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Chip shape analysis during dry machining of nodular cast iron

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Abstract – Chip shape in machining of metals not only reflects the quality and success of the operation but also carries the signs about the cutting mechanism. Most importantly, chips are responsible for the heat removal from the cutting zone which directly eliminates the thermal effects such as fatigue, shock, and early failure of edge due to excessive wear. Therefore, analysis of the chips is not only important in these aspects but also have significance in determination of the cutting parameters, lubricating and cooling conditions. This study addresses mentioned points by evaluating the milling parameters under dry cutting conditions to compare chip properties such as color, length, and helix etc. The evaluation was carried out by examining the microscopic images according to the experimentally obtained chips under two different levels of cutting speed, feed rate and depth of cut. The results of this experimental work are expected to be an idea for the future studies in the metal cutting sector.

Keywords – Chip Analysis, Cast Iron, Dry Cutting, Milling, Machinability

I. Introduction

Ductile (nodular) cast iron material is preferred in especially automotive industry due to their high strength and toughness and castability properties [1, 2]. Further, austempering process, which is consist of austenitizing, quenching, and transform of ferrite and austenite with different temperature and time conditions, enhance the mechanical properties of cast irons [3, 4]. In addition, it has low material cost, low production cost, low density and good machinability advantages [5]. But fast wear of cutting tools is a critical problem for machining of ductile cast iron [6]. Ghani et al. conducted an experimental study on nodular cast iron to explain the changing surface finish under the different cutting conditions. The results show that the ceramic tools are insufficient in terms of tool life [7]. Şeker and Hasırcı evaluated the surface finish and cutting force of ductile iron. It is revealed that the higher surface quality can be obtained under the low cutting speed conditions [8]. Long analyzed the influence of cutting speed on tool life, surface roughness, and chip formation during turning with coated carbide tools. It was stated that the tool wear rate increases with increasing the cutting speed and c-shaped discontinuous chip formation was obtained for all grade of ductile iron [9]. Chip formations are classified as continuous, discontinuous and build up edge (BUE) [10]. Continuous chip formation can lead to deterioration of the surface quality and an increase in the temperature of the cutting tool when high-speed machining of ductile materials [11, 12]. The environmental machining is a critical aspect of manufacturing. It is ensured that the need for lubricant is reduced in dry or near-dry machining. Meena and Mansori conducted an experimental study on dry machining of ductile cast iron. The results of experiments showed that the low feed rate and higher cutting speed leads to higher cutting force and higher mechanical and thermal loads on the cutting edge of tool. The segmented chip formation revealed with higher cutting speed. The failure of tools was obtained such as flank wear, crater wear, chipping, breakage and BUE. Chip morphology and tool wear were evaluated by surface roughness analysis [13]. The formation of chips and removing this material from the workpiece affect the surface finish quality [14]. The shape of chips are strictly related to microstructure and mechanical properties of workpiece material and cutting conditions [15]. Yazman et al. evaluated the chip morphology based on cutting speed. It was reported that the highest BUE was observed under the low cutting speed condition and unstable BUE was observed with increasing cutting speed. Long and helical chip patterns was specified in high cutting speed conditions [16].

Chip formation has an impact on the surface finish quality and tool wear.

As seen, chip analysis was done before from the researchers in the field for different types of materials. The main objective of this study is to investigate the chip shape of nodular cast iron during dry machining. In this direction,

II. Materials and Method

GGG50 nodular cast iron specimens were used in tests that chemical composition is seen in Table 1. The dimensions of the workpiece billets were 30 mm width and 100 mm in length. TiC coated CCMT 09T308-304 series cutting tool was used. Cutting tools were renewed after every try. Tests were conducted with a three axis CNC milling *(SUNMILL*) machine with different cutting parameters as specified in Table 2. The full factorial method was used in designing the tests. Chips were evaluated based on different cutting conditions.

Table 1 Chemical composition of GGG 50 specimens.

