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Machining Process Performance of Ductile Cast Iron

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***Abstract* - In this paper, the performance of machining processes on ductile cast iron (DCI) was investigated. There were 3 DCI specimens made with variations in the amount of graphite per mm^2, graphite size and percentage of pearlite and ferrite. The machining performance was measured is by cutting force, feed force and tool wear. The machining process was carried out at various cutting speeds from 45 – 120 m/min, a feed of 0.1 to 0.3 mm/rev and a depth of cut of 1 mm. The results obtained show that the machining process of ductile cast iron is influenced by its microstructure, where the amount and size of nodular graphite is more dominantly affecting the cutting force and feed force, while the percentage of ferrite and pearlite is more influential on tool wear.**

Keywords: Machining Process, Ductile Cast Iron, Cutting Force, Feed Force, Tool Wear.

I. INTRODUCTION

As much as 70% of the world's total cast products are made of cast iron [1], including ductile cast iron (DCI). DCI is currently widely used for automotive components and other industrial components and has been able to replace steel [2]. The advantage of DCI compared to steel is due to its better casting ability. DCI has the same castability as gray cast iron and strength as good as medium carbon steel [3]. Besides that, the performance of DCI is also higher and the cost is lower when compared to steel [4].

DCI also has good machinability. The presence of spherical graphite makes the material easier to cut, because graphite can act as a solid lubricant and as a chip breaker [5]. The volume and distribution of nodular graphite affect the frictional characteristics i.e. ensuring continuous lubrication at the interface of the workpiece and tool surfaces

The casting process for components made of DCI is usually followed by machining processes, especially at the finishing process stage. In order to reduce costs and production time as well as improve the quality of the final product and dimensional tolerances, it is necessary to know what factors affect the characteristics of the machining process in DCI. There are several things that will affect it, such as the shape and size of the spherical graphite, the presence of carbides, inclusions and matrix structure. All of these things are strongly influenced by factors when it is made through the casting process, such as chemical composition, inoculation process, cooling rate and applied heat treatment.

In this study, the effect of the amount and size of nodular graphite and the percentage of ferrite and pearlite phases in DCI on the performance of the DCI machining process will be investigated by measuring cutting force, feed force and tool wear.

II. EXPERIMENTAL SETUP

The orthogonal turning process was used to cut the workpiece. The workpiece material used in this study is DCI FCD 500-7 with variations in the amount of graphite, graphite size, percentage of ferrite and pearlite. The workpiece specimen is cylindrical in shape with a diameter of 70 mm and a length of 400 mm. The cutting tool used is of the K20 carbide type, TMNA 220408. The machining process is carried out at various cutting speeds from 45 – 120 m/min, a feed of 0.1 to 0.3 mm/rev and a depth of cut of 1 mm. The performance of the machining process is determined by measuring the cutting force and the amount of tool wear. Experimental setup of the machining process and measurement of cutting force using a dynamometer can be seen in Figure 1.

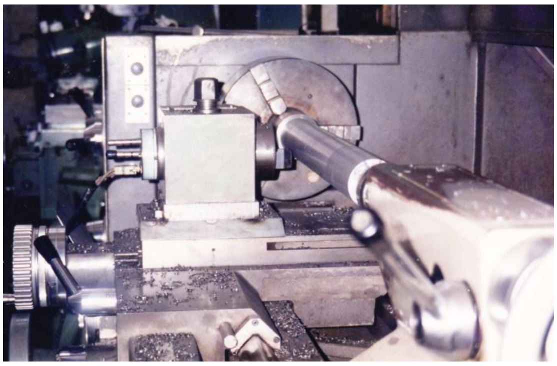

Figure 1: Experimental Setup

III. RESULTS AND DISCUSSIONS

The shape and size of nodular graphite can be seen in Figure 2. The amount of nodular graphite per mm2 (NG) and

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the size of nodular graphite (SG), mm x 100, can be seen in table 1. The role of graphite in the cast iron machining process is as a solid lubricant and chip breaker [5]. The size of the graphite in specimen 1 looks smaller than specimens 2 and 3. From Figure 2 it can also be seen that there is graphite in the form of small flakes which are spread evenly in the DCI. From table 1 it can be seen that the highest amount of graphite per mm2 is found in specimen 3, while the largest size of graphite is found in specimen 2.

