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A Comparative Analysis of Aluminium and Mild Steel on CNC Milling Using CAD/CAM Programming

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Abstract

Material selection is determined by the purpose of the product. Material selection is critical when considering the quality of the final products and waste produced during CNC milling machining. Based on previous study, multiple ductile and brittle material were being tested to undergo high speed machining to identify which material category has better surface roughness. The goal of this project is to evaluate machining time and surface roughness for aluminum and mild steel with varying spindle speeds. This study focuses on the comparison of aluminum and mild steel for CNC milling operations utilizing CAD/CAM programming. Mastercam software is used to design the 2D and 3D of the sample block, and simulation is used to get a preview of how the toolpath of the machining will look and to gain the expected time for the machining time of each parameter, which are 1000rpm, 1200rpm, 1400rpm, 1600rpm, and 1800rpm with a constant feed rate of 500mm/rev and a constant depth of cut of 0.5mm. As a result, when both aluminium and mild steel are machined using Computer Numerical Control (CNC), it is proven that aluminium have better surface roughness and time saving then mild steel.

1. Introduction

Machining is a manufacturing procedure that involves removing material from a larger item to obtain the desired form. It is utilized in the production of finished goods as well as the processing of raw materials. Subtractive manufacturing methods are another name for machining operations.[1] By cutting out undesired material from an initial piece of material, machining is a prototype and manufacturing process that produces the desired final appearance. Contrary to additive manufacturing, which uses a carefully regulated addition of material, these procedures use the removal of material to produce a product.[2] The term CNC stands for "computer numerical control," and according to the definition of CNC machining, it is a subtractive manufacturing process that typically uses computerized controls and machine tools to remove layers of material from a stock piece known as the "blank" or "workpiece" to create a custom-designed part.[3] A program called Mastercam is committed to offering cutting-edge solutions for CAD/CAM manufacturing applications. Mastercam supports the design of computer-generated parts on a desktop computer screen and directs the production of parts for machinists.[4] A list of coordinates that the machine must follow to extract the required shape from the stock material is contained in the output file, which frequently ends in.nc. G-code is the most widely used language for this instruction set.[5] The purpose of this project is to evaluate the machining time and analyze the surface roughness for aluminum and mild steel. This project focuses on the analysis of

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comparison of aluminum and mild steel only to undergoes the CNC milling operation by using the CAD/CAM programming. At the end of the project, suitable material for certain parameters on CNC milling operation can be identified. The analysis of data on surface roughness machining time for each material can be differentiate. The majority of articles that address this topic concentrate on optimizing cutting conditions using the cutting forces as a basis for computation. Author [6] emphasizes the need of managing cutting conditions in point-milling techniques to cut down on machining time. When complex shape parts are point milled using circular cutting tool techniques, the actual point of contact between the tool and the workpiece is constantly changing. Author [7] focuses on the optimization of tool axis orientations in multi-axis toolpaths to increase surface quality and productivity. The actual cutting diameter and the cutting speed during the toolpath are calculated as the basis for the method. The interpolator then uses a machine tool kinematic model to process the NC code. The work of author [8] proposes a unique and complete approach to the planning of minimal cycle time tool trajectories that takes into account the feed drive control system's limits as well as constraints linked to the machining process. According to article [9] examined how vibration, contingent on sound amplitude, affects CNC face milling in an experimental setting on aluminium material. Author [10] focuses on finding the ideal milling process parameters to reduce the ankle-foot's machining time as a component of transtibial prostheses. Nevertheless, no research has been identified comparing the surface roughness and duration of machining of mild steel and aluminum in order to establish a method for achieving the appropriate cutting speed and, ultimately, optimizing feedrate. That is the main topic of this study.

2. Materials and Methods

In this section, all materials and methods used will be described and cover the guiding principles, practices, and regulations used to the acquisition of knowledge in that area.

2.1 Flowchart

The project flow chart shows the steps of the method used to conduct the project. Fig. 1 shows the flowchart of the project from the beginning till end.

