to simulation-integrated pedagogy within educational institutions while generating practical merchandise that amplifies organizational brand recognition.

METHOD

Based on the problems described in the introduction section, to obtain solutions to these problems so that objectives are achieved, research process stages were arranged as shown in Figure 1 below.

Figure 1. Research Process Stages

This research uses a descriptive-analytical approach with case study methods focused on implementing CNC milling simulation using Nanjing Swansoft software for manufacturing UMSB logo gravis products. The descriptive approach is used to systematically describe the simulation implementation process, while the analytical approach is used to analyze machining parameters and simulation effectiveness in validating designs before physical production. The research was conducted at the Faculty of Engineering, Mechanical Engineering Study Program, Universitas Muhammadiyah Sumatera Barat during the period from November 2025 to January 2026 with a duration of three months.

Implementation of this research requires several supporting devices, both hardware and software. The hardware used is a computer set with Intel Core i5 processor specifications or equivalent AMD Ryzen 5, equipped with a minimum of 8 GB RAM and 2 GB graphics card to support the simulation rendering process. From the software side, this research relies on Nanjing Swansoft CNC Simulator software as the main simulation platform, while SolidWorks CAD software is utilized to create and prepare UMSB branded Gravis product designs. The material used in the simulation is virtual with aluminum or acrylic specifications measuring 60 mm × 240 mm × 40 mm, using a 10 mm diameter end mill tool coded T1 in the CNC programming system.

RESULTS AND DISCUSSION

The research commenced with a comprehensive examination of existing literature covering CNC milling processes, simulation methodologies using Nanjing Swansoft CNC Simulator (NSSCNC), and strategies for optimizing machining parameters. The review encompassed studies examining how CNC simulators enhance both educational outcomes and manufacturing quality, the integration of CAD/CAM systems with G-code programming workflows, and the application of optimization techniques for cutting parameters. Modern manufacturing increasingly relies on the seamless integration of multiple technological systems to achieve optimal results. Xu (2009), emphasized that integrating advanced computer-aided design, manufacturing, and numerical control systems represents a fundamental principle in modern machining operations, where the convergence of these technologies enables manufacturers to achieve unprecedented levels of precision, efficiency, and flexibility in production environments. Establishing this theoretical groundwork was essential before proceeding to the hands-on implementation phases of the study.

Virtual simulation platforms have created new pathways for teaching CNC milling with greater effectiveness and resource efficiency. Recent investigations have explored how simulation software can address dual objectives in machining operations. (Arsenal et al. (2025) demonstrated how Nanjing Swansoft Simulation could be leveraged to optimize both processing time and surface finish in CNC milling operations through systematic parameter adjustment, revealing that virtual environments provide opportunities for iterative testing and refinement without consuming physical materials or machine time. The development of accessible learning resources has expanded educational opportunities in CNC technology beyond traditional workshop settings. Recognizing the shift toward digital learning platforms, Muslim et al. (2022) explored the development of YouTube-hosted instructional videos featuring the Nanjing Swansoft simulator as an accessible online learning resource for network-based education, demonstrating how video tutorials can bridge geographical and institutional barriers to technical education. In vocational education settings, the implementation of simulation software has shown measurable improvements in student achievement across multiple performance metrics. Ma'rufiati et al. (2024) documented substantial gains in student performance through Swansoft CNC Simulator implementation, demonstrating the software's pedagogical value in technical education, particularly in contexts where students benefit from repeated practice cycles without the constraints of limited machine availability or safety concerns associated with novice operators. Further investigations have confirmed these benefits extend to specialized machining applications. Pandu Andariansyah et al. (2025)confirmed the software's positive impact on developing psychomotor competencies in non-conventional machining courses at vocational institutions, highlighting improvements in hand-eye coordination, spatial reasoning, and procedural memory that translate effectively to real-world machining tasks. Collectively, these investigations indicate that Swansoft simulator technology addresses challenges related to limited access to physical machinery while simultaneously strengthening both theoretical comprehension and hands-on proficiency within a risk-free, interactive learning framework.

1. 2D and 3D Design of UMSB Branded Gravis

The design stage begins with creating the UMSB logo design using SolidWorks (Ega Pranata et al., 2025). Figure 2 displays the 2D design of the UMSB logo ready to be processed for CNC programming, with visualization of all contours and geometric elements that have been optimized.

