Evaluation of Surface Roughness and Power Consumption in Machining FCD 450 Cast Iron using Coated and Uncoated Irregular Milling Tools

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Abstract. In this project, the effects of different cutting parameters on surface roughness and power consumption when machining FCD450 cast iron were studied using coated and uncoated irregular milling tool geometry of variable helix and pitch. Their responses on roughness and power consumption were evaluated based on the spindle speed, feed rate, and depth of cut, machining length and machining time. Results showed that except spindle speed and machining length, other parameters such as feed rate, axial and radial depth of cut and also machining time proportionate with surface roughness. The power consumption proportionately increase for all cutting parameters except feedrate. It is showed that the average decrement 27.92 percent for surface roughness and average decrement 9.32 percent for power consumption by using coated compared to uncoated tool. Optimum cutting parameters for both minimum surface roughness and power consumption can be determined. The coated tools performed better than uncoated milling tools for responses of surface roughness and power consumption to increase machining productivity and profit.

1. Introduction

Machining can be considered as the most essential process in manufacturing processes to manufacture high quality product and low cost production. One of the most important elements in machining is the tools and cost of each tool can be varied and expensive according to their function and endurance. A new cutting tool performance behaviour test can be applied to help businesses gain a competitive edge and it is also describe all the tool characteristics’. Performance of machining process depends on the surface smoothness, and power consumption so that it is become the major topics in process planning and machining optimization in industry to increase the productivity of the product and lowering tooling cost. Cutting process parameters such as depth of cut, feed and speed most popular influence factors in achieving high quality product with less cost and time [1].

In machining process target to minimize the cost, it should be considered total power consumption used in making the machined product. Kant and Sangwan [2] predicted power consumption before further optimized multi objective of power consumption and surface roughness using grey relation coupled with principle component analysis and response surface methodology in [3]. Machining of 27 turning data collected from cutting speed and feed and depth cut machining parameters with three levels for each parameters. Brushan [4] considered to maximize tool life and minimize power consumption in machining composites by optimizing the cutting speed, feed, depth of cut and nose
radius. Minimum power consumption is not enough to eliminate environmental effect, Campatelli et al. [5] also considered machining in dry condition instead of power consumption.

Beside power consumption, surface roughness also considered as quality tools in turning alloy steel with cutting parameters influences [6]. Both optimum energy consumption of power consumption and cutting quality of surface roughness and productivity are considered by Negrete [7] to machine aluminium. On the other hand, cutting tool materials also essential to target high quality product with minimum cost where coated tools enhance productivity but increase production cost. Shao et al. [8] compared uncoated and coated tools in machinability of alloy in term tool life, failure and wear. Both tools also compared the wear mechanism, cutting force and surface finish in micromilling of hard materials of inconnel [9]. Coated carbide tool used in [10] to minimize force in dry and flood lubrication conditions with different cutting parameters range. Yusup et al. [1] and Dhabale et al. [11] reviewed on utilized of artificial intelligent to optimize process parameters for product quality and productivity improvement.

Above reviews shows that more attention pay on power consumption and surface roughness evaluation by changing cutting parameters, but minor researcher studied to optimize both responses using coated and uncoated milling tool in machining. This study objective is to evaluate both surface roughness and power consumption in machining cast iron using coated and uncoated irregular milling tools.

2. Experimental Method

In this section, experiment procedure and cutting process parameters for evaluating the surface roughness and power consumption are presented. Both coated and uncoated solid carbide milling tool by used for cutting FCD 450 cast iron workpiece with dimension of 150x150 x50 mm³ (Fig. 1). Table 1 shows the experimental parameters and values of spindle speed, feed rate, axial depth of cut, radial depth of cut, machining length and machining time. Both types of coated and uncoated cutting tools are used on CNC Makino KE55 milling machine (Fig. 1). Each experiment were repeated three times to achieve average value for maintaining accuracy and repeatability of experiment.

| Cutting parameters          | 1000  | 1487  | 2015  | 2495  | 3026  | 120   | 165   | 375   | 520   | 720   | 0.75  | 1.25  | 1.75  | 2.50  | 3.50  | 5     | 10    | 15    | 20    | 150   | 300   | 450   | 600   | 750   |
|-----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Spindle speed, v (rev/min)  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Feed rate, f (mm/min)      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Axial depth of cut (mm)    | 0.75  | 1.25  | 1.75  | 2.50  | 3.50  | 5     | 10    | 15    | 20    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Radial depth of cut (mm)   |       |       |       |       |       | 5     | 10    | 15    | 20    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Machining length (mm)      | 150   | 300   | 450   | 600   | 750   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Machining time (s)         | 60    | 120   | 180   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

During cutting, the power consumption were measured by using Power Meter Model 3600. Figure 2a shows the power meter display is collected for total active power energy (kWh) from CNC machine. Each workpiece from machining was measured the surface roughness using surface roughness tester (Mitutoyo surftest SJ-301). Surface roughness measurements were recorded along the centreline of the slot cut at three locations. In each slot, the entry, middle and exit points were measured, as shown in Figure 2b.

