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Experimental and Simulation of CNC Milling Process Towards Product Quality of Mild Steel

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Abstract: The surface finish is used to gauge the machining quality. It is essential to adjust the machining parameters properly and optimally during the machining process to improve the surface quality. Since CNC machines are extremely sophisticated machinery based on the previous study there are a few of the problems that occur in CNC machining are frequently caused by programming. The aim of this experiment is, to simulate the changing of the feed rate and spindle that can affect the cycle time. Besides, to analyze the effect of simulation by using Mastercam software and machining the surface by using CNC milling and checking the quality of the surface using a surface roughness machine. The importance of this research is that it can speed up machining by using simulation. Additionally, it can increase productivity with quality when run on a machine. From there, it can be shown that the simulation's expected time is accurate because it is virtually identical to actual time machining. Other than that, feed rate and spindle speed are the variables that were evaluated, which is three different feed rate 200mm/rev, 300mm/rev, and 400mm/rev, and three different spindle speed which is 1300 rpm, 1400 rpm, and 1500 rpm to obtain the best machining time and surface quality on workpieces. As a result, the feed rate has a greater impact on machining time during the operation. Based on the outcomes of the experiment changing the parameter of spindle speed can affect the surface roughness result, the spindle speed is the most significant element impacting the surface roughness.

Keywords: CNC Milling, Simulation, Mastercam, Mild steel, Surface roughness

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1. Introduction

The numerical control (NC) machine was created by combining mechanical and electrical technologies. This CNC machine has a computing system and is automated [1].

A Computer Numerical Control (CNC) machine is a modern metal (material) removal computerized equipment that can manufacture any complex shape. [2] Furthermore, CNC machines can make a more accurate product, have greater quality, and have a reduced rejection rate. Moreover, NC machine tools are classified into two categories: "cutting machines" and "non-cutting machines." Milling machines, turning machines, and EDM machines are examples of cutting machines that execute a removal process to create a completed product. [3] This experimental study was made for experimental and simulation comparison of the CNC milling process toward the product quality of mild steel. This experiment used a CNC machine to produce the final product and a CAD/CAM simulation to compare the results.

On CNC machines, alphanumeric instructions are used along with coordinates. [4] The alphanumeric command is represented by the G and M codes. The definition of surface roughness is the finely spaced micro-irregularities on the surface texture, which is composed of three components: roughness, waviness, and form. [5]

2. Materials and Methods

This experiment's approach specifies the procedures that will be used. There is a few processes and method that achieve the objective of the experiment. Mild steel will be the primary testing material in this investigation. Mild steel is an iron and carbon-based ferrous metal. It's a low-cost material with qualities that make it ideal for a wide range of technical applications. There are six workpieces have been used in this experiment. Three of the six workpieces are used to test parameter feed rate and another three are used to test parameter spindle speed. All workpieces must be checked for surface quality using a surface roughness machine after CNC milling operations have been completed.

2.1 Simulation process

Designing the product is the first step. The type of machine used in this experiment will be a mill. Next, select the tool setup tabs to see a variety of options for the tool setting and the stock, such as feed calculation, toolpath configuration, advance option, and sequence number. Define the tool setting and stock configuration to construct the toolpath in that circumstance.

After choosing the required toolpath, choose the face that will be cut with it as well as the geometry that will be cut during this phase. At this point, the spindle speed and feed rate parameters can be altered. then establish the linking parameter for the product and the depth of cut. Set the cutting toolpath for the part. The tool's intended path for cutting the segment is displayed on the back plot at this step. By back plot the tool path, the Mastercam software can show any workpiece and tool collisions. This test will ensure that the program has the best cut for the simulation process and that any flaws in the code may be identified, as well as the location of the part in the machine. Once the simulation is finished, run the post-processor to create the NC program. A software program known as a post-processor converts a toolpath into an NC program. The CNC machine is prepared to execute the G code.