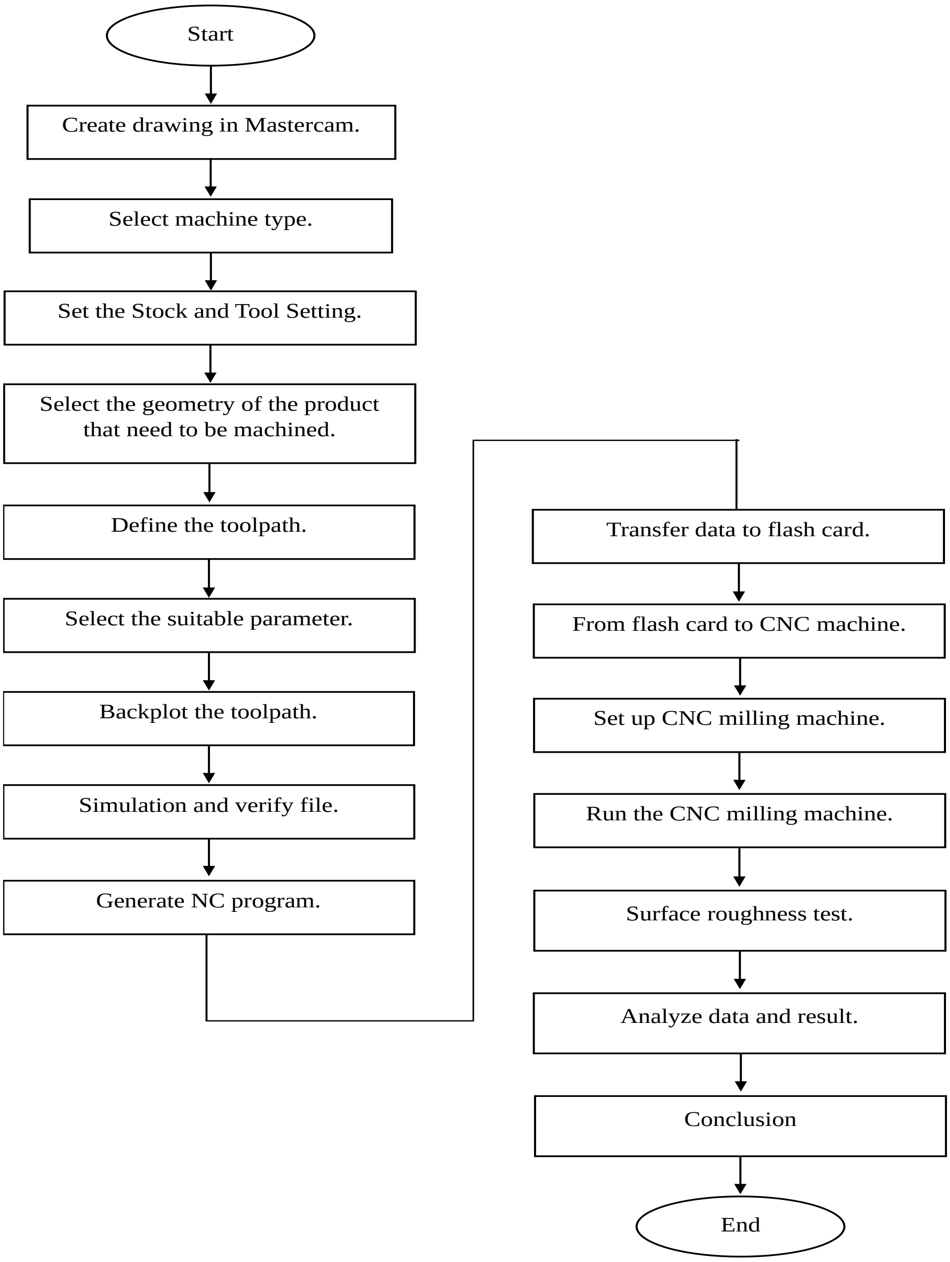


Fig. 1 *Project Flowchart*

2.1.1 Flowchart Explanation

Mastercam and CNC milling machine will be used to complete this project. Mastercam is used to create the drawing and to generate simulation of the machining operation. After creating the drawing, selecting the type of machine used, set up the stock and tool setting is very important to generate the NC program. The G-Code language used to operate the CNC machine is generated automatically by a CAM system.[11] Then from the NC program, the CNC milling machine will run according to NC program generated. After that, the machined materials will be tested using the surface roughness equipment to gain the analysis data of each material which are aluminium, mild steel, and alloy steel. Surface roughness is a measure of a surface's texture using numbers rather than tactile or visual perception.[12]

2.2 Materials

Material that has been chosen for this research are aluminium 1061 and mild steel SAE1018. Each material has a unique set of physical and chemical characteristics that make them ideal for a particular purpose.

2.2.1 Aluminium

Aluminium is one of the most adaptable, affordable, and visually appealing metallic materials for a variety of tasks, from soft, highly ductile wrapping foil to the most demanding engineering applications. In the Earth's crust, aluminium is the most prevalent metal and the third most abundant element (after silicon and oxygen). By weight, it makes up around 8% of the solid surface of the Earth. Because of how chemically reactive aluminium metal is, natural examples are uncommon and only found in extremely reducing settings. Instead, it can be found in over 270 distinct minerals in combination. Bauxite is the primary resource of aluminium.[13]

2.2.2 Mild steel

