

## APPLIED STUDY ON OPTIMIZING MDF DOOR PROCESSING THROUGH CNC TECHNOLOGY

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### RESEARCH ARTICLE

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#### Abstract

*This paper addresses the implementation of CNC (Computer Numerical Control) technologies in the processing of MDF doors, highlighting their impact on efficiency, quality, and the sustainability of industrial manufacturing. The analysis starts from the principles of CNC programming, including the structure of main programs and subprograms, G and M commands, motion functions, tool offsets, and spindle speed control. The research was carried out on the 2130 ATC CNC Router, used for producing decorative and structural door models. The results show that integrating CNC technologies optimizes the production flow by reducing machining time, increasing accuracy, and improving product uniformity while also allowing design customization. The paper contributes to understanding how the automation and digitalization of technological processes can modernize the wood processing industry, providing a practical model for applying theoretical concepts to real furniture production.*

**Keywords:** CNC, Software-ul ArtCAM, CAD/CAM, MDF

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#### INTRODUCTION

In the current industrial context, marked by advances in digitalization, automation, and Smart Manufacturing concepts, computer numerical control (CNC) technologies play a fundamental role in modernizing the processing of wood and wood-based materials.

The implementation of these systems has led to a profound transformation of design and manufacturing stages, offering superior quality control, high product repeatability, and increased efficiency in the use of material and energy resources.

In the last two decades, research in the field of CNC technologies has experienced significant development, focusing on the optimization of machining parameters, the automation of technological workflows, and the full integration of digital solutions into the production of furniture and architectural components.

The study conducted by Zhang et al. (2021), published in the Journal of Manufacturing Processes under the title "Optimization of CNC machining parameters for wood-based materials using hybrid computational models," highlights that adjusting the feed rate and spindle speed has a direct influence on surface quality and tool durability. (Zhang et al., 2021, "Optimization of CNC machining parameters for wood-based materials using hybrid computational models", Journal of Manufacturing Processes)

In a similar direction, Liu and Chen (2020), in their article "Digital integration of CAD/CAM systems in furniture production," published in Wood Material Science and Engineering, emphasize the importance of ArtCAM and Fusion 360 software in digital design and the creation of complex decorative models from MDF and particleboard. (Liu și Chen, 2020, "Digital integration of CAD/CAM systems in furniture production", Wood Material Science and Engineering)

Additionally, Mousavi et al. (2022), in the study "Intelligent control systems for multi-axis CNC machining," published in Procedia CIRP, demonstrate the efficiency of adaptive control systems in optimizing working times and preventing collisions during machining processes. (Mousavi et al., 2022, "Intelligent control systems for multi-axis CNC machining", Procedia CIRP)

In addition, the research by Wang et al. (2019), published in Holz als Roh- und Werkstoff under the title "Implementation of CNC automation in wood furniture manufacturing," analyzes the advantages of automation in furniture factories, concluding that the integration of CNC systems with industrial dust extractors, automatic tool changers (ATC), and digital control leads to an increase of over 30% in production efficiency. (Wang et al., 2019, "Implementation of CNC automation in wood furniture manufacturing", Holz als Roh- und Werkstoff)

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## MATERIAL AND METHODS

The analyzed example presents all essential stages of the CNC machining process in a structured and logical way, from creating the control program to producing the finished part, offering an overview of how the system operates.

The technological process begins with developing the CNC program based on the standardized G and M codes, which define the sequence of operations carried out by the machine tool.

This program can be generated offline, either through manual coding or with specialized CAD/CAM applications that support assisted design and automatic generation of machining toolpaths.

Afterward, the program is transferred to the memory of the machine's control unit. At this stage, the operator can adjust the technological parameters and run virtual simulations of the process using the equipment's graphical interface. The simulation is a key tool for checking the program logic, optimizing motion paths, and preventing collisions or execution errors. After the final validation, the control unit interprets and sends the instructions to the machine's functional assemblies such as the motion axes, the main spindle, the cooling system, and other auxiliary components, coordinating the entire process in a precise and automated way to produce the finished part. The experimental study was carried out at DANIMOB PRODUCT SRL, using the professional 2130 ATC CNC Router, designed for machining wood-based materials and related composites.