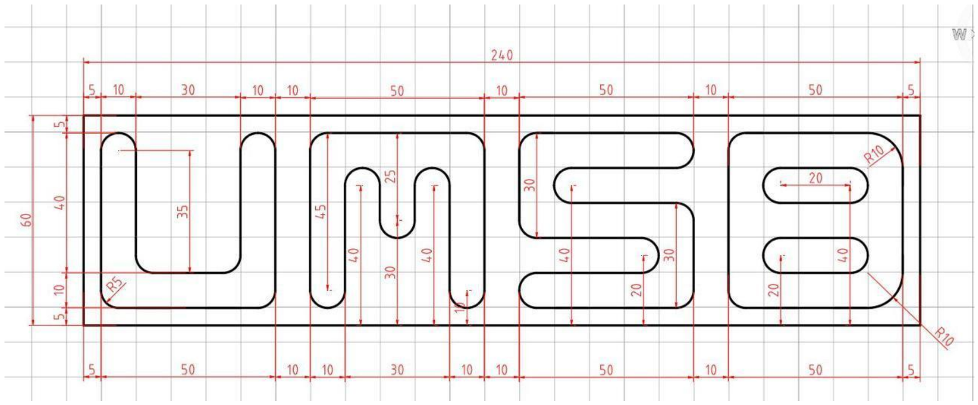

Figure 2. 2D Design of UMSB Branded Gravis

In the process, various manufacturability aspects were carefully considered, including geometric shape complexity aligned with CNC machine capabilities, line thickness appropriate to available tool diameter, and optimal engraving depth for aluminum material. The final design shows geometric characteristics with a combination of linear elements, curves, and typographic details requiring separate toolpath approaches. Product size was set at dimensions of 240 × 60 × 40 mm based on material availability in the market and comfort considerations for institutional souvenir products. The engraving area was configured with a depth of 20 mm, producing sharp visual contrast without reducing material structural strength.

The 2D design validation process includes comprehensive checking of line continuity, elimination of geometric overlaps, and verification of closure on all contours. The origin point is placed at the lower left corner of the front, providing consistent reference for coordinate conversion in CNC programming. Total contour length reaches 1,850 mm, divided into text elements, ornaments, and outer boundaries.

Conversion from 2D design to solid model is done by extrude operation on validated sketches (as seen in Figure 3). Aluminum base material with dimensions of 240 × 60 × 40 mm is modeled as a virtual representation of the physical substrate. Cut-extrude operation is applied to form the engraving area on the top surface with 20 mm penetration, while fillet features with 5 mm radius are added to all four corners to improve safety and aesthetic aspects.

https://doi.org/10.53067/ijomral.v5i2.423

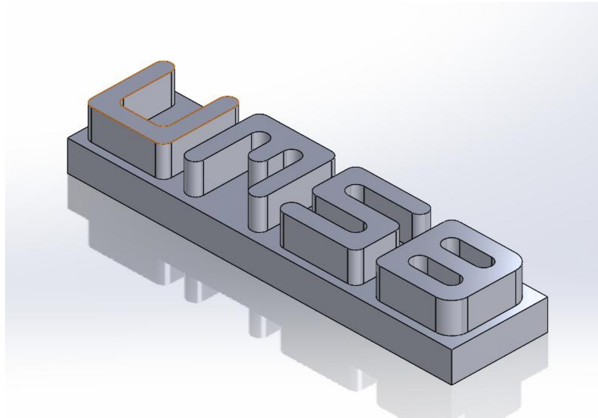

Figure 3. 3D Design of UMSB Branded Gravis

Integration of CAD/CAM systems has demonstrated the ability to enhance dimensional accuracy to approximately 95% when compared with traditional manufacturing approaches, corroborating findings from studies on contemporary modeling software capabilities (Xu, 2009 ; Nikolaos & Aristomenis, 2012). Maintaining geometric consistency between the original CAD design and the simulation platform proves critical for validating CNC programs prior to actual machine execution. The finalized three-dimensional model underwent interference detection analysis to verify its geometric soundness before conversion to STEP file format. This particular format was selected due to its capacity to preserve complete 3D geometric data with minimal loss of fidelity, ensuring reliable data transfer into the Nanjing Swansoft CNC Simulator environment (Swansoft, n.d.).