3. Results

The evaluation of surface roughness and power consumption to machining parameters during machining are now presented. In this experiment, it is found that surface roughness decrease with an increasing in spindle speed with better surface finish of coated compared with uncoated tools, as shown in Figure 3a. Figure3b shows the average value of surface roughness for uncoated tool
increased linearly from 0.796 µm to 2.432 µm when increasing feedrate. For coated tools, the surface roughness increases from 0.781 µm to 1.230 µm, but better than uncoated tools. Similar trend happened to when increasing radial depth of cut (Figure 3d). In Figure 3c, it shows that increasing of axial depth of cut increases the surface roughness. However, uncoated tools shows better surface roughness compared to coated tools. Figure 3d and Figure 3e show the longer the machining time and length resulting poor surface roughness with coated better than uncoated milling tools.

Figure 1. Experiment of cutting cast iron using coated and uncoated irregular milling tools

Figure 2. Measurement for power utilization and surface roughness

Figure 4 shows the cutting process parameters effects to surface roughness, now the evaluation results represent for power consumption, as shown in Figure 4. In Figure 4a, it was found that as spindle speed increases, power consumption also increases. Figure 4b shows that there is a negative relationship between feed rate and power consumption. However, coated tools show larger power consumption than uncoated tools for both effects of spindle speed and feed rate. From the effects of radial and axial depths of cut, there are linear relationship between power consumption and for both cutting parameters (Figure 4c and Figure 4d). However, coated shows better power consumption than uncoated tools. Figure 4e and Figure 4f show the longer the machining time and machining length the higher the power consumption.
consumption. Power consumption for coated tools is lower than uncoated tools when increasing of machining time and machining length. Machining length for uncoated tools significantly increases power consumption compared coated tools, as shown in Figure 4d.

![Graphs showing the effect of machining parameters on surface roughness for coated and uncoated carbide tools.](image)

**Figure 3.** Effects of machining parameters to surface roughness for coated and uncoated carbide tools

### 4. Discussions

For surface roughness evaluation, surface roughness almost increases as cutting parameter increasing (Figure 3). Except spindle speed and machining length, other feedrate, axial and radial depth of cut and also machining time proportionate with surface roughness. At low spindle speed, friction between the work-piece and the cutting tool is high due to discontinuous chips formed which are deposited in the workpiece and tool interface [2]. Uncoated tools shows better surface roughness when increasing...
the spindle speed. As increasing machining length, there no effect to surface roughness for both coated and uncoated tools. All cutting process parameters showed that coated tools better surface finish compared to uncoated tools. It is found that the coated tool failure occur at short machining time in comparison uncoated tool runs for a machining time much longer than coated tool [7]. Uncoated tools the surface defect occurs at a short distance which causes to increase the roughness value.

**Figure 4.** Effect of machining parameters to average power for coated and uncoated carbide tools.
Figure 4 shows that the power consumption proportionately increase for all cutting parameters except feedrate. Increases in radial depth of cut will increase the chip load along a single cutting edge. If the radial depth of cut increases enough, the number of contact points between cutting edges and the workpiece could increase, leading to a rise and subsequent increase in power requirements for machine tool. Coated tools performed better for axial and radial depth cut, machining time and length compared to uncoated tools. However, uncoated tools performed better to decrease power consumption compared to coated tools for spindle speed and feed rate cutting process parameters.

Figure 5a shows the effect of spindle speed to average surface roughness and average power for coated solid carbide. Thus, the optimum cutting condition was found at cutting speed (2587.95 rev/min) with average power (4.1968 kWh) and average surface roughness (0.7638 µm). Best surface roughness and power used value are obtained at low value depth of cut. Figure 5b shows the effect of feed rate to average surface roughness and average power for coated solid carbide. The optimum value from this experiment was found at feed rate (280.2772 mm/min) with average power (2.7749 kWh) and average surface roughness (1.0244 µm). The optimum power consumption at the lowest depth of cut (0.75 mm) with (1.5 kWh) of power consumption and (0.472 µm) surface roughness as shown in Figure 5c. The optimum value from Figure 5d was found at radial depth of cut (10.8845 mm) with average power (1.4981 kWh) and average surface roughness (0.7630 µm). Its shows the optimum parameter was found at machining time (73.5 second) with average surface roughness (0.7356 µm) and power consumption (2.3503 kWh) as shown in Figure 5f. In determining optimum cutting conditions of experiments to be conducted under the same conditions for machining length (269.4 mm) with average surface roughness (2.7428 µm) and power consumption (0.4335 kWh) as shown in Figure 5f.

5. Conclusion

Results showed that cutting parameters such as feed rate, axial and radial depth of cut and also machining time increase cause increasing of surface roughness. The power consumption increases as other cutting parameters increase except feedrate. It is showed that the average decrement 27.92 percent for surface roughness and average decrement 9.32 percent for power consumption by using coated compared to uncoated tool. Optimum cutting parameters for both minimum surface roughness and power consumption can be determined for cutting process parameters. Coated tool can reduce the surface roughness and power consumption when compared uncoated irregular milling tools in machining cast iron. The coated tools can be used to increase machining productivity and profit.

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Figure 5. Effects of machining parameters to average surface roughness and average power for coated solid carbide.