### 1. Dimensions and structure

The equipment has a worktable measuring 2100 × 3000 mm (optional: 1500 × 3000 mm or 2100 × 4000 mm), equipped with a vacuum hold-down system that keeps the parts stable during machining. The Z axis has a standard travel of 200 mm, with optional configurations between 300 and 600 mm, depending on the thickness of the material being processed. (CNC Tool - Tool Database & Cutter Specs, <https://www.cnc-tool.com>, accessed on 16.02.2025).

The load-bearing structure is made of high-hardness steel, heat-treated to remove internal stresses. The linear guiding system uses PMI precision rails from Taiwan, protected against dust and wear.

### 2. Automatic tool change system (ATC)

The machine is equipped with an 8-position carousel-type tool magazine (also available in a linear version), which allows fast automatic tool changes and significantly increases operational efficiency. The HSD spindle from Italy, with a power of 9.6 kW, provides variable speeds between 6000 and 24 000 rpm and uses air cooling for stable and durable operation.

The system includes an automatic tool calibration function, which reduces setup time and positioning errors. (CNC Tool - Tool Database & Cutter Specs, <https://www.cnc-tool.com>, accessed on 16.02.2025)

### 3. Motors, transmissions, and control system

Axis movement is driven by Yaskawa servo motors (850 W) and Shimpo reducers from Japan, which provide precise, smooth, and stable motion. Transmission on the X and Y axes uses a helical rack system from Taiwan or Germany, while the Z axis is powered by a TBI ball screw that ensures high accuracy. (CNC Tool - Tool Database & Cutter Specs, <https://www.cnc-tool.com>, accessed on 16.02.2025). The numerical control system is the Syntec 6MB controller (with LNC as an alternative), equipped with an MPG hand wheel and USB/LAN interfaces that support fast communication and data transfer.

### 4. Functions and auxiliary equipment

The equipment includes automatic loading, unloading, and labeling systems that reduce manual work and streamline the production flow. It also features an automatic lubrication system with a 1.5 L reservoir and CE/UL-certified Igus cables that ensure easy maintenance and high electrical protection. The worktable combines T-slot mechanical clamping with a vacuum hold-down system, while dust extraction is provided by a 1.5 kW unit. For operator safety, the machine is equipped with light curtain optical guards. (CNC Tool - Tool Database & Cutter Specs, <https://www.cnc-tool.com>, accessed on 16.02.2025)

### 5. Technical performance and application areas

The machine reaches a maximum travel speed of 80 m/min and an adjustable working speed between 0–25 m/min, with a repeatability accuracy of ±0.03 mm and a positioning resolution of ±0.0025 mm.

Typical applications include nesting for MDF and particleboard parts, furniture manufacturing, door processing, decorative panel production, vertical and horizontal

drilling operations (with the HSD 5+4 drilling head), 3D milling, and precision engraving.

6. Main advantages

The 2130 ATC CNC Router stands out through:  
High productivity due to the automatic tool changer and the automatic part-handling systems

Operational versatility that allows milling, drilling, labeling, and nesting on the same machine

High precision and repeatability, suitable for industrial series production (CNC Tool – Tool Database & Cutter Specs <https://www.cnc-tool.com>, accessed on 16.02.2025).



