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Effect of feed rate and depth of cut on face milling process on surface roughness of Al-Mg alloy using CNC milling machine 3 axis

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Abstract. The purpose of this study was to determine the effect of feed rate and depth of cut on the surface roughness of Al-Mg aluminum using a DIY CNC Milling Machine and Krisbow Universal Milling Machine as a comparison. The open-loop control system is a control system used in the design of DIY CNC Milling machines. A PC with Mach3 software is used as a PC Based Direct Digital Controller to control the system. In this study, the feed rate variation 24 mm/minute and 42 mm/minute and depth of cut 0.25 mm, 0.5 mm, and 0.75 mm were used. After the face milling process, the surface roughness test was carried out using the Mitoyo Surface Roughness Tester to determine the level of surface roughness of the machining results the DIY Milling Machine and Krisbow Universal Milling Machine as a comparison. The results showed that as the feed rate and depth of cut increased, the surface roughness values of both tools increased.

Keywords. Al-Mg, DIY CNC Milling Machine, Face Milling, Surface Roughness, Feed Rate

1. Introduction

The potential that exists in Kedawung Village, Nglegok District, Blitar Regency, Indonesia is for fruits (mangosteen and pineapple), tourism (Penataran and Mount Kelud), fisheries, and animal husbandry (raised chickens and ducks). Blitar Regency is one of the centers for broiler and duck farming in East Java. Duck farming is a side job for the community apart from farming as the main occupation. The result of raising ducks is one of the pillars of the community's economy. Hamlet Salam is one of three hamlets in the Kedawung District, a duck, and salted egg farming center.

The development of machining process technology in the livestock industry, especially in the duck feed and salted egg industry, currently requires a numerical control system with computers on CNC (Computer Numerical Control) machine tools. CNC Milling Machine is an automated machine tool equipped with a computer-based control system that can read and interpret G&M code to regulate work as desired [1].

One of the weaknesses of a small industry based on manufacturing production is the low ability to produce products with complex contours and a high level of precision. Since small industries still use conventional machines as their production tools. As it is known that conventional machine tools have limited degrees of freedom, it is impossible to make products with specific contours. To increase its production capability, a small industry is required to use numerical control machines in its production process so that various specifications of consumer demand can be adequately fulfilled. However, the realization of the procurement of numerical control machine tools is not an easy thing because the procurement requires quite a high cost, so it is considered very burdensome for a business field of the small industry class. Based on these conditions, it is necessary to design and manufacture numerical control machine tools at a low cost, which can later be used for small industries in Indonesia [2].

Aluminium is a light metal with good corrosion resistance, good electrical conductivity, and other good properties such as metal properties. The mechanical strength, which is significantly increased by adding Cu, Mg, Si, Mn, Zn, Ni, etc., individually or together, gives other good properties such as corrosion resistance, wear resistance, low coefficient of expansion, etc. This material is used in a vast field, not only for household appliances but also for aircraft, cars, ships, construction, etc. The aluminium used in this study is aluminium Al-Mg. Alloys with 2-3% Mg are malleable, rolled, extruded, and used as forging materials [3].

Many machining processes exist and are used to turn various equipment that uses metal as primary materials. Face milling is a process where the position of the tool is placed on a shaft that has an axis perpendicular to the position of the workpiece surface [4].

Surface roughness in the form of scratches or small indentations on an object. Surface roughness is one factor that affects the quality of a product because it affects the mechanical properties (resistance to fatigue, corrosion resistance, etc.) and functional attributes (friction, ability to reflect light, adaptability, thermal conductivity, etc.) [5]. Machining parameters that greatly determine surface roughness are depth of cut, feeding rate, and cutting speed [6].

Feed rate and depth of cut affect the surface roughness of the machined result. The higher the feed rate and depth of cut, the higher the surface roughness value. This is because when the value of the feed rate and depth of cut increases, the friction between the tool and the workpiece will be higher, it will increase the surface roughness value [7].

2. Materials and methods

This study uses an experimental method involving several variables: independent, controlled, and dependent variables. In this study, the independent variable is the variation of feed rate and depth of cut. The dependent variable is surface roughness, while the controlled variable uses an end mill chisel with a diameter of 3 mm and a spindle speed of 1800 rpm. This study uses a DIY CNC milling machine and uses a milling machine as a comparison.