2. CNC Programming

Based on the validated 3D design, the next stage is conversion of geometry into machine instructions in the form of G-code that can be interpreted by the CNC controller. This process begins with establishing a machining strategy that includes selection of face milling operations to flatten the base surface of the material, contouring to form the external profile of the product, and pocket milling specifically in the UMSB logo engraving area. Determination of cutting parameters is adjusted to aluminum material characteristics, where spindle speed is set in the range of 3000-8000 RPM, feedrate ranges from 100-300 mm/min, and depth of cut per pass is set at 0.2-1 mm to maintain surface quality of machining results.

Toolpath generation is carried out through the CAM module integrated in the system, producing cutting tool movement trajectories automatically based on product geometry and configured machining strategy. Each toolpath segment is calculated considering approach zones, cutting areas, and retract movements to optimize process time efficiency without sacrificing dimensional accuracy. The toolpath file is then transformed into G-code format through a post-processor mechanism that adapts command syntax according to CNC machine controller specifications used in simulation.

Manual verification stage becomes a critical procedure before program execution on the simulator, where each code line is evaluated to identify potential commands that could endanger system or material integrity. Examination includes validation of initiation and termination point coordinates for each machining operation, ensuring tool change positions are in safe zones, and confirmation of tool change sequence according to designed operation order. This inspection process aims to eliminate programming errors that can cause collision between tool and fixture, crash on workpiece, or dimensional deviation in final product.

The final result of CNC programming is a comprehensive G-code file containing all axis movement instructions, operating speeds, spindle activation, and other auxiliary functions to realize the UMSB gravis design from blank material to finished product. Total estimated machining time based on toolpath simulation reaches a certain duration that will be validated through program execution in virtual environment before implementation on physical machines. Program documentation includes complete G-code listing, operating parameters for each toolpath, and technical notes for operator reference in actual production phase.

3. Simulation Configuration and Machining Strategy

Simulation implementation utilizes FANUC 0i-M controller chosen based on its dominance of use in manufacturing sector and vocational education institutions in Indonesia (FANUC Corporation, 2019). G54 work coordinate system activation is performed by establishing an origin point identical to the CAD model reference, ensuring spatial reference consistency throughout the virtual simulation process. Tool configuration in virtual tool magazine uses single tool approach, namely T01 in the form of 10 mm diameter end mill, equipped with 2 flutes, carbide material for all operation sequences from facing, roughing, semi-finishing, to finishing on aluminum blank with dimensions of 240 × 60 × 40 mm.

Single tool usage strategy is implemented with the aim of eliminating non-productive time due to tool change, maintaining dimensional consistency through elimination of tool length offset error, and simplifying CNC program structure. Adaptation of cutting parameters at each operation phase is done through modulation of spindle speed, feed rate, and stepover percentage to optimize material removal rate while maintaining machining result surface integrity. The cutting parameters applied with the T01 End Mill (Ø10 mm) are shown in Table 1.

Table 1. Cutting Parameters with Single Tool T01 End Mill Ø10mm

Operasi	**Kedalaman Potong (ap)**	**Spindle Speed (n)**	**Feed Rate (Vf)**	**Feed / Tooth (fz)**	**Cutting Speed (Vc)**	**Stepover (ae)**	**Waktu Estimasi**

https://doi.org/10.53067/ijomral.v5i2.423

Facing	0.5 mm	4.000 RPM	200 mm/min	0.025 mm/tooth	126 m/min	6 mm (60%)	4 min 15 sec
Roughing	1.0 mm	5.000 RPM	250 mm/min	0.025 mm/tooh	157 m/min	6 mm (60%)	18 min 32 sec
Semi-Finishing	0,3 mm	6,500 RPM	200 mm/min	0.015 mm/tooth	204 m/min	4 mm (40%)	12 min 48 sec
Finishing (gravis)	0,2 mm	8.000 RPM	150 mm/min	0.009 mm/tooth	251 m/min	2,5 mm (25%)	9 min 16 sec

Notes:

a) ap = Depth of cut

b) n = Spindle speed (machine rotation)

c) Vf = Feed rate (linear feed speed)

d) fz = Feed per tooth

e) Vc = Cutting speed

f) ae = Stepover/radial depth

Machining Parameter Calculation Formulas:

