New Technology for Environmentally Friendly Machining in Gray Cast Iron using Uncoated Carbide Tool

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Abstract*— The main activity of the metal cutting industry is machining various kinds of metal materials to make various products such as bolts, couplings, gears, shafts, bearings, turning metal casting objects and other engine components for sale in the local market as well as for export needs. Cutting fluid (coolant) is often used for metal machining to obtain a long tool life and low machined surface roughness, but the use of such coolant has a negative impact on machine operators and environment. The negative impact on operators is cause lung disease and temporary skin disease while for the environment, it will cause environmental pollution because coolant from synthetic materials cannot be decomposed in nature. Due to this reason, scientists are trying to eliminate the use of coolant on metal machining. In this study, a dry machining test is performed on cast iron with 8 (eight) varying cutting conditions (23factorialmethod), as follows V1, V2, f1, f2, a1, a2. In this test, some information can be collected such as toolwear (VB), machining time (t), surface roughness (Ra), machining length (L), machining volume (Q) and material removal rate (MRR). The test data are then analyzed to obtain optimum cutting conditions for the 8 (eight) cutting conditions to be applied to environmental friendly machining (green machining).

***Keywords*— Coolant, Cast Iron, Green Machining**

I. Introduction

Machining process or metal cutting process is the main activity carried out by small and medium metal industry by using conventional machine tools (Nasution, Ginting, Hamsi, & Harahap, 2005). This machining process is intended for manufacturing engine components or other equipment (Cerce & Pusavec, 2016; Nugroho & Senoaji, 2010)

Green machining is desirable for environment and it will be considered as a need in the upcoming future for manufacturing companies. For the protection of environmental laws and health regulations industries will be forced to consider dry machining. The benefits of dry machining includes: non-pollution of the atmosphere (or water); no left over on the swarf which will be displayed in reduced disposal and cleaning costs; no threat to health; and it is non-injurious to skin and is allergy free. And it also offers cost reduction in machining (Jain & Kansal, 2017; Nasution et al., 2005).

In high speed machining the coolant cannot reach the tool-chip interface, so it has no effect on the heat that occurs, in addition, the cooling liquid is not environmentally friendly, so it is necessary to make a law on machining that directs the metal cutting industry players to cut dry or green machining (Amini, Khakbaz, & Barani, 2015; Gaafer, Ghaith, Khalil, & Mostafa, 2015).

When cutting metal, coolant has an important function to remove chips on the workpiece. Thus, the use of coolant is very possible in high performance operations, while the function of coolant is not available in dry cutting, this means that there will be more friction and adhesion between the cutting tool and the workpiece. Cutting tool and Specimens will experience a higher thermal load. This can result in a high level of tool wear, for example the process of forming a crater wear on cutting cast iron using an uncoated carbide tool (Galanis, Manolakos, & Vaxevanidis, 2008; Nayyar, Kaminski, Kinnander, & Nyborg, 2012).

Basically, in a normal machining process, the process of dumping waste into the environment in a solid, liquid or gas condition, as a result of processes involving chisels, workpieces and coolasnt, While machining systems using cutting tools require a certain amount of power associated with machining activities as well as non-machining, usually, research studies are directed at cutting energy in the machining system, where a certain amount of energy is needed to remove a certain amount of material. However, from the point of view of green machining, the energy consumption used must be considered as a whole not limited to only cutting energy (Lee, Tarng, & Li, 2000; Nugroho & Senoaji, 2010).

A. Problem

Real conditions in small and medium-sized metal enterprises where preliminary studies of the machinability of cast iron materials for producing parts are carried out, are as follows:

1. The type of equipment used is High Speed Steel (HSS) in dry cutting which is not appropriate because HSS has some limitations in strength and stiffness, and it is not reliable in high temperatures, so tool life is lower [9] . This was evident in the cutting process, it was also observed that the operator always sharpened the tool after cutting the product or around 35 minutes.

2. Geometric tools are unstable because they only hone the operator's instinct and experience, this makes the surface roughness of product variations high. Research conducted by Y. Lin [10] on ferrous metal cutting showed that surface roughness depends not only on the flank wear, but also on the tool nose radius.
3. Inconsistent cutting conditions including cutting depth, tool geometry, cutting and feeding speed, contribute to the geometric consistency of the resulting product, or in other words the accuracy and precision of the resulting product is poor. Cutting conditions also contribute to surface roughness as reported by Gafeer et al. [11] in ferrous metal cutting, feed is a very influential factor in surface roughness..

II. Research Pusposes

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

III. Materials, Tools and Method

A. *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.

B. *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.

C. *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

IV. 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.

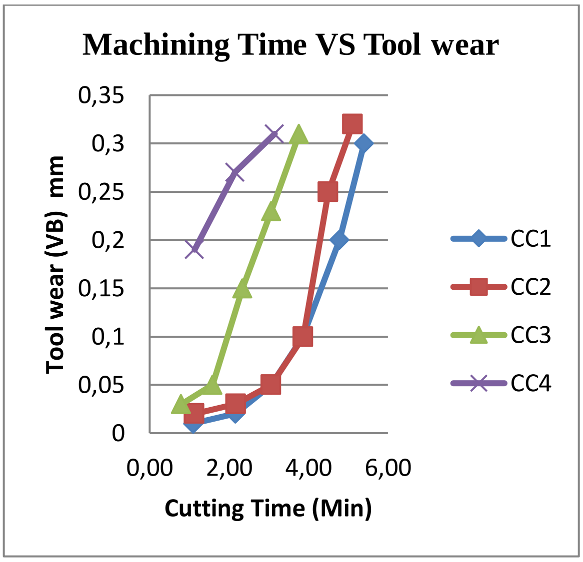

Figure 1. Graph of tool wear and machining time

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.