Figure 1. Prototype CNC Milling Machine

CNC DIY Parts

A. Lead screw and brass nut
It is a mechanical component that serves to translate rotational motion into translational motion. This machine uses a lead screw with a pitch of 2 mm and a start tread of 4 mm. The lead referred to in the leadscrew is a value that indicates the length of the translational motion produced in one rotational motion [8].
Lead = pitch x the number of start tread
Lead = 8 mm
The value above shows in one rotation, the leadscrew will convert the stepper motor into 8 mm of translational movement.
B. Linear Bearing and Rod Shaft Linear bearing, and Rod Shaft is mechanical components. This component is used on each axis (x, y, and z axes) to obtain linear motion.
C. Parallel Port
Parallel Port on the PC is used to connect between hardware as input and output. DIY CNC utilizes the functions of the initial Mach3 software testing.
D. Stepper Motor
A stepper motor is an electric motor that drives to move the chisel by the desired trajectory. The stepper motor used is a Nema 23 stepper motor from Sanyo Denki 1.8 degrees per step.
E. Stepper Motor Driver
Stepper Motor Driver serves to drive the stepper motor.

3. Result and Discussion

The surface roughness data for aluminum can be seen as follows:

Table 1. Results of the Milling Machine Surface Roughness Testing

Feed Rate (mm/minute)	*Depth of Cut* (mm)	Average Roughness (µm)
24	0.25	0.661
	0.5	0.712
	0.75	0.736
42	0.25	0.771
	0.5	0.854
	0.75	0.931

Table 2. Surface Roughness Test Results prototype CNC milling machine

Feed Rate (mm/minute)	*Depth of Cut* (mm)	Average Roughness (µm)
24	0.25	0.653
	0.5	0.702
	0.75	0.729
42	0.25	0.756
	0.5	0.830
	0.75	0.884

Table 1 and Table 2 are the results of surface roughness testing using a milling machine and a prototype CNC milling machine.

The highest surface roughness (Ra) in conventional milling machines is found in the specimen groove with a feed rate variation of 42 (mm/min) and a depth of cut of 0.75 (mm) which is 0.931 (µm), and the lowest surface roughness (Ra) on the machine. Conventional milling is found in the specimen groove with a feed rate variation of 24 (mm/min) and a depth of cut of 0.025 (mm) which is equal to 0.661 (µm). Furthermore, the highest surface roughness (Ra) on the CNC Milling Machine prototype is found in the specimen groove with a feed rate variation of 42 (mm/min) and a depth of cut of 0.75 (mm) which is equal to 0.884 (µm), and the lowest surface roughness (Ra) on the CNC Milling

Machine prototype is found in the specimen groove with a feed rate variation of 24 (mm/min) and a depth of cut of 0.025 (mm) which is 0.653 (µm). From the graph, it can be concluded that the higher the feed rate and depth of cut used, the higher the surface roughness in the specimen groove will increase.

The results of the variation of feed rate and depth of cut on surface roughness are by the theoretical basis, namely that the higher the feed rate and depth of cut values are used, the higher the surface roughness value will be. More significant the feeding speed, the greater the speed of feeding and the faster the slicing process, causing the surface roughness to increase. A deeper cut value results in a higher surface roughness value. Since it can increase the speed of producing furious increases, the load used in the machining process is greater and will produce specimens with a high roughness value. There is no significant difference in the surface roughness of the machining results between the two tools, but the surface roughness results using DIY CNC are lower than the surface roughness results using conventional machines.

