Effect of cutting conditions on power demand and surface roughness through sustainable turning of mild carbon steel

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Abstract. Sustainable turning is a lathe machining process to carry out production in particular by paying attention to the sustainability of machinery without reducing production output. The machining process is done by optimizing the turning process parameters when carrying out the cutting process on medium carbon steel. Some parameters affect the lathe process, including speed, feed rate, and cooling. The purpose of this study was to determine the machining conditions in order to optimize the electric power consumption and surface roughness of the medium carbon steel turning process. The research method used was experimental and analysed using the ANOVA method. From the results of the research, it was concluded that the minimum electricity consumption was obtained in the process of turning steel St 42 without cooling with a speed of 237 rpm and a feeding of 0.157 mm/rev. The lower surface roughness was obtained in the turning process of St 60 steel with a rotation speed of 840 rpm and a feed rate of 0.157 mm/rev. The results of data analysis using ANOVA analysis method to get optimal conditions in order to minimum power demand and low surface roughness at 425 rpm of speed and 0.052 mm/rev of feed rate.

1. Introduction

Manufacturing or industry runs on the principle of sustainability as a major step in efforts to save energy. In the principle of a sustainable manufacturing industry there are efforts to reduce the amount of energy used in producing goods and services [1]. One of the big energy uses resulting from this production activity was to process waste and rubbish. In the principle of sustainable manufacturing this waste treatment must use minimal energy. In fact, according to him, waste management does not consume energy but produces new alternative energy. It efforts to recycle waste and garbage are also one of the principles in sustainable manufacturing [2].

The technology of the machining process or the manufacturing process should consider the concepts of research and development and cooling lubrication fluids, because both of these will produce quality products. The concept of research and development is a study that focuses in depth on objects, in this case the technology used in a sustainable manufacturing process. Likewise, the concept of cooling lubrication fluids is focused on new techniques and methods that can improve product quality and reduce production costs [3]. Whereas the sustainable concept in conventional machining focuses on environmentally clean work so that the use of the crystalline method is suitable for its development. Furthermore, efforts to implement sustainable development methods are intended so that quality systems, processes and final products can be achieved by implementing the 6R method.

The concept of sustainability offered should consider the following; production costs, energy consumption, waste management, influence on the environment, operational safety and operator health factors [4].

Savings in energy consumption are part of sustainability so that humans are able to balance their lives. Sustainability is an increasingly important need for human activities, this has led to making sustainable development a view that social, economic and environmental problems must be handled simultaneously and holistically in the development process. Sustainability has been applied in various fields, including engineering, manufacturing, and design. Producers are increasingly concerned about sustainability issues. For example, the recognition of the relationship between manufacturing operations and the natural environment has become an important factor in decision making among industrial communities [2].

Sustainability has become an important issue in the manufacturing sector. In the literature, it is generally agreed that sustainable development must cover three pillars, namely economic, social and environmental considerations [3]. Therefore, to achieve sustainable development, the industry must produce sustainable production. One of the ways to achieve environmentally friendly production is to reduce energy consumption through the use of products.

Sustainable production is a solution to overcome the problem of high electricity use which results in high costs. This applies to the field of engineering, including the machining process [5]. Machinery is an integrated part of the production. Thus, reducing energy consumption during machinery will contribute to reducing energy consumption to produce parts.

Optimizing energy demand in manufacturing is important to reduce the energy intensity of products and their vulnerability to rising energy prices, this is an important addition to reducing energy costs in manufacturing and to optimize energy from machine products. Production machines are one of the most widely used production processes and require an electricity supply. Several studies have been conducted to optimize cutting conditions based on machinery and economic considerations. For example, Hinduja and Sandiford present models and methodologies for selecting optimum cutting conditions based on minimum cost considerations in the milling process [6]. Lee and Tang developed a cutting model to maximize production levels and minimize production costs using polynomial networks [7].

This paper aims to determine the effect of machining parameters (rotation and feed rate) on various responses to electrical power consumption and surface roughness.

2. Experimental Design

The research will be carried out in the Mechanical Workshop and Mechanical Laboratory of the Mechanical Engineering Department. In this study, the equipment used was the lathe machine (PINDAD) with a maximum power of 5620 Watt and maximum rotation of 1500 rpm.

2.1. Materials and Tools

The material being machined was medium carbon steel (Strength of 42 N/mm^2 and 60 N/mm^2). The cutting tool used was an uncoated carbide tool with type tool holder of TCLNR2020K12. Surface roughness resulting from turning can be measured by surface roughness tester Surftest SJ-310 (Figure 1). Power consumption can be determined by measuring voltage and current using Clamp meter (Figure 2).

Figure 1. Surface roughness tester surftest SJ-310

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Figure 2. Clamp meter

2.2. Experimental Setup

Schematic design of the turning process on the workpiece is shown in Figures 3 and 4 below.

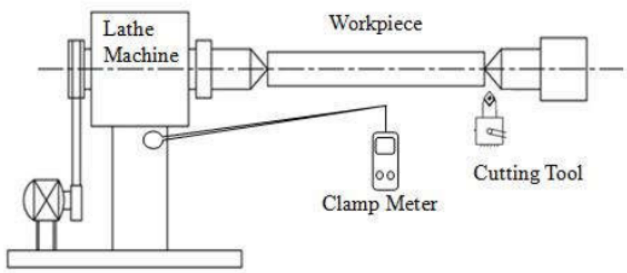

Figure 3. Schematic design of the turning process

Figure 4. Turning processes

The experimental design was based on a number of machining parameters that are varied as shown in Table 1.