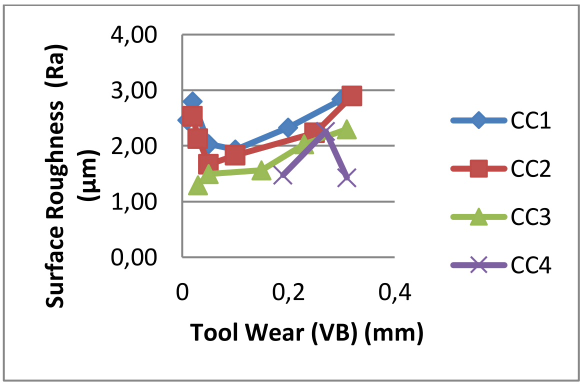

Figure 2. Graph of tool wear and surface roughness

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

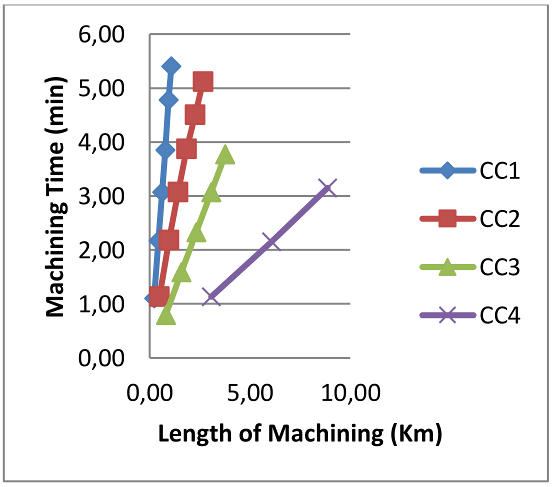

Figure 3. Graph of Machining Length and Machining Time

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.

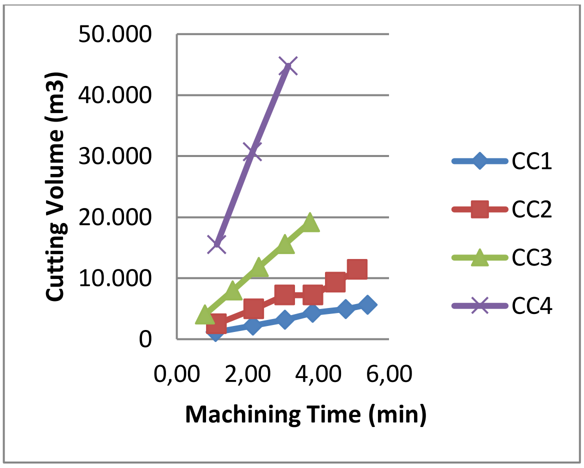

Figure 4. Graph of Machining Time and Machining Volume.

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.

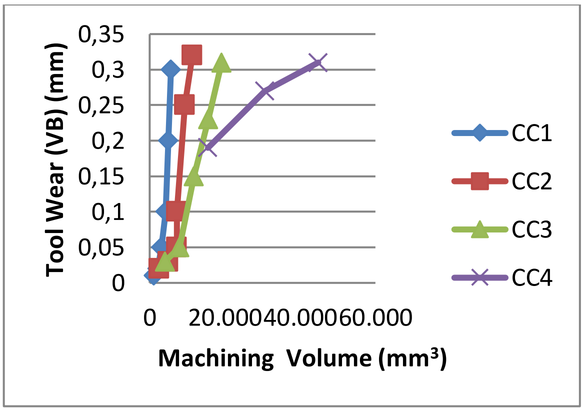

Figure 5. Graph of Machining Volume and Tool Wear

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.

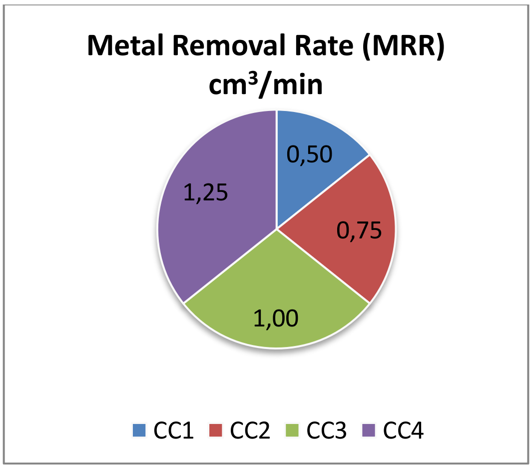

Figure 6. Material Removal Rate per Cutting Condition.

V. Conclusions

Based on the data analysis above, the following conclusions can be drawn: In terms of tool wear, CC1 and CC2 are better because the tool life is longer than CC3 and CC4. 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. In terms of surface roughness CC3 and CC4 fall into the criteria with surface roughness below 2.4 µm. 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. 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. 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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