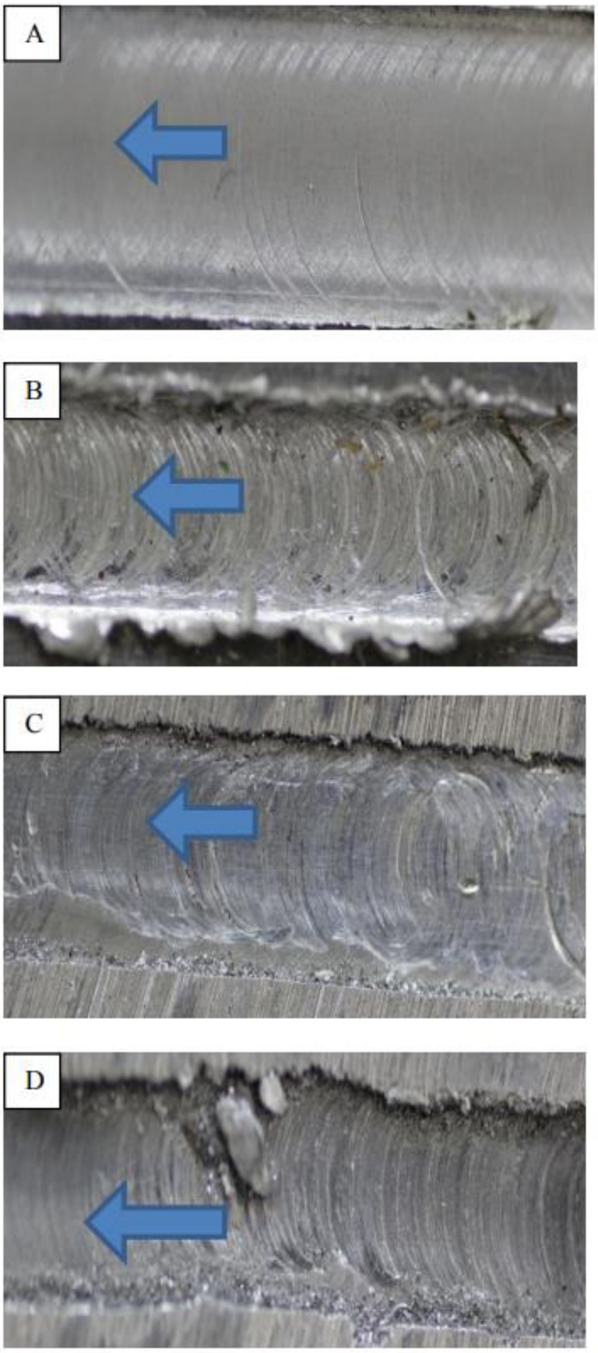

Figure 2. Macroscopic photo of 5052 aluminium surface machined by Krisbow Universal Milling Machine (1) feed rate 24 depth of cut 0.25, (2) feed rate 24 depth of cut 0.75, (3) feed rate 42 depth of cut 0.25, (4) feed rate 42 depth of cut 0.75

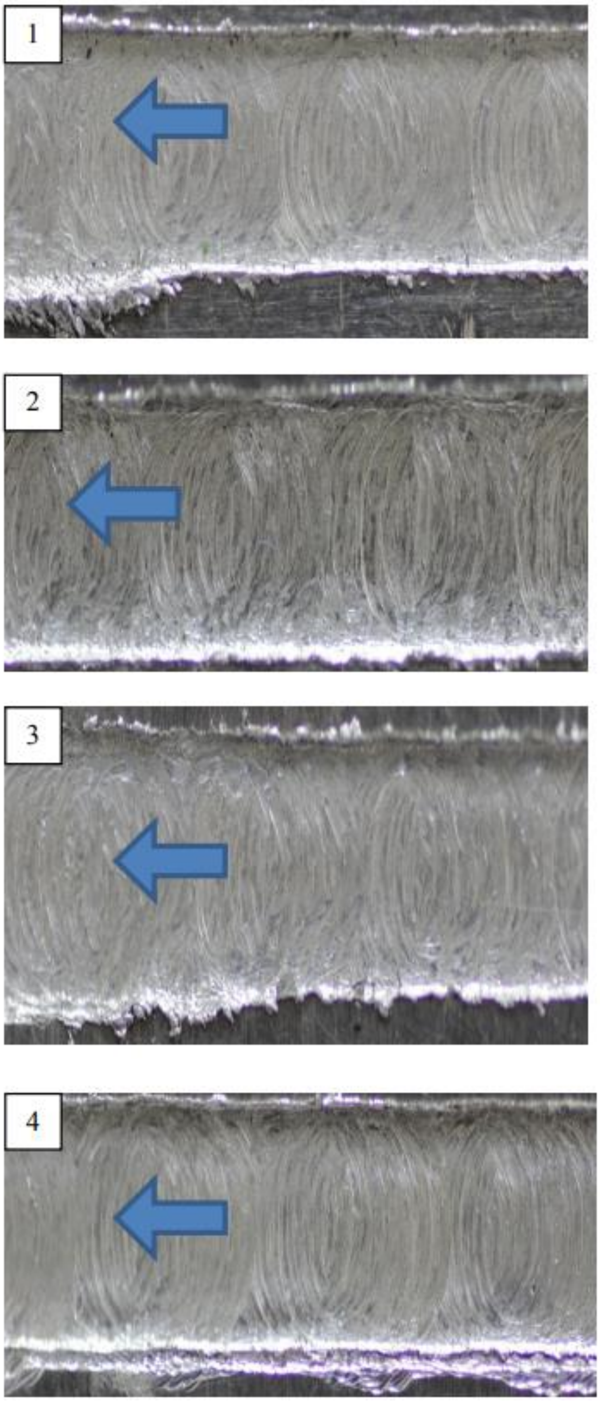

Figure 3. Macroscopic photo of 5052 aluminium surface machined by DIY Milling Machine (1) feed rate 24 depth of cut 0.25, (2) feed rate 24 depth of cut 0.75, (3) feed rate 42 depth of cut 0.25, (4) feed rate 42 depth of cut 0.75

After the face milling process is carried out, macroscopic photo testing at the Materials Testing Laboratory of Brawijaya University using a Canon SLR camera with an SP macro lens at 90 mm dF/2.8 with a scale of 1:1.