The form of low carbon steel is mild steel. Metals called carbon steels have a very little amount of carbon (maximum 2.1%), which improves the qualities of pure iron. Depending on the requirements for steel, the carbon content varies. Carbon content in low carbon steels ranges from 0.05 to 0.25 percent. This steel is a very machinable metal due to its low carbon content. Without subjecting the workpiece to disproportionate stresses, it can be cut, machined, and molded into complicated designs. Additionally, it promotes improved weldability.[14]

3. Result and Discussion

The expected outcome of this research will be covered in this chapter including the simulation of Mastercam and time comparison between aluminium and mild steel will be evaluated to gain the optimal time of machining. As for the comparison analysis between aluminium and mild steel, change in parameter need to be analyses and the least surface roughness reading on the surface of the sample will be selected.

3.1 Simulation on Mastercam

Fig. 2 shows the drawing in 2D and 3D of the workpiece. The dimensions of the workpiece were set using drawing tools of rectangle with dimensions 50mm x 50mm to create 2D geometry representing the outline of the workpiece. Utilize the 3D modelling tools to extrude or revolve a 2D profile into a 3D shape starting with a base shape representing the 50mm x 50mm footprint with thickness 40mm for the workpiece. Afterward, the material, toolpath and the parameters for the experiment were set up refer to the appendix for the expected machining time for each face milling experiments. In this study, there will be 5 parameters setup with different spindle speed with constant feed rate and depth of cut. All the parameters can be adjusted before generating the NC code of the program following the data will be transferred to the Computer Numerical Control (CNC) Milling machine.

