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New Technology For Environmentally Friendly Machining In Gray Cast Iron Using HSS Tool

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Abstract - The primary function of the metal cutting industry is to machine various metal materials into products like bolts, couplings, gears, shafts, bearings, and other engine components for local and international markets. To achieve long tool life and smooth surfaces, cutting fluids are often used, but this practice has significant negative effects on operators and the environment. Operators can develop lung and skin diseases, and the environment is polluted by coolant that cannot be naturally decomposed. Scientists are working to eliminate coolant use in metal machining. This study performs a dry machining test on cast iron with eight varying cutting conditions to collect data on tool wear, machining time, surface roughness, machining length, machining volume, and material removal rate. The data are analyzed to determine the optimal cutting conditions for environmentally friendly machining.
Keywords- Coolant, Cast Iron, Green Machining

1. INTRODUCTION

Background

The machining process, which is a primary activity in small and medium-sized metal industries, involves the use of conventional machine tools to manufacture engine components and other equipment. Green machining, which is environmentally friendly, is becoming increasingly necessary due to environmental laws and health regulations. Dry machining offers several benefits, including reduced pollution, lower disposal and cleaning costs, and improved health and safety. However, it also poses challenges such as higher tool wear and thermal loads.

In high-speed machining, the coolant cannot reach the tool-chip interface, and the cooling liquid is not environmentally friendly. This necessitates the adoption of dry or green machining practices. Coolant plays a crucial role in removing chips from the workpiece, but its absence in dry cutting leads to increased friction and adhesion, resulting in higher tool wear and thermal loads.

Traditional machining processes involve waste disposal, which can be in solid, liquid, or gas form. Research focuses on cutting energy in machining systems, but from a green machining perspective, total energy consumption must be considered. In small and medium-sized metal enterprises, preliminary studies on the machinability of cast iron materials for producing parts reveal several issues:

1. **Equipment Limitations**: High Speed Steel (HSS) tools used in dry cutting are not suitable due to their limitations in strength, stiffness, and reliability at high temperatures, leading to lower tool life.
2. **Geometric Tool Instability**: Geometric tools are unstable because they rely on operator instinct and experience, resulting in high variations in surface roughness.
3. **Inconsistent Cutting Conditions**: Inconsistent cutting conditions, including cutting depth, tool geometry, and cutting and feeding speed, contribute to poor accuracy and precision of the resulting product.

2. RESEARCH PURPOSES

To obtain a cutting condition without coolant which has tool wear and roughness according to good standards and productivity.

3. MATERIALS, TOOLS AND METHODS

Material

This research method will describe the materials, equipment and methods used, as follows:
The workpiece material is cast iron with a chemical composition of C = 3.27 % , Cr = 0.3%, Cu = 0.2%, Mn = 20%, Mo = 0.07%, Ni = 0.1%, P = 0.1%, S = 0.11 %, Si = 2 %, and mechanical properties: Rockwell Hardness = 20.49 Rockwell C (RC), Tensile Strength = Min 396.045 Mpa,
Ultimate Compression Strength = 1034 Mpa. Figure 1 shows a cast iron workpiece and figure 2 shows the dimensions of the workpiece.

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Equipment
The equipment used is a conventional lathe which is commonly used in Small and Medium businesses where research is carried out and the tool used is an HSS tool.

Methods
The data collection method is to collect data from 4 (four) variations in cutting conditions, namely: cutting time, surface strength. The collected data was then analyzed to see the performance of Small and Medium Companies in terms of quality and quantity using conventional machines, then tests were carried out on several variations of cutting conditions to obtain the following data: machining time (t), tool wear (VB), machining length (L), material removal rate (MRR), surface roughness (Ra) of the machining workpiece. The data obtained is then processed to obtain machinability performance in terms of quality and quantity and to see the extent to which improvements in quality and quantity are obtained by cutting the conditions recommended by the results of this research.
There are 4 (four) variations in Cutting Conditions, namely:
CC1: v = 10 m/min; f = 0 .1 mm / rev; a = 0.5mm
CC2: v = 15 m/min; f = 0 .1 mm / rev; a = 0.5mm
CC3: v = 20 m/min; f = 0 .1 mm / rev; a = 0.5 mm
CC4: v = 25 m/min; f = 0 .1 mm / rev; a = 0.5mm

4. RESEARCH RESULTS

Research results
The data on the results of machining work objects are as follows:

a. Tool Wear
Tool wear measurements were carried out using portable Loupe/.
In Figure 1 it is shown that each cutting process is carried out for about five minutes, and the faster wear occurs on the tool with CC3 and CC4 cutting conditions, but the results obtained are still below 0.3 mm , which means it is still within the permitted conditions.

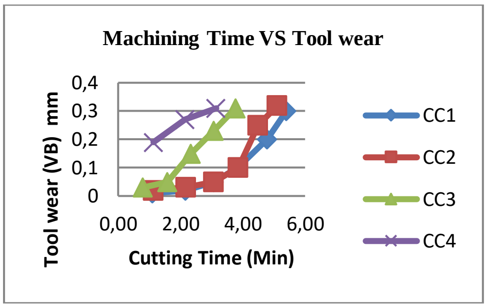

Figure 1. Graph of tool wear and machining time

b. Surface roughness
Measurement of the surface roughness of the workpiece (specimen) using a Surface Roughness Profillometer as in Figure 7 below.