The picture above shows the chiselled groove in the face milling process; it looks not as neat as the grooves usually formed by chisels in general. The feed rate used is low, namely 0.013 mm/rev and 0.023 mm/rev, and the spindle rotation is too high, causing friction between the specimen and the chisel in the face milling process to be more significant. Friction occurs for a longer time, causing the surface of the specimen to look like melting when viewed visually.

Visual analysis of macroscopic photos on the surface of Al-Mg aluminium resulting from the face milling process using a milling machine and a prototype CNC milling machine, there are significant differences, as shown in the figure. Figure 2 (1) is a photo of the macrostructure of the face milling process with a feed rate variation of 24 mm/minute and a depth of cut of 0.025 using a milling machine, where the tool groove looks quite neat compared to the other tool paths. The process is the first feeding process so that the process has not experienced a significant temperature increase so that the results look better than the following process. Figure 2 (2) results from the face milling process with a feed rate variation of 24 mm/minute and a depth of cut of 0.75 mm. In Figure 2 (2), the surface of the face milling process looks rough, and the boundaries of the machining process are compressed; this happens because the temperature changes due to friction between the chisel and the workpiece are getting bigger do not use coolant. If the coolant used has a good level of heat absorption, the surface results of the workpiece will be better [9]. Figure 2 (3) shows the face milling process with a feed rate variation of 42 mm/minute and a depth of cut of 0.25 mm. In Figure 2 (3), there is a difference in the cross-sectional area of the shear plane; this occurs because the temperature continues to increase and does not use cooling liquid, resulting in a decrease in cutting speed. The cutting speed is determined based on the material of the workpiece and the chisel [10].

Figure 2 (4) results from the face milling process with a feed rate variation of 42 mm/minute and a depth of cut of 0.75 mm. In Figure 2 (4), the tool groove looks very irregular; there are residual snarls left in the feed groove and the edge of the grinding against the boundary side of the feed groove. It is caused by tool wear due to temperature that continues to increase as the machining process progresses, resulting in the process Feeding occurs not due to the tool's sharpness but due to too high heat, which causes the surface of the specimen to melt. Figure 5 is a microscopic photo of the results of the face milling process using a prototype CNC milling machine with a feed rate variation of 24 mm/minute and a depth of cut of 0.25 mm. There is a change in the cross-sectional area of the machining results; the end of the feed looks slightly more significant than at the beginning of the feed. The prototype CNC milling machine workbench uses wood as a base material and uses a clamp as a chuck which causes a shift in the workpiece due to vibrations during the machining process. It also happens in Figure 3 (3), where the face. Process milling with a feed rate variation of 42 mm/minute and a depth of cut 0.25 mm. Figure 3 (4) results from the face milling process with a feed rate variation of 42 mm/minute and a depth of cut of 0.75 mm. From the picture, there is erosion at the edge of the tool groove boundary. It happened because the strength of the DIY CNC device, especially the body and spindle bracket, was not strong enough to withstand the load from the chisel during the feeding process. It resulted in an unstable chisel position during the feeding process, causing it to shift from the G-code step, which should be. The body is made of a set of wood and aluminium profile with x, y, and z movement axes that is not much different from the size of the body frame so that it is not able to balance the loading due to the feeding process.

4. Conclusion

Based on the results of this study, the following conclusions are drawn:

1. The results of the aluminium roughness test in the face milling process using DIY CNC and milling machines have a roughness value that continues to increase as the feed rate and depth of cut increase. The higher the feed rate value, the faster the feeding process, so the tool does not feed the workpiece more often, increasing the surface roughness value. Meanwhile, the higher the depth of cut value will cause the speed of producing fury be higher so that the load used in the machining process is huge and will result in high roughness values. Of the two tools with no significant difference in surface

roughness value, the surface roughness results using DIY CNC are slightly lower than milling machines.
2. Surface roughness test results obtained Roughness the average on the milling machine, namely: 0.661, 0.712, 0.771. Whereas on the prototype CNC milling machine, namely: 0.653, 0.702,0.756.
3. Macroscopic photo test results using a Canon Eos 600D DSLR camera with a magnification of 10X on the specimen surface due to the machining process using both tools, the low roughness value has a more stable groove on both tools. The difference in feeding on the two tools based on macroscopic photo testing is caused by differences in the specifications of the two tools where DIY CNC uses components, especially electrical components designed for the home industry, so that the output produced is different. Plus, not using cooling liquid makes the results of using a milling machine even worse.

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