

Analysis of chip geometry and surface roughness at low speed turning in various commercial steels

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Abstract. Rapid development of technology in manufacturing facilitates the industry to produce mass, high quality and affordable products. The challenge for small industries in manufacturing is to compete for product quality. Small manufacturing industries in controlling the quality of product deal with financial problems. Chip and surface roughness of low speed machining were tested to control the quality of material mechanical properties. The purpose of this study is to investigate the relation between chip characteristic and surface roughness with material hardness. This study used a conventional lathe with low rotation, cutting depth of 1 mm, dry turning process with variations of feed rate of 0.1 mm/rev, 0.2 mm/rev and 0.3 mm/rev, test material of AISI steel (1020, 1045, 1090, D2 and 4340) and tool material from carbides. Stereoscopic Optical Microscopy (SOM) was used to measure temporary shear angle while surface roughness tester was used to measure surface roughness. The results show that the shear angle of the chip and the surface roughness correlated with the hardness of the material.

1 Introduction

The rapid development of technology in manufacturing facilitates the industry to produce mass, high quality and affordable products. The challenge for small industries is to compete particularly for product quality. Small manufacturing industries in controlling product quality deal with financial problems. Chip and surface roughness of machining with low speed were tested to control the quality of material mechanical properties. The result of the machining process is always related to the final surface and chip. The surface finish is an indicator of quality and precision in the machining process and is considered as an important parameter in the industry [1]. Chips are leftover cutting materials in the machining process and are often regarded as waste.

Recent studies of chip dimension measurements aimed to determine optimal cutting conditions and generally used light alloys (magnesium, aluminum, titanium alloys) as the development of the aircraft industry. Research on dimension measurement of titanium chip was similar to shear angle measurement, height of peak, height valley and chip thickness [2]. Measuring the dimensions of chip in aluminum alloys where measurements were performed

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similarly to Batista et al and added distance measurements between chips (S) and the width of chips (bv) [3]. Analyzing the dimensions of aluminum alloy chips (UNS A97075-T6 (Al-Zn) and UNS A92024-T3 (Al-Cu)) by comparing the dimensions of chips [4]. Whereas in the steel the measurement of chips from machining lathe has not been done, the study still refers to formation of chip by analyzing the shear angle.

The purpose of this study is to investigate the hardness level of steel viewed from shear angle and surface roughness resulting from the process of machining lathe. It is expected to contribute positively to small industries in controlling the quality of material hardness.

2 Experimental

This study used various types of commercial steel. The chemical composition is shown in Table 1.

Table 1. The chemical composition of commercial steel (% wt).

No	Material	Chemical composition (%)							
		C	Si	Mn	P	S	Cr	Mo	Ni
1.	1020	0.10	0.16	0.43	0.016	0.007	0.041	0.006	0.023
2.	1045	0.44	0.21	0.59	0.015	0.008	0.03	-	0.008
3.	1090	0.68	0.29	0.77	0.019	0.15	1.13	0.22	0.17
4.	D2	1.54	0.27	0.32	0.023	0.014	11.46	0.66	0.26
5.	4340	0.34	0.29	0.63	0.012	0.023	1.57	0.214	1.41

The experiment used the following cutting parameters: low rotation of n 65 rpm, cutting depth of p 1 mm and the variations of feed rate f of 0.1, 0.2 and 0.3 mm/rev. Chips were generated on a dry machining process on a cylindrical bars (with the length of 120 mm and diameter of 19 mm) of commercial steel, Figure.1 (a). Testing using the C6127A model KIANGSI lathe, with WC-Co coated with Ti.N and Ti.CN from the Iscar manufacturer TMNG 332-GN ICR3028, Figure. 1 (b). A new cutting insert was used in each test in order to avoid the wear influence on the process and, by that, in the geometry of the chip [2].