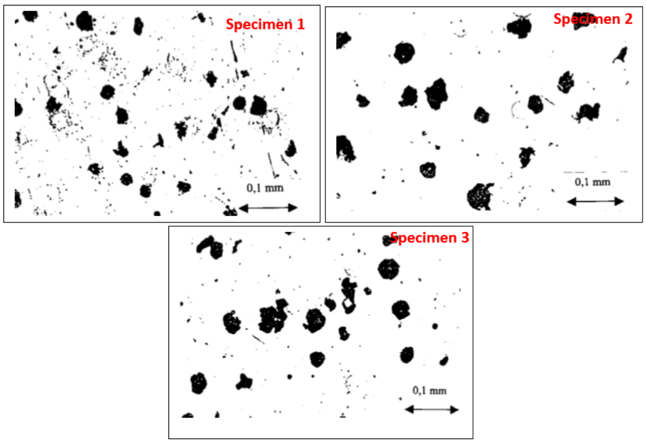

Figure 2: Nodular Graphite

From table 1, it can be seen the percentage of ferrite and pearlite in the three specimens. The pearlite phase has a dominant effect on the strength and hardness of ductile cast iron. While the ferrite phase will cause an increase in ductility. From table 1 it can also be seen that the most pearlite phase is found in specimen 1 which causes the hardness value of specimen 1 to be higher than specimens 2 and 3. Increasing the DCI hardness will reduce the DCI machinability [6].

Table 1: Graphite and matrix data on DCI

Specimen	NG	SG	% Ferrite	% Pearlite	HB
1	51	1,5	51.7	48.3	237
2	71	4.1	67.7	32.3	204
3	100	3.9	73.7	26.3	198

Figures 3 – 6 show the cutting and feed forces on the three specimens at various cutting speeds and feeds. In Figure 3 it can be seen that the increase in cutting speed has no significant effect on the resulting cutting force. It is possible that this is due to the presence of graphite which can act as a lubricant in the friction area between the surface of the workpiece and the surface of the cutting tool during the machining process. However, the cutting force will increase as the feed increases (see figure 4). This naturally happens, because the cutting area will increase with the increase in feed. And the same thing also happens to the feed force, where an increase in feed causes an increase in feed force (see Figure 6). Meanwhile, an increase in cutting speed has a tendency to decrease feed force (see Figure 5).

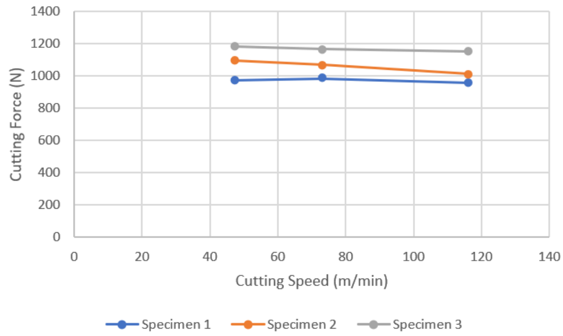

Figure 3: Cutting Force vs Cutting Speed

Among three specimens, specimen 1 has the lowest cutting force and feed force both at cutting speed and feed variations. The highest cutting force and feed force are found when cutting specimen 3. From table 1 it can be seen that specimen 1 has the highest hardness value and highest percentage of pearlite compared to the other 2 specimens so that the cutting force that occurs in specimen 1 is greater than the other 2 specimens. From the photo of the microstructure in Figure 2, specimen 1 has the smallest graphite size and there are also small graphite in the form of scattered flakes which cause the chips to break easily during the machining process. This is similar to what happens to gray cast iron which has a graphite flake shape. Maybe this causes the cutting force in specimen 1 to be the lowest.