2.2 Machining process

When transferring data, a flashcard can be used. First, the flashcard must be connected to a computer. Next, insert the flashcard into the CNC milling machine, pick the program, and transfer it. The distance between the part and the machine Set up the datum of a machine, as per Figure 1. When using a CNC machine, it is necessary to know where the part is always located reference (home) location is defined by the datum. The face mill was the only cutting tool used in this experiment, refer to Figure2.

After that, pick a file programmed and start the machine. Next, run a simulation to see how the program flows by setting the Z-axis coordinate to 2. The machine just runs without making any cuts to the workpiece. Run the CNC milling machine once the program's flow has been verified to be accurate. Refer to Figure 3 for the running CNC machine milling.

Figure 1: Set up the workpiece on vice

Figure 2: Face mill

Figure 3: Running the CNC milling machine.

2.3 Surface roughness measurement

The surface roughness is measured with a Mitutoyo SJ-410 surface roughness tester as per Figure 4. The output measurement data will be connected to the printer, and the pickup drive unit will be connected to a monitor. The surface roughness is measured with a Mitutoyo SJ-410 surface roughness tester. The output measurement data will be connected to the printer, and the pickup drive unit will be connected to a monitor. An analysis will be performed utilizing data and graph charting to compare the structure of the surface roughness after machining. Using this method, it is possible to analyze how the parameter value impacts the surface roughness structure. The relation between the parameters has been examined utilizing a graphical way of analysis.

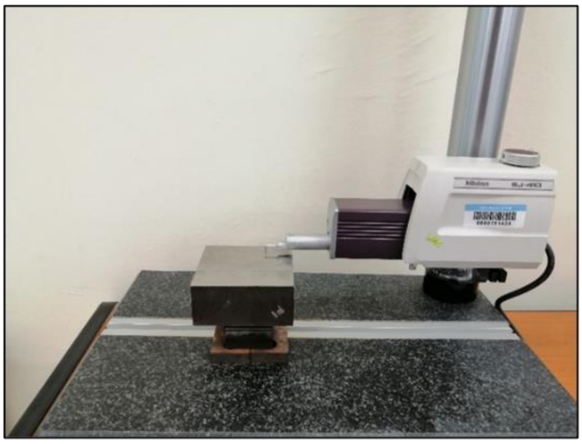


Figure 4: Surface roughness tester

3. Results and Discussion

The purpose of this experiment is to compare simulation and real CNC milling while also analyzing the impact of feed rate and spindle speed on surface quality. Based on the findings and analyses in this experiment, the impacts of feed rate and spindle speed on the surface have been identified. As an expected result of this experiment, it is possible to get a perfect combination parameter between feed rate and spindle speed to get the best machining time and the best quality of the surface.

3.1 Results

Based on the result obtained from Table 1 and Table 2 there is a difference between the expected time and the actual machining time. Based on the common practice of using a CNC milling machine, recommended spindle speed at the range of 1000 rpm to 1500 rpm and feed rate at 200mm/min to 400mm/min.

Table 1: Expectation time and machining time in changing feed rate

Expectation time	Machining time	Feed rate	Spindle Speed
18 min 9s	20 min 37s	200	1000
12 min 8s	13 min 1s	300	1000
9 min 7s	9min 37s	400	1000

Table 2: Expectation time and machining time in changing spindle speed

Expectation time	Machining time	Spindle Speed	Feed rate
18 min 9s	19min 8s	1300	200
18min 9s	18min 55s	1400	200
18min 9s	19 min 10s	1500	200

Figure 5 illustrates a graph that compares the simulation's expected run time with the actual CNC milling run time. From the illustration, machining time decreases as the feed rate increases. The difference between the expected time and machining time may be seen in the graph in Figure 6.