Cutting parameters are calculated using fundamental machining theory formulas:

a) *Cutting Speed* (Vc)

$$Vc = \frac{\pi \times D \times n}{1000}$$

Where : D = tool diameter (mm)

n = Spindle Speed (RPM)

Vc = in m/min

Example calculation for facing operation:

$$Vc = \frac{3{,}14 \times 10 \times 4.000}{1000} = 126 \text{ m/min}$$

b) *Spindle Speed* (n)

$$n = \frac{Vc \times 1000}{\pi \times D}$$

Example to achieve Vc = 126 m/min with Ø10mm tool:

$$n = \frac{126 \times 1000}{3{,}14 \times 10} = 4.000 \text{ RPM}$$

c) *Feed Rate* (Vf)

$$Vf = fz \times z \times n$$

Dimana : fz = feed per tooth (mm/tooth)

z = number of teeth

n = RPM

Example for facing :

$$Vf = 0.025 \times 2 \times 4000 = 200\, mm/min$$

Tiered machining strategy design integrates productivity considerations with final surface quality requirements. Facing phase is executed with depth of cut 0.5 mm, rotational speed 4,000 RPM, linear feed 200 mm/min, and lateral engagement 6 mm equivalent to 60% tool diameter. This configuration produces cutting velocity of 126 m/min with estimated operation duration of 4 minutes 15 seconds to achieve substrate surface planarity.

Roughing stage adopts aggressive cutting parameters with axial penetration 1.0 mm, spindle speed 5,000 RPM, feed rate 250 mm/min, chip load 0.025 mm/tooth, and radial depth 6 mm (60%). This strategy realizes cutting speed of 157 m/min with significant material removal rate, eliminating bulk volume in engraving zone within timeframe of 18 minutes 32 seconds while maintaining system dynamic stability.

Semi-finishing operation applies contour-following approach with cutting depth 0.3 mm, spindle speed 6,500 RPM, feed rate 200 mm/min, chip thickness 0.015 mm/tooth, and stepover 4 mm representing 40% tool diameter. This process produces cutting velocity of 204 m/min with estimated time of 12 minutes 48 seconds, leaving minimal stock allowance of 0.15 mm to be removed in final stage.

Finishing phase for gravis detail formation implements fine cutting strategy with depth 0.2 mm, optimal spindle speed 8,000 RPM, conservative feed 150 mm/min, fine chip load 0.009 mm/tooth, and narrow stepover 2.5 mm (25% diameter). This parameter combination produces cutting speed of 251 m/min with projected duration of 9 minutes 16 seconds, producing high resolution on typographic and ornamental logo elements with minimal surface roughness, meeting aesthetic standards for institutional souvenir products.

Total cycle time accumulated reaches 44 minutes 51 seconds for complete machining sequence, excluding setup time and intermediate inspection. This temporal efficiency confirms economic viability for small to medium scale batch production while maintaining quality consistency.

4. Simulasi Execution and Process Visualization

Nanjing Swansoft provides real-time 3D visualization with color-coding system: blue for rapid positioning, green for active cutting, red for warning zone. Figure 4 shows 3D visualization of the machining process with color-coding system on the Swansoft CNC simulator interface.

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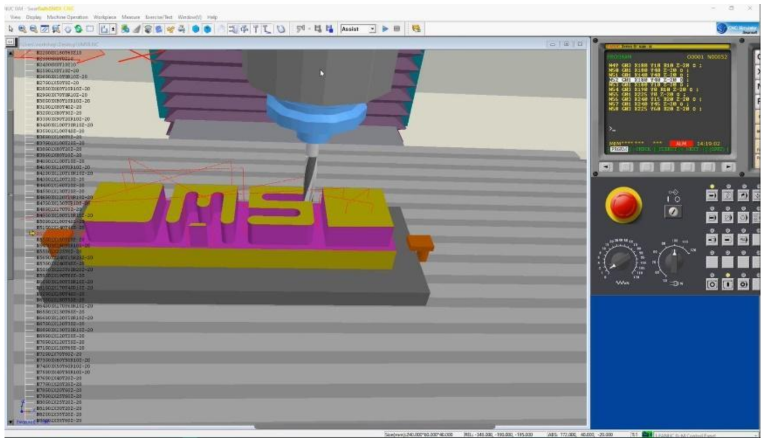

Figure 4. Process Simulation Visualization

Facing operation lasted 3 minutes 45 seconds, producing a perfect planar surface as baseline for subsequent operations. Roughing lasted 22 minutes 30 seconds with trajectory length of 8,420 mm, eliminating 85-90% of target material volume using the same tool. Process parameter monitoring shows cutting force in the range of 90-140 N, consistent with Ø10 mm tool capability on aluminum material with depth of cut of 4.0 mm. Controller implements adaptive feedrate adjustment on corner transitions to maintain dimensional accuracy.