Figure 1 Vacuum on/off levers (own power supply, DANIMOB PRODUCT SRL)

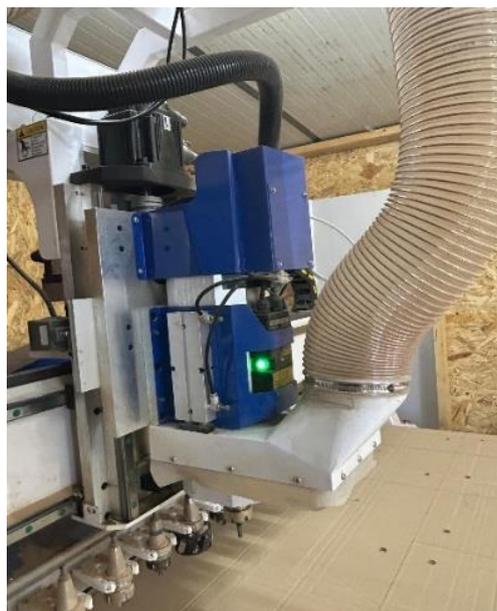


Figure 2 The motor that drives the cutting tool (own power supply, DANIMOB PRODUCT SRL)



Figure 3 Dust extraction system (own power supply, DANIMOB PRODUCT SRL)



Figure 4 Tool holder head (own power supply, DANIMOB PRODUCT SRL)



Figure 5 Directional axis (own power supply, DANIMOB PRODUCT SRL)



Figure 6 Control panel (own power supply, DANIMOB PRODUCT SRL)



Figure 7 Manual control mode (own power supply, DANIMOB PRODUCT SRL)



Figure 8 Workpiece machining (own power supply, DANIMOB PRODUCT SRL)

## RESULTS AND DISCUSSIONS

For the practical application of the results and the validation of the proposed methodology, the experimental model was created in the ArtCAM software. (Manual ArtCAM 2018–2024 – Autodesk technical documentation, original PDF, online).

To begin the CAD/CAM model, the ArtCAM software is opened and a new project is created for designing a decorative MDF door. The initial workspace parameters are set to 400 × 400 mm, since the goal is to produce a small-scale prototype suitable for testing machining parameters and optimizing milling toolpaths.

The material thickness is set to 18 mm, corresponding to the MDF board used, and this value is essential for correctly defining the

engraving and milling depths in the following stages. (Autodesk, ArtCAM Software Overview, <https://www.autodesk.com/products/artcam>, accessed on 15.02.2025)

After configuring the Work Plane, a square geometric contour matching the exact dimensions of the board is drawn using the “Vector Draw – Rectangle” tool. This step defines the actual perimeter of the workpiece and forms the basis for generating the toolpaths. By accurately setting the initial contour, a precise correlation is ensured between the digital model and the physical part, preventing positioning errors during the CNC machining process.

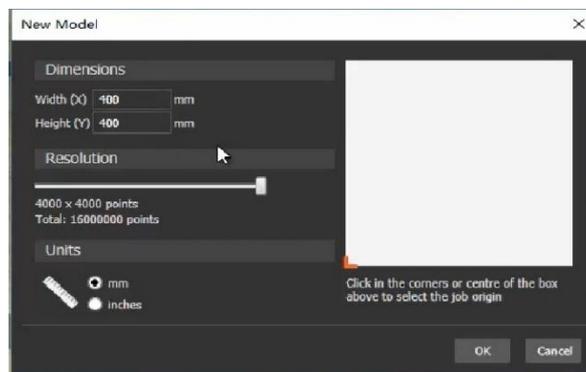


Figure 9 Creating a door (own source)

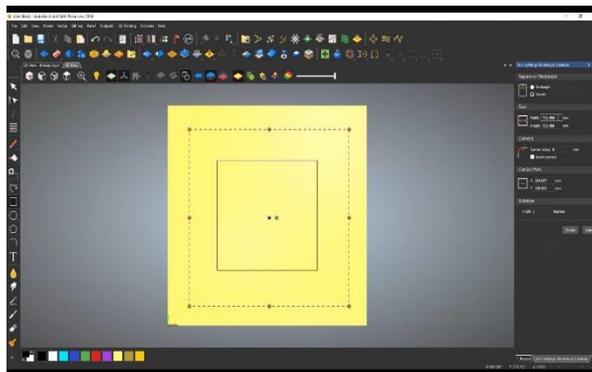


Figure 10 Creating concentric squares (own source)