Table 1. Machining parameters

Levels	Low (-1)	Centre (0)	High (+1)
Rotation Speed (Vc) [rpm]	237	425	840
Feed Rate (f) [mm/rev]	0,052	0,105	0,157
Depth of cut (a_p) [mm]		0,5 mm (constant)	
Coolant		No fluid	

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3. Results and Discussion

The research will be carried out in the Mechanical Workshop and Mechanical Laboratory of the Mechanical Engineering Department.

3.1. *Power Demand*

The power demand was obtained from the measurement data of current and voltage. It was used by the clamp meter to measure the current and voltage. The result of the power demand can be described in Figure 5.

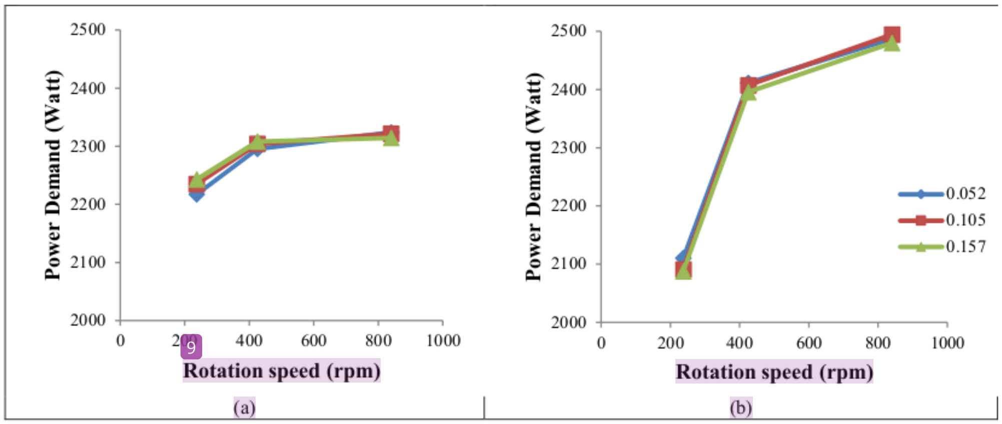
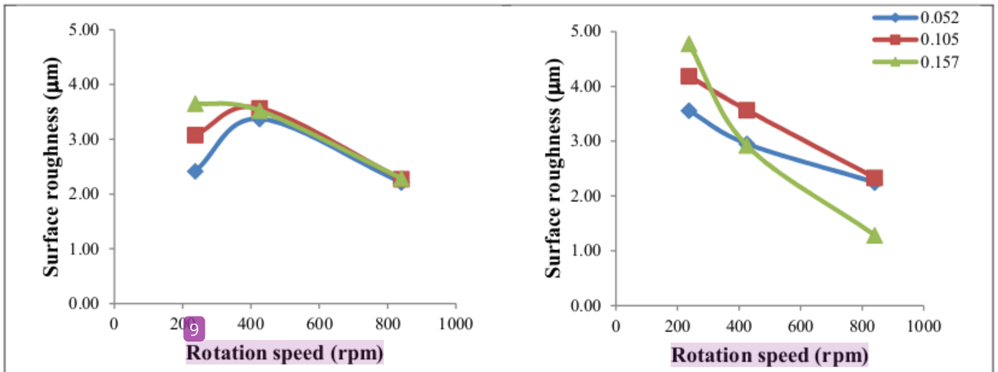


Figure 5. Graph of power demand for St 42 (a) and St 60 (b)

Based on the resulting the calculation of power demand with a variation of rotation speed and feed rate as shown in Figure 5(a), it shows that the highest power demand is 2324 Watt at 840 rpm and 0.052 rev/mm. The lowest power demand is 2217 Watt at a rotation speed of 237 rpm and the feed rate of 0.052 rev/mm. Likewise, for St 60, Figure 5 (b) shows that the highest power consumption is at 840 rpm and the feed rate is 0.105 rev/mm at 2494 Watt, and conversely, the lowest power consumption is 2087 Watt at 237 rpm of speed and 0.157 rev/mm of feed rate. Some researchers observed the effect of cutting speed on power consumption in the process of turning aluminum alloy [8,9].

3.2. *Surface Roughness*

The surface roughness was measured using Surftest SJ-310 (Mitutoyo). The data of surface roughness was repeated to 5 times for each measurement. The results of surface roughness were described in Figure 6.



(a) (b)

Figure 6. Graph of surface roughness for steel of St. 42 (a) and St. 60 (b)

Based on the results of the measurement of surface roughness as in Figure 6, it shows that the highest surface roughness is 3.655 µm at 237 rpm of speed and the 0.157 rev/mm of feed rate, and the lowest surface roughness is 2,215 µm at 840 rpm and 0.052 rev/mm. Likewise, on the material of St. 60, it shows that the highest surface roughness is 4.780 µm at 237 rpm and 0.157 rev/mm, and the lowest surface roughness is 1.288 µm at 840 rpm and the feed rate is 0.157 rev/mm. These responses were observed Nur et. when turning of 316L stainless steel [10].

4. Conclusion

Based on the results of research and data analysis, it can be concluded as follows:

1. Power demand is only affected by the variable rotation, where the greater the rotation used, the higher the value of power demand, whereas the smaller the rotation is used, the lower the power demand. While the feed rate does not affect power demand.
2. Surface roughness is influenced by the variable rotation speed and feed rate, where a large rotation and a small in feed rate will produce a low (smooth) surface roughness. Conversely, if a small round and large feed rate will get a high surface roughness.

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