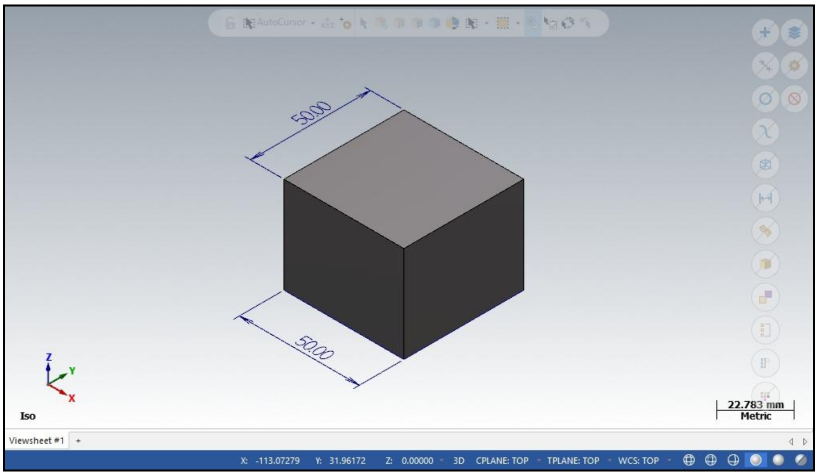


Fig. 2 *Drawing in 2D and 3D of workpiece*

3.2 Time Comparison Between Aluminium and Mild Steel

In this project, the estimated time for machining is determined using Mastercam simulation for both materials. Table 1 shows the expected time and actual machining time for aluminum, whereas Table 2 shows the expected time and machining time for mild steel. Although the projected time for both materials is the same, the machining time differs.

Table 1 *Expected time and machining time for aluminium*

Expected Time	Actual Machining Time	Spindle Speed, rpm	Feed Rate, mm/rev
1min 19.09s	1min 33s	1000	500
1min 19.09s	1min 23s	1200	500
1min 19.09s	1min 38s	1400	500
1min 19.09s	1min 27s	1600	500
1min 19.09s	1min 20s	1800	500

Table 2 *Expected time and machining time for mild steel*

Expected Time	Actual Machining Time	Spindle Speed, rpm	Feed Rate, mm/rev
1min 19.09s	1min 58s	1000	500
1min 19.09s	2min 05s	1200	500
1min 19.09s	2min 08s	1400	500
1min 19.09s	2min 25s	1600	500
1min 19.09s	2min 33s	1800	500

Fig. 3 depicts the bar chart of time versus spindle speed for aluminum and mild steel whereas The discrepancy between the estimated time and the machining time for aluminum is around 30 seconds. In the case of mild steel, the discrepancy between predicted and machining time is about 1 minute.

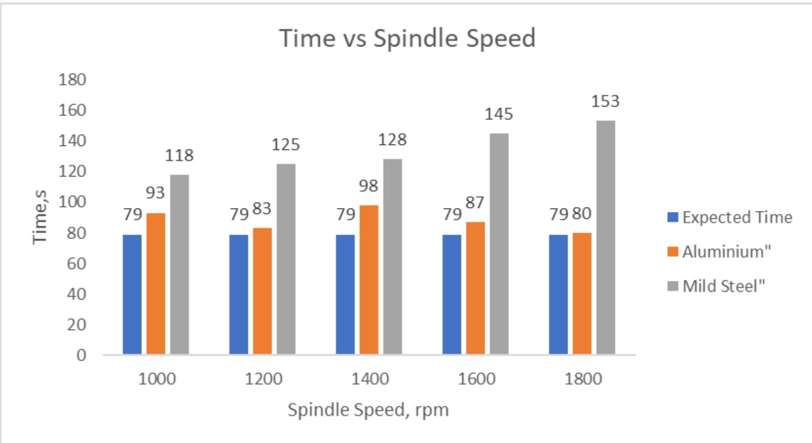
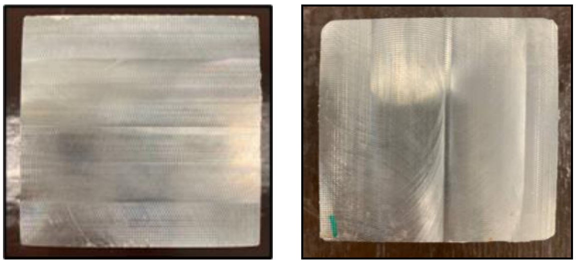


Fig. 3 *Bar chart time against spindle speed for aluminium and mild steel*

3.3 Surface Roughness Analysis of Aluminium and Mild Steel

For this project, the data is collected using five different sets of parameters for each material which are aluminium and mild steel. The spindle speed was set with increment of 200rpm starting from 1000rpm, 1200 rpm, 1400rpm, 1600rpm and 1800rpm with a fixed feed rate of 500mm/rev and depth of cut of 0.5mm for both materials. Fig. 4 (a) and (b) shows the surface comparison between aluminium and mild steel. It shows that aluminium block has better surface roughness then mild steel.