Element	**C wt%**	**Si wt%**	**Mn wt%**	**Mg wt%**	**P wt%**	**S wt%**
GGG50	3.5-3.8	2-3	0.4	0.06-0.12	0.1	0.01

Table 2. The parameters of milling

Cutting Speed (m/min)	**Feed Speed (mm/rev)**	**Cutting Depth (mm)**
150-200	0.15-0.3	0.2-0.4

III. Results

Chip analysis is highly important in machining due to the listed reasons:

i) Chips can remove the excessive heat from the cutting zone which makes it critical to elongate the cutting tool life by eliminating accelerated tool wear and reduced mechanical properties of the work material.

ii) Ideally, chips are expected to break by the natural flow of the machining process. There are two undesired ways for breakage of the chips such as breaking by crashing to cutting tool or workpiece. In these scenarios, there is possibility to make damage on cutting tool edge or workpiece surface. Therefore, breakage of chips by itself not guarantees the desired chip shape but increases the possibility in obtaining the desired form.

iii) When stable chip breakage can be carried out during machining, same quality indicators of the workpiece through all faces such as surface roughness, dimensional accuracy and surface topography can be obtained. This is highly criticial to reach sustainable and reliable manufacturing.

iv) Since the metal cutting is an art of the chip formation, all basic mechanisms around the cutting zone is related with the chip shape. Therefore, understanding of the chip shape opens new doors in the way of improved machinability.

Figure 1 represents the chips obtained from the experiments. Some examples taken from the group of chips are demonstrated in here. Also, cutting parameters are given at the top of the figures. Milling experiments can generate short chips as per the cutting mechanism. Especially, in the perspective of this study, a brittle material was used. Brittle materials are expected to produce serrated and short chips. From this point of view, it can be clearly seen that 8 chips in the figures have serrations. Some serrations look much more deeper which are generally at lower cutting speeds namely 150 m/min. On the other hand, chips may have different shapes such as c, comma, curled. Especially in the curved type, helix number may be higher which is an undesired situation due to the reason of heat accumulation at the contact surfaces between chip and tool or chip and workpiece. When looking at the chips morphology, higher feed rate namely 0.3 mm/tooth is much better than the lower value in this perspective. Seemingly, depth of cut has no important effect on the chip shape. When looking at the colors of the chips, no big difference was seen. It should be noted that chip shapes may show differences from starting point to the finish of the machining.

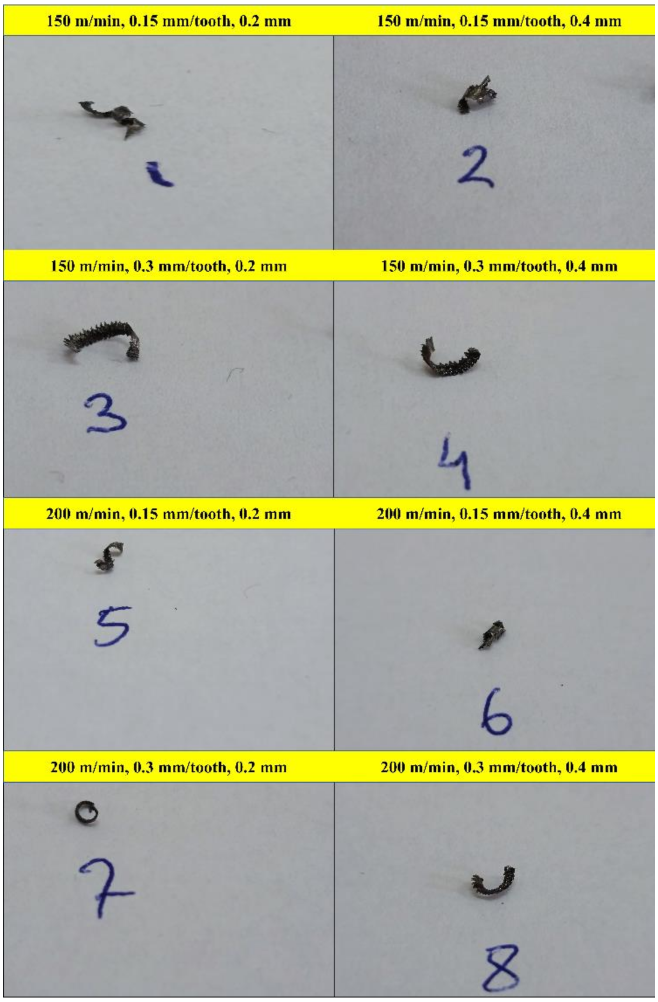

Figure 1. Chips obtained from the experiments.

IV. CONCLUSION

The observations of this study can be listed in the following:

- Seemingly, depth of cut has no important effect on the chip shape.
- 8 chips obtained from milling of the cast iron in the figures have serrations.
- Higher feed rate namely 0.3 mm/tooth is much better than the lower value.
- Some serrations look much deeper which are generally at lower cutting speeds namely 150 m/min.
- When looking at the colours of the chips, no big difference was seen.

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