In the basic geometry stage, two concentric square vector contours are drawn in ArtCAM, defining the outer perimeter of the door and the central area intended for decorative machining. Using the “Rectangle Creation” tool in the design panel, the dimensions of each contour are set precisely, as well as the coordinates of their center in the workspace. The yellow-highlighted background

represents the active surface of the workpiece, and the generated vectors form the geometric basis required for the subsequent toolpath programming steps used in the milling operations. Next, the model will be completed by drawing the inner grooves and the ornamental elements that will give the part the desired aesthetic character.

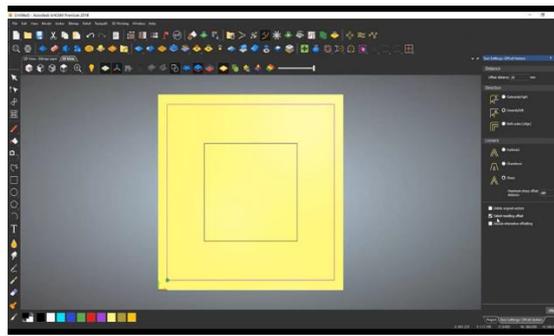


Figure 11 Offset Vectors function (own source)

In the next stage of geometric modeling, the Offset Vectors function in ArtCAM is applied to generate a secondary contour, parallel to the outer one, positioned toward the inside of the workspace. The offset distance is set to 10 mm, and the direction is set to inwards so that the new vector is created toward the center of the part. This operation defines the area where the

decorative grooves will later be created through CNC milling. In the settings panel, the corners are kept in the Sharp configuration, and the original contour is retained to ensure flexibility in the further development of the design elements. Through this delimitation, the surface that will be subjected to the actual machining process is clearly defined.

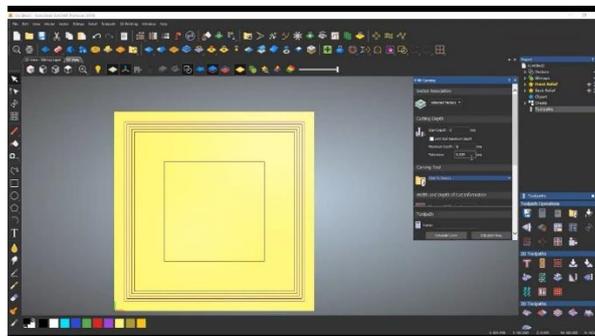


Figure 12 V-Bit Carving function (own source)

In this stage, the milling toolpath is configured using the V-Bit Carving function, suitable for creating decorative patterns with angled edges and precise profiles. After generating the parallel contours with the Offset function, the vectors to be machined are selected, and in the settings panel on the right side of the interface the maximum cutting (Maximum Depth), together with a tolerance of

0.025 mm to ensure high accuracy. Next, the V-bit tool is selected from the tool library, and the generated toolpath is given a specific name for later management. This step is essential both for correctly defining the profile of the decorative grooves and for checking, simulating, and exporting the toolpath as a G-code file required for execution on the CNC equipment.

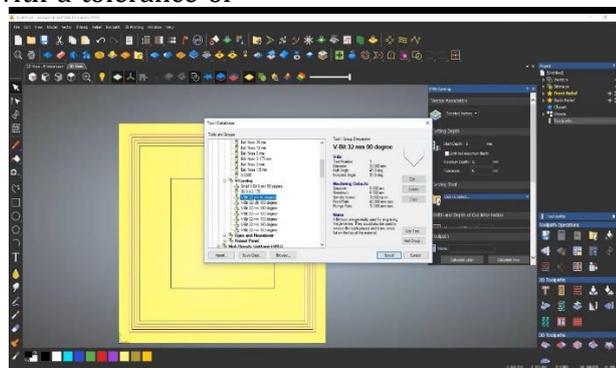


Figure 13 Tool type (own source)

In this stage, the optimal tool for machining the decorative profile is selected. From the tool database, the V-bit cutter with a diameter of 32 mm and a 90° angle is selected, since it is suitable for creating wide grooves with uniform edges and well-defined boundaries. In the configuration panel, the technological parameters specific to the tool are displayed, including the effective diameter, active length, spindle speed, and feed rate.