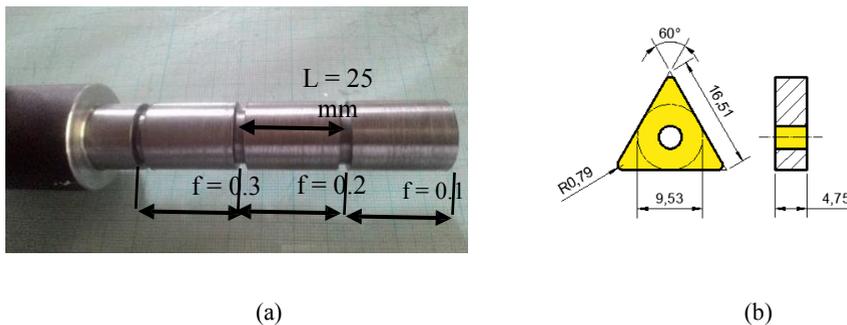


Fig. 1. (a) Cylinder tests bars; (b) Geometry and dimension that define the tool used.

Chip samples were prepared for observation with Stereoscopic Optical Microscopy (SOM). In the making of metallographic processes, chip samples were mounted on the resin, sanded and lastly polished with aerosol until they were as smooth as glass. Chips were placed in longitudinal positions to show the longitudinal side. A digital microscope with cooling-tech software measured the shear angle. Figure 2 (a) shows the longitudinal chip of commercial steel with a microscope. In this figure the shear angle can be measured and distinguishable, Where ϕ : angle sliding on grating. The measurement of surface roughness as shown in Fig. 2 (b) used Mitutoyo Portable Surface Roughness Tester SJ_210.

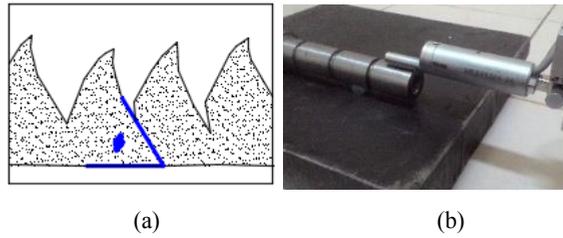


Fig. 2. (a) Measured shear angle on the chip (b) Measured surface roughness.

3 Results

The chips formation of commercial steel the dry cutting proses are as shown in Table 2.

Table 2. Chips formation of various commercial steel.

	Feed rate 0.1 mm/rev	Feed rate 0.2 mm/rev	Feed rate 0.3 mm/rev	HB
AISI 1020				131
AISI 1045				195
AISI 1090				220
AISI D2				258
AISI 4340				346

The results of the research on the chip formation as shown in Table 2 in general were that ribbon-shaped chips along with increasing spiral feed rates tended to be spiral in accordance with research conducted on aluminum alloy chips. The greater the rate of feed, the shorter the chip, or the smaller and more easily broken the diameter of the spiral [2]. The chip formation of commercial steel as set out in Table 2 is in accordance with ISO standards [5], thus for the AISI 1020 steel all feed rates were categorized in the form of arc type chip, AISI 1045 steel for all feed rates into short conical helical type, AISI 1090 steel for all feed rates into short tabular type, AISI D2 steel for all feed rates into elemental form and AISI 4340 steel for feed rates of 0.1 mm/rev washer type chip, the feed rate of 0.2 mm/rev for long washer type chip and 0.3 mm/rev for chip formation of short type washer. The chip shape for feed rates of 0.1 mm/rev and 0.2 mm/rev of commercial steel, the hardness value of ≤ 258 HB formed favorable chips while the hardness value of ≥ 258 HB steel formed unfavorable chip that could harm the operator.