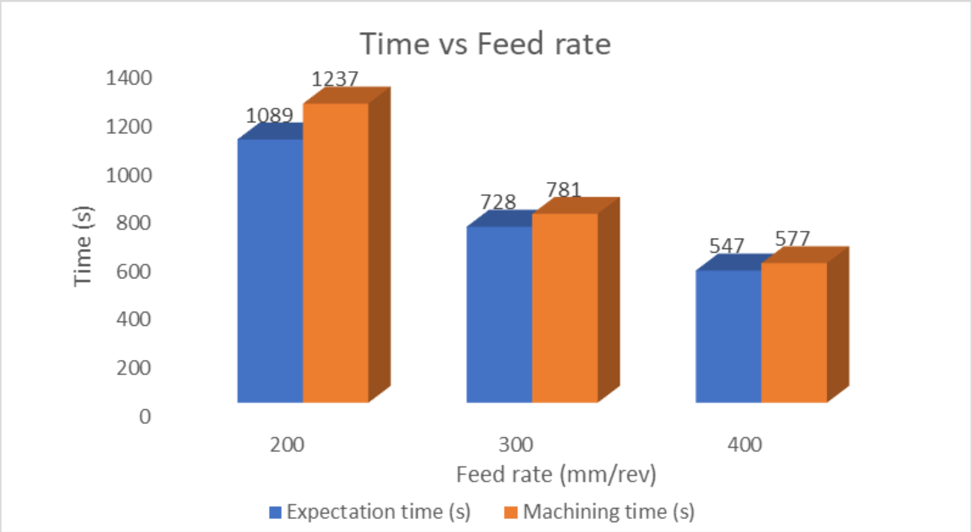


Figure 5: Graph time against feed rate

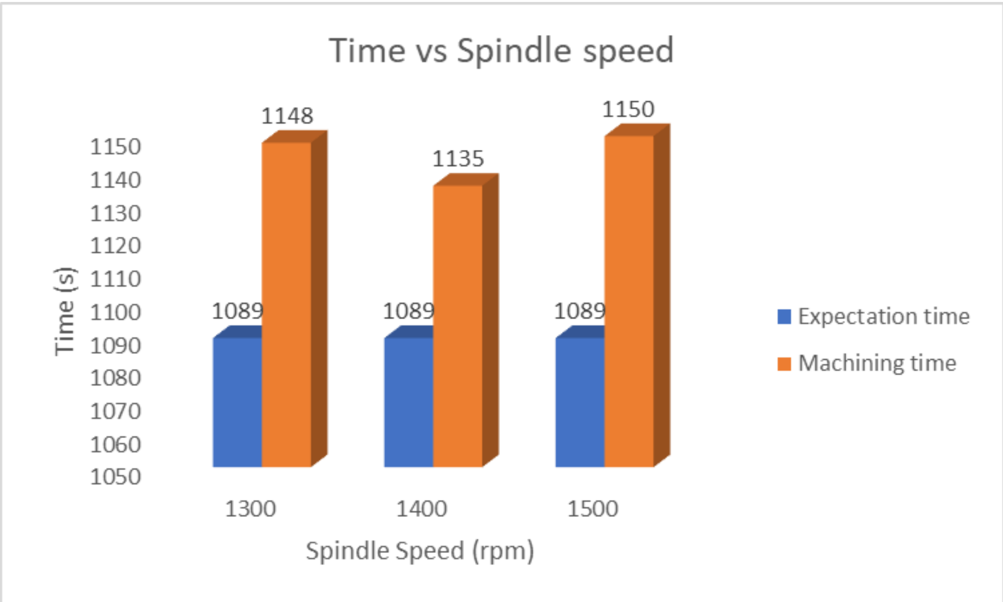
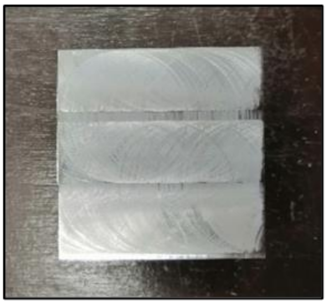


Figure 6: Graph time against spindle speed

For a picture of the actual product, refer the Table 3 for the appearance result. Additionally, refer to Figure 7 the graph shows the relationship between the average surface roughness against the feed rate. It is clear from the graph that as the feed rate increases, so does the reading for surface roughness also increase.