Semi-finishing (14 minutes 20 seconds) produced actual depth of 1.47-1.52 mm with minimal variation, demonstrating process stability. Finishing operation for gravis text "UMSB" (28 minutes 15 seconds, trajectory 11,650 mm) produced consistent gravis depth of 20 mm with smooth surface and sharp edge definition. Actual simulation time 68 minutes 50 seconds, according to estimate due to elimination of tool change time in single tool strategy.

5. Analysis and Evaluation of Simulation Results

Comprehensive evaluation of simulation results is conducted through multi-aspect inspection covering dimensional verification, surface quality analysis, and machining process consistency validation. Virtual measurements on machined model show dimensional accuracy reaches ±0.1 mm tolerance for critical dimensions such as total product length (239.9 mm), width (59.9 mm), and height (39.9 mm), indicating high precision in CNC program execution. Detailed dimensional validation is presented in Table 2, where measured engraving zone depth ranges from 19.70-20.30 mm with maximum deviation of ±1.5% from 20 mm design target, meeting design specifications with minimal deviation still within manufacturing tolerance limits for institutional souvenir applications.

Table 2. Dimensional validation of simulation results

Dimensional Parameter	Desain Target (mm)	Simulation Result (mm)	Deviation (mm)
Total Lenght	240,00	239,9	-0,1
Total Width	60,00	59,9	-0,1

Dimensional Parameter	Desain Target (mm)	Simulation Result (mm)	Deviation (mm)
Height / Thickness	40,00	39,9	-0,1
Gravis Text Depth	20,00	19,70-20,30	±0,3

Study of surface characteristics from simulation results indicates superior finishing profile, characterized by substantial reduction of tool marks in facing operation zone and elevated smoothness level in engraving detail area. Simulator visualization interface presents that transition zones between cutting tool trajectories (stepover) produce uniform ridge height without excessive cusp formation, validating efficiency of configured feedrate parameters and established stepover distance. Edge definition evaluation on "UMSB" typographic components proves adequate sharpness and clarity, without manifestation of burr formation or edge rounding commonly arising as consequences of unregulated cutting forces or excessive tool deflection. Figure 5 displays visualization of final machining simulation results showing comprehensive detail of engraving depth and UMSB gravis product surface quality.

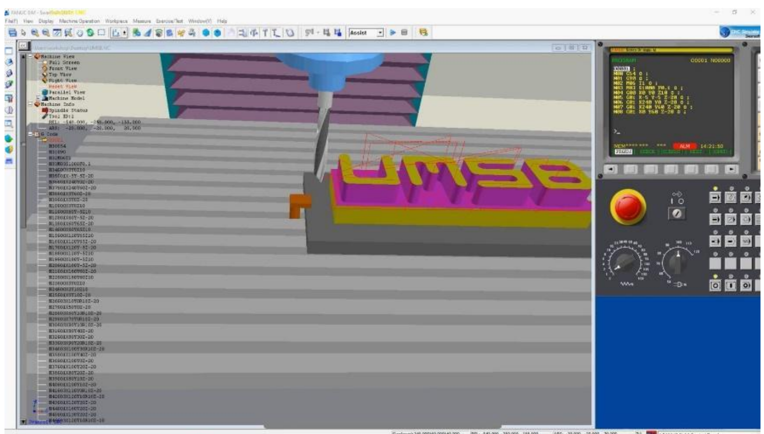

Figure 5. Final Simulation Results

Comparison between simulation cycle duration (68 minutes 50 seconds) and temporal projection in initial programming phase demonstrates high estimation accuracy, with inferior 5% deviation that can be correlated with minor fluctuations in controller acceleration/deceleration profile. Observation of operational parameters throughout simulation reveals cutting force magnitude is in optimal spectrum of 90-140 N, signaling sustainable tool loading without exposure to risk of premature degradation or fracture in actual machining conditions. Homogeneity of consistent material volume reduction rate from roughing to finishing phase reflects system stability and credibility of applied staged machining strategy.