(a) (b)

Fig. 4*Surface comparison*

Fig. 5 plots surface roughness (Ra) versus spindle speed (revs per minute). The graph compares the surface roughness of aluminum and mild steel blocks at various spindle speeds with a constant feed rate. As the spindle speed increases, the surface roughness of the aluminum block diminishes. The surface roughness of mild steel, on the other hand, diminishes as the spindle speed increases to 1000rpm, 1200rpm, and 1400rpm then it increases significantly when the spindle speed is between 1600rpm and 1800rpm.

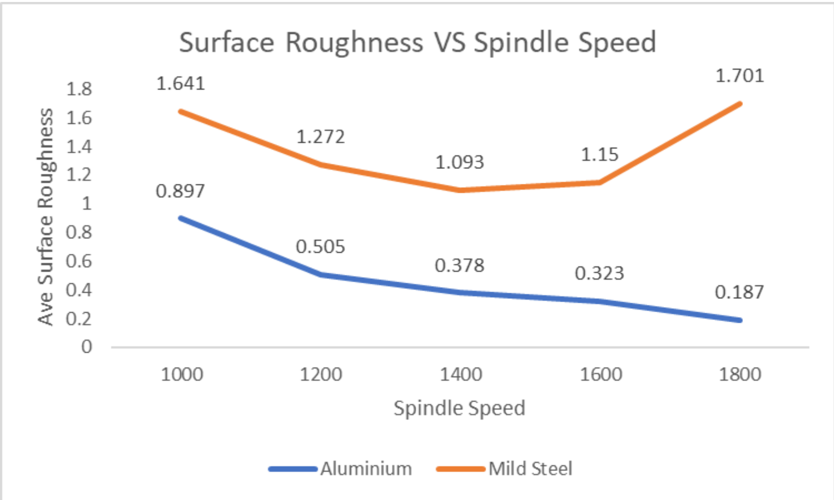


Fig. 5 *Surface roughness (Ra) against spindle speed (rev per minute)*

4. Conclusion

In summary, the research objectives of evaluating the machining time for aluminum and mild steel in Computer Numerical Control (CNC) operation, as well as comparing the surface roughness for both materials when altering the spindle speed with constant feed rate and depth of cut, were met effectively. The Mastercam software was used to create the dimensions of the block, and the simulation of the machining process was done using the face mill cutting tool. Furthermore, based on the observation of the graph result of the two metals during the face milling process, the machining time between aluminium and mild steel demonstrates that mild steel requires more time than aluminium. Aside from that, the surface roughness for aluminum results reveals that the greater the spindle speed, the smoother the surface roughness of the aluminum block. This demonstrates that a faster spindle speed results in a thinner chip during the cutting process. When compared to the surface roughness of mild steel, aluminum is rougher. In other words, when both aluminium and mild steel are machined using the Computer Numerical Control (CNC) operation, aluminium is likely to be more suited since the quality of its surface roughness is better than mild steel and the machining time is also shorter.

4.1 Recommendation

There are some recommendations that should be emphasized to guide future researchers, practitioners, and findings in understanding and implementation of Computer Numerical Control (CNC) operation. The following are the recommendations that need to be pointed out. The first suggestion is to create and implement methods for tool life maintenance. Monitor tool wear and replace tools as needed to avoid unexpected tool breakdowns and excessive downtime. Second suggestion is to reduce vibration during the operation, make sure to locate the correct feed rate depending on the spindle speed that was established as a result for a superior surface roughness in the future. Finally, use another measurement tool, such as measuring microscope, to get a better view of the surface condition during the data gathering phase.

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