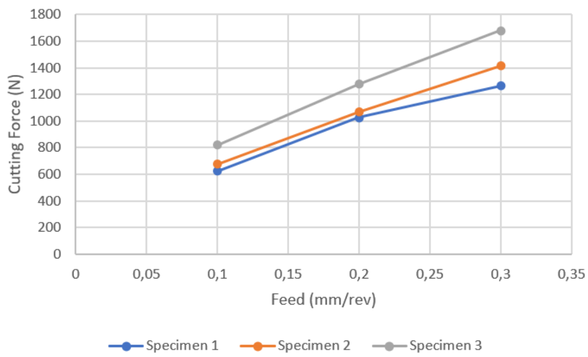

Figure 4: Cutting Force vs Feed

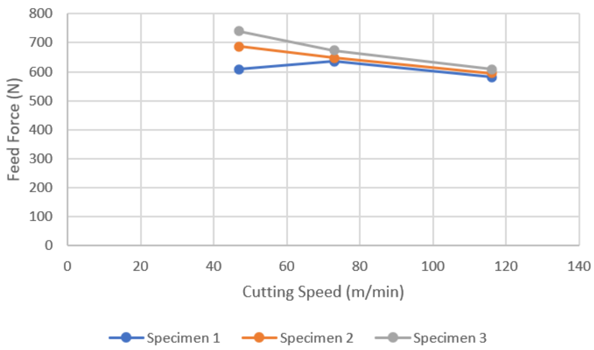

Figure 5: Feed Force vs Cutting Speed

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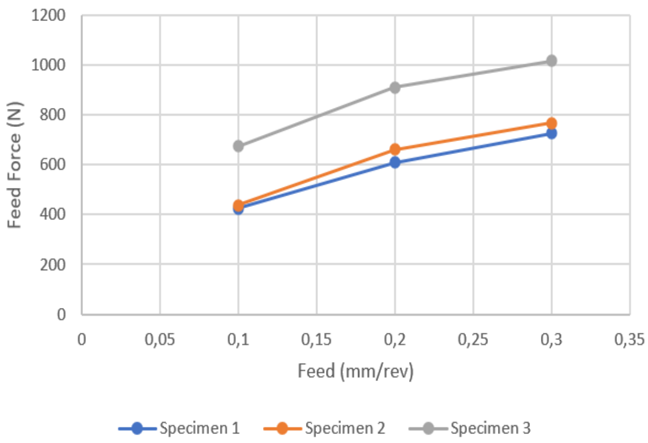

Figure 6: Feed Force vs Feed

Table 2 shows flank wear data at cutting speeds of 148 and 163 m/min. The wear limit for flank wear for carbide tools ranges from 0.4 to 0.6 mm. From table 2 it can be seen that the highest wear value occurs in the carbide tool for cutting specimen 1 and the smallest wear occurs when cutting specimen 3. This data is in contrast to the cutting force data. This may be due to the hardness factor of the workpiece which is caused by the large number of pearlite phases which dominantly affect tool wear. The same thing was also found by Martinez et al where tool wear easily occurs in ductile cast iron with a pearlite phase [7]. At a cutting speed of 148 m/min, all tool wear that occurs is smaller than 0.6 mm. However, at a higher cutting speed (163 m/min) the wear that occurs on the cutting tool when cutting specimen 1 is greater than 0.6 mm, while the other 2 specimens show tool wear that is lower than 0.6 mm.

Table 2: Flank Wear

Specimen	V_B (mm)	
	148 m/min	163 m/min
1	0.59	0.69
2	0.46	0.56
3	0.39	0.51

IV. CONCLUSION

The conclusion that can be drawn from this study is that the machining performance of ductile cast iron is influenced by its microstructure. The amount and shape of nodular graphite is more dominantly affecting the cutting force and feed force, while the percentage of ferrite and pearlite is more influential on tool wear. By increasing the percentage of pearlite in ductile cast iron, the hardness will also increase so that wear also becomes easy on cutting tools.

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