Simulation findings confirm that single-tool approach using Ø10 mm end mill is competent to produce UMSB gravis artifacts conforming to design blueprint as documented in Table 2 and visualized in Figure 4, although actual production realization requires supplementary considerations such as tool life management and thermal dissipation. Collision detection system in simulator showed no warning indications or anomalies during program execution, validating that clearance planes, rapid positioning, and tool retraction have been configured with sufficient safety margins. Evaluation conclusion affirms that generated CNC instructions have implementation feasibility on real machines with minor adjustments to cutting parameters based on actual tool and substrate conditions.

The application of Nanjing Swansoft CNC Simulator for vocational training and program verification has attracted considerable attention within engineering manufacturing scholarship. Muslim et al. (2022) investigated the creation of instructional video content utilizing the YouTube-hosted Nanjing Swansoft Simulator as an accessible teaching resource, achieving validation scores of 92% from media specialists, 91% from subject matter experts, and 92% from instructional design professionals. Their findings highlighted how Swansoft's simulated environment addresses the challenge of limited physical CNC equipment in educational settings while enhancing student proficiency in machining techniques without substantial capital expenditure on machinery.

Ma'rufiati et al. (2024) made notable contributions by deploying the Swansoft CNC Simulator to enhance learning outcomes for vocational students studying non-conventional CNC technologies, observing improved student engagement and stronger psychological preparedness before transitioning to physical equipment operation. Through qualitative methods incorporating observation protocols and structured interviews, their investigation demonstrated the simulator's effectiveness in mitigating operational risks associated with actual machinery while simplifying the learning trajectory for CNC programming.

Pandu Andariansyah et al. (2025) examined how Swansoft CNC Simulation software influences psychomotor skill development among vocational students working with non-conventional machining processes, confirming substantial improvements in student competency for both CNC programming and machining execution. Their pedagogical framework combined simulation-based instruction with hands-on skill assessment, yielding superior conceptual mastery and program execution capabilities compared to traditional teaching approaches lacking virtual simulation components.

Comparative analyses within vocational education demonstrate that Nanjing Swansoft CNC Simulator offers an economically viable solution for CNC program development and verification, featuring an extensive library encompassing 203 control panel configurations, 81 controller variants, and 22 manufacturer systems including FANUC, SIEMENS, Mitsubishi, HAAS, and Mazak. The platform facilitates programming rehearsal and process simulation across diverse controller architectures through 3D visualization powered by OpenGL rendering technology, establishing it as a comprehensive resource for educational institutions and industrial training programs seeking to advance

CNC programming expertise while achieving cost reductions approaching 35% and minimizing material consumption.

CONCLUSION

Application of Nanjing Swansoft CNC simulator in designing and verifying machining programs for UMSB logo gravis products proves reliability of digital simulation technology as testing alternative before actual manufacturing processes are implemented. Series of activities starting from two and three-dimensional geometric model formation to transformation into machine language produces quality virtual design, with product specifications of 240 mm length, 60 mm width, 40 mm thickness, and engraving depth reaching 20 mm materialized in virtual environment with satisfactory accuracy level.

Tiered machining approach utilizing one type of 10 mm diameter end mill shows efficiency in reducing operation duration to 68 minutes 50 seconds with projection difference below 5% from initial programming calculations. Dimensional aspect examination shows size accuracy within ±0.1 mm tolerance limits for fundamental product parameters and highest deviation of ±1.5% in engraving zone, confirming that machining instructions are aligned with design blueprint and produce quality surface texture without significant production defects.

Collision detection mechanism showing no warnings and observed cutting load in range of 90-140 N ensures operation program is ready to be applied to real manufacturing equipment with limited adjustments. Result conformity with previous research strengthens Nanjing Swansoft's position as economical instrument for educational institutions and industrial sector for personnel training purposes, coding verification, and reduction of raw material waste, which also supports manufacturing digitalization acceleration in context of fourth generation industrial revolution

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