These must be set correctly to ensure dimensional accuracy and the quality of the machined surface.

After confirming the selection using the “Select” command, the cutter is assigned to the toolpath, allowing the subsequent generation of the actual milling trajectory corresponding to this tool.

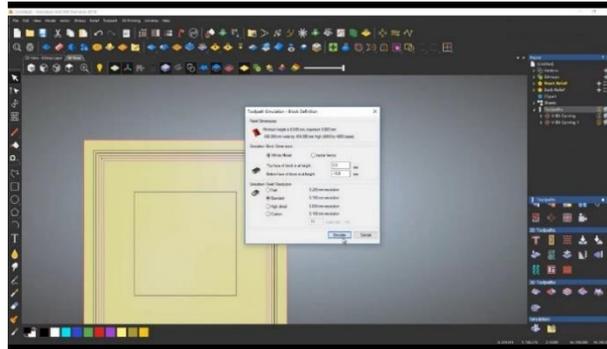


Figure 14 Simulation of the milling process (own source)

After configuring the toolpath with the V-bit cutter, the simulation stage of the machining process is started. In the Toolpath Simulation – Block Definition window, the dimensions of the simulation block are set, with a thickness of 18 mm (range 0 to -18 mm), corresponding to the actual material used. To obtain a complete representation of the operation, the Whole Model option is selected, and the simulation resolution is set to 0.1 mm, a value that provides an optimal balance between visual accuracy and processing time. By activating the Simulate command, a preview is generated showing how the milling operations will be executed on the workpiece.

This stage plays an essential role in the visual validation of the toolpaths and technological parameters before exporting the G-code file for the CNC machine. Following the CNC machining of the MDF boards, the resulting doors show dimensional precision, aesthetic accuracy, and consistent quality, due to the technology’s ability to produce fine details and uniform contours regardless of the design’s level of complexity.

The finished products are defined by the following characteristics:

- Customizable design – The geometry of the doors can be configured in a wide range of shapes and styles, from minimalist models with modern lines to classic frames, decorative profiles, and complex ornaments, accurately machined through integrated CAD/CAM systems.

- Precision and uniformity of machining – CNC machines provide clean cuts, well-defined edges, and perfect symmetry, ensuring process repeatability and a high level of dimensional accuracy.

- Prepared for accessory integration – The recesses for hinges, handles, hardware, or glass panels are produced automatically with millimetric positioning, removing the need for additional manual operations.

- Optimal compatibility with finishes – The uniform MDF surface, combined with the precision of CNC machining, allows easy and even application of paint, lacquer, PVC foil, or veneer, contributing to a high-quality finish.

Consistent appearance and quality – Whether producing a single piece or a series, CNC technology ensures aesthetic and dimensional uniformity, guaranteeing the same quality for every manufactured element.



**Figure 15** MDF door after painting (own source)



**Figure 16** Doors mounted on cabinets (own source)

## CONCLUSIONS

The use of computer numerical control (CNC) machines in wood processing represents a key step in modernizing and increasing the efficiency of the industry. These machines provide high precision, repeatability in execution, and flexibility in producing complex shapes, optimizing material use and significantly reducing human errors. In particular, in the machining of MDF doors, CNC technologies enable the creation of detailed decorative patterns, three-dimensional milling, and precisely controlled joints, contributing to

both the aesthetic quality and the functionality of the finished product. At the same time, the integration of these technologies allows fast adaptation to market demands for customization, small-series production, or rapid prototyping. Therefore, CNC machines not only increase the economic competitiveness of companies in the wood and wood-based products industry, but also support a sustainable and innovative production process aligned with current quality standards.

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