The expected limit of Surface Roughness is 2.4 µm, from the Surface Roughness graph in figure 8 that the cutting conditions CC3 and CC4 obtain suitable surface roughness as expected, while the roughness in the cutting conditions at CC1 and CC2 is rougher.

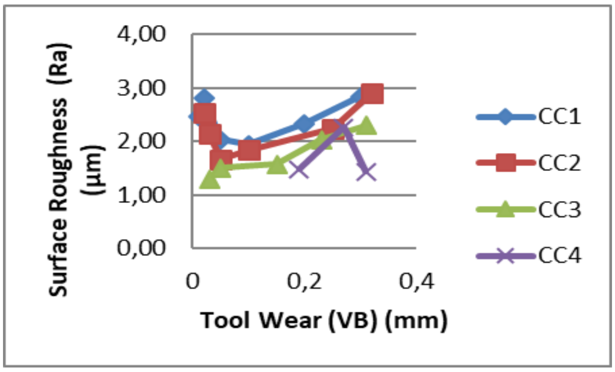

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Figure 2. Graph of tool wear and surface roughness

c. Machining Length

From Figure 3 it can be seen that the length of machining carried out in Small and Medium Enterprises, CC1, CC2, CC3, is very short, which means the productivity is very low compared to CC4

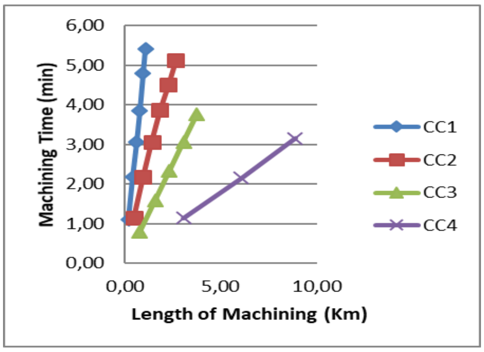

Figure 3. Graph of Machining Length and Machining Time

d. Machining Time

From figure 4 in the perspective of machining time, it can be seen that the fastest machining is in CC4, with v = 25 m / min, f = 0 .1 mm / rad; a = 0.5mm.

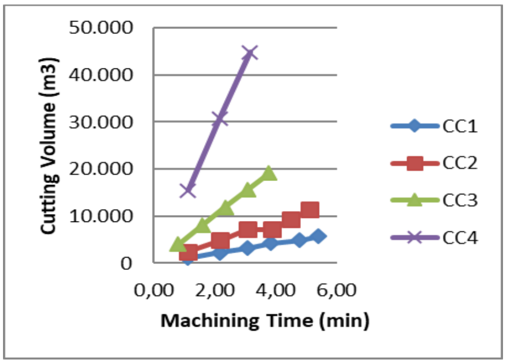

Figure 4.Graph of Machining Time and Machining Volume.

e. Cutting Volume

In the perspective of cutting volume, it can be clearly seen in figure 5 that the cutting volume obtained by CC4 is higher than that of CC1, CC2 and CC3.

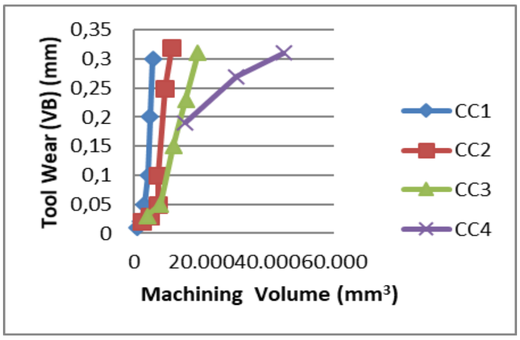

Figure 5. Graph of Machining Volume and Tool Wear

f. Material Removal Rate (MRR)

From Figure 6 it can be seen that the highest Material Removal Rate (MRR) is in CC4 with 1.25 cm3 / minute. This shows that the productivity of CC4 is better than others.

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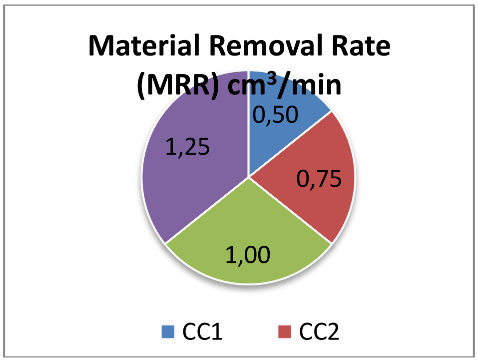

Figure 6 Material Removal Rate per Cutting Condition.

5. CONCLUSIONS

Based on the data analysis above, the following conclusions can be drawn:
1. In terms of tool wear, CC1 and CC2 are better because the tool life is longer than CC3 and CC4.
2. In terms of long machining, CC4 is better than others because it can process workpieces for a long time of 8.8 km in 3.15 minutes
3. In terms of surface roughness CC3 and CC4 fall into the criteria with surface roughness below 2.4 µm
4. In terms of cutting volume, CC4 is better than other cutting conditions, as it can produce a cutting volume of 4.807 mm3 in 3.15 minutes despite shorter tool life.
5. The highest Material Removal Rate (MRR) is at cutting condition 4 (CC4), namely 1.25 cm3 / min. This shows the best productivity of the four cutting conditions in CC4
6. The best cutting condition of the four cutting conditions above is CC4, where V = 25 m / min, f = 0.1 mm / rev.

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