Table 3: Surface roughness by changing feed rate

No.	Ra µm	Feed Rate	Spindle Speed	Appearance surface	Parameter
1	1.248				
2	1.074				
3	1.066				
Ave	1.658	200	1000		1
.	.				
1	1.988				
2	1.468				
3	1.418				
Ave	1.625	300	1000		2
1	1.685				
2	1.636				
3	1.652				
Ave	1.658	300	1000		3

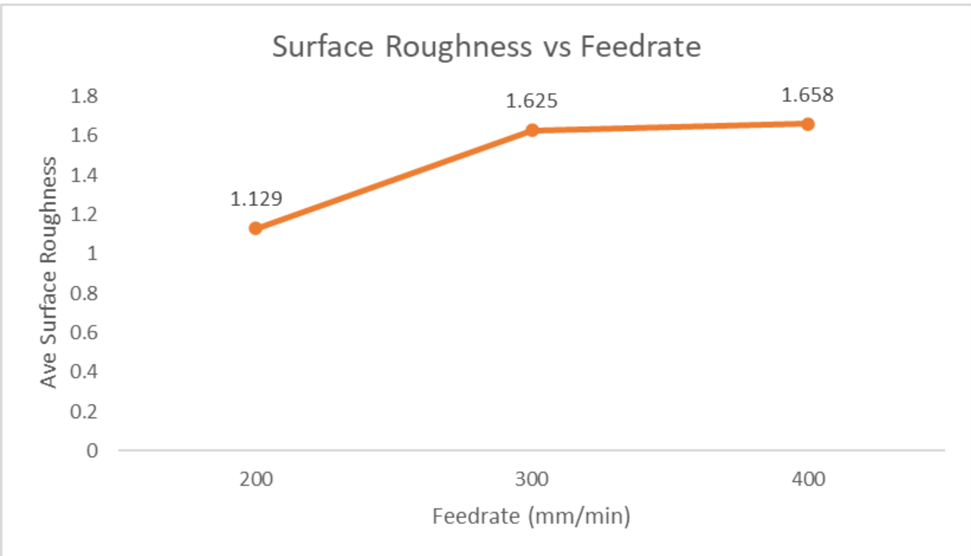


Figure 7: Surface roughness (Ra) against feed rate (mm/min)

According to Table 4, it is strongly advised to utilize a spindle speed between 1300 and 1500 rpm with a constant feed rate of 200 mm/min in order to achieve surface roughness in the range of 0.219 µm, 0.693 µm, and 0.640 µm. Furthermore, based on the graph in Figure 8 shows the relationship between the surface roughness with the spindle speed. Based on the graph in figure 8 shows the relationship between the surface roughness with the spindle speed.

Table 4: Surface roughness by changing Spindle speed

No.	Ra µm	Spindle Speed	Feed Rate	Appearance surface	Parameter
1	0.303				
2	0.183				
3	0.172				
Ave	0.219	1300	200		1
1	0.631				
2	0.944				
3	0.504				
Ave	0.693	1400	200		2
1	0.692				
2	0.552				
3	0.677				
Ave	0.640	1500	200		3

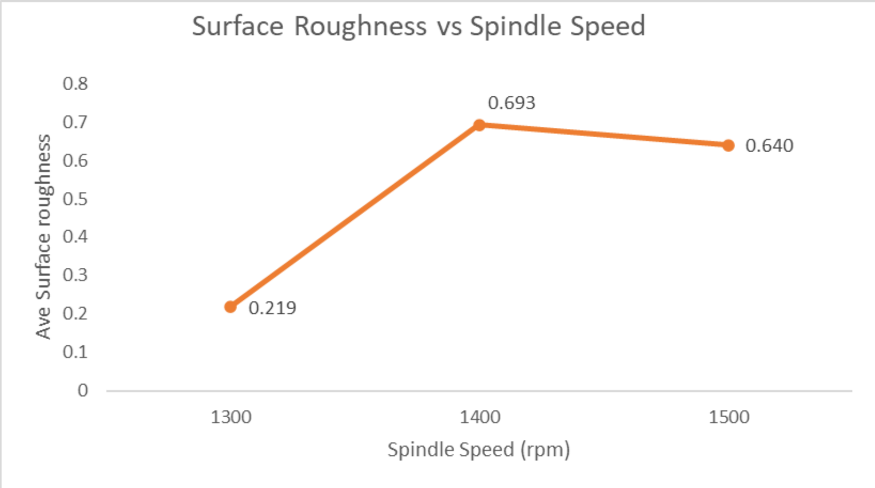


Figure 8: Surface roughness (Ra) against spindle speed (rpm)

3.2 Discussions

According to previous research conducted by Miss. Sumaiyya S.Nadaf and Prof. Mrs. Minakshi Y. Shinde in 2020, the range of spindle speed used in their experiment was 1000 rpm to 1800 rpm and the feed rate was 600 mm/min to 1000mm/min. In this experiment, there are three sets of data have been collected using different parameters which are three different feed rates 200mm/rev, 300mm/rev, and 400mm/rev. Another parameter that has been used is spindle speed which is 1300 rpm, 1400 rpm, and 1500 rpm. Based on the result comparison between simulation and CNC milling in expected time and machining time, there is an insignificant difference between the expected time and the actual machining time, the difference is around 1 min to 2 min for both experiments. From there, it can be shown that the simulation's expected time is accurate because it is virtually identical to actual time machining.

For the surface roughness, as stated in the result the average of Ra in experiment 1 increased from 1.129 µm to 1.658 µm as the feed rate increased from 200mm/min to 400mm/min while the spindle speed is constant at 1000 rpm. For experiment 2, it is strongly advised to utilize a spindle speed between 1300 and 1500 rpm with a constant feed rate of 200 mm/min in order to achieve surface roughness in the range of 0.219 µm, 0.693 µm, and 0.640 µm.

According to surface appearance, the parameter with a spindle speed of 1300 rpm and a feed rate of 200 mm/min is the best one for a smooth surface. Besides, the parameter with a feed rate of 400 mm/min and the spindle speed constant at 1000 rpm the texture of the finished product appears to be rather rough compared to another product that changes the parameter of spindle speed.

4. Conclusion

In conclusion, the experiment's objective of comparing the performance of Mastercam simulation to CNC milling machining by varying the parameters of feed rate and spindle speed to obtain the best machining time and surface quality on workpieces was accomplished. Using Mastercam software, the workpiece was designed in two and three dimensions. The expected time of machining can then be seen by altering the parameter in the simulation. The operation was totally completed using face mill cutting tools, and the workpieces were made of mild steel.

By using variables that have been set up for machining, such as spindle speed and feed rate. Therefore, in comparison to other factors, the feed rate has a greater impact on machining time during the operation. Based on the result changing the value of the feed rate from 200mm/min to 400mm/min can impact the machining time which is cycle time that can be sped up with a higher feed rate. However, if the feed is too quick, the surface quality becomes rougher and there may be irregular or diminished tool life. The outcomes of the experiment by changing the parameters of spindle speed can affect the surface roughness result, the spindle speed is the most significant element impacting the surface roughness. Surface roughness decreases linearly compared to feed rate as spindle speed is raised to

1300 rpm, 1400 rpm, and 1500 rpm. This trend is a result of the cutting forces diminishing with faster cutting speeds.

Based on the observation of overall data from the experiment can conclude that using the software can simulate all machining processes with the expectation of total time machining by changing the parameter. Then, it increasing the feed rate can reduce the machining time, and increasing the spindle speed will get the best surface quality.

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