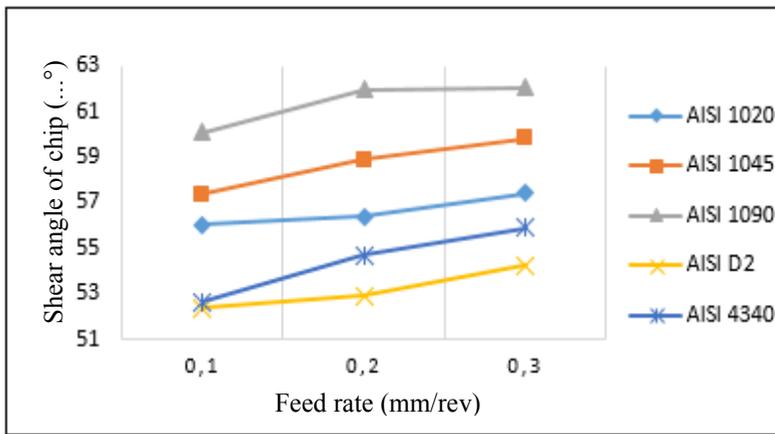


Fig. 3. Graph of the relationship between feeding with the shear angle of chip various commercial steels.

As shown in Figure 3, it can be concluded that higher feed rate will influence the increase of shear angle. In addition, the material hardness also affects the shear angle, the harder the carbon steel and the alloy steel, the increase of shear angle will be more significant.

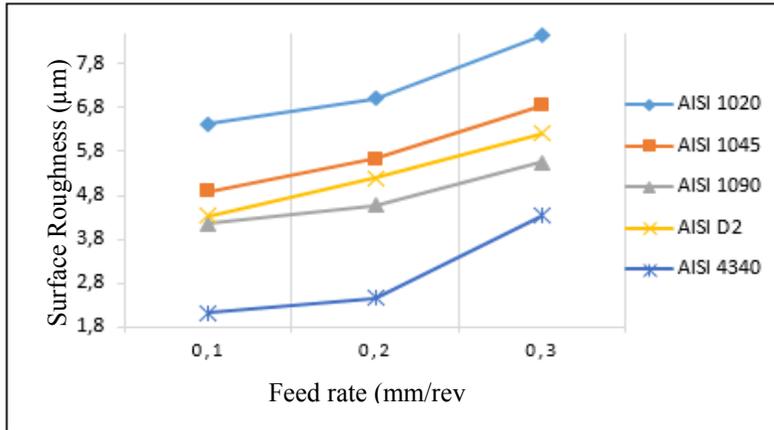


Fig. 4. The surface roughness value of commercial steel.

The study was conducted on the prediction of surface roughness of AISI 4340 steel (69 HRC). One of the testing parameters was feed rate. The process of machining lathe was without cooling and it was found that the increase in feed rate value correlated with the increase in the surface roughness value [6].

Analyzing the surface roughness of dry turning proses. The machining parameters used were cutting depth (a_p), feed rate (F), cutting speed (v_c) and tool radius (R). The result showed that the cutting depth and feed rate were the most influential surface roughness factors [1]. Figure 4 shows that the increase in feed rate values has implications for surface roughness values. This means that the higher the feed rate, the higher or more coarse the surface roughness.

The study that was conducted on the hardness of stainless steel revealed that the steel hardness would increase the quality of surface roughness, influenced by several factors, such as feed rate and cutting speed [7]. Based on the results shown in the Figure 4, it can be analyzed that the level of hardness of the material takes effect in the surface roughness value. The harder the carbon steel and the alloy steel, the better the quality of the surface roughness in the conventional lathe machining process.

4 Conclusion

Based on the results of data analysis in this study, it can be concluded that:

- The formation of chip generated on the commercial steel from conventional lathe machining processes with low rotation can be characterized as follows: that the increase in feed rates of the chip formation will tend to be shorter or the spiral diameter will be smaller and more easily broken. The chip form for feed rate of 0.1 mm/rev and 0.2 mm/rev of the hardness level of commercial steel ≥ 258 HB was favourable while the steel hardness value of ≤ 256 HB the chip was unfavorable.
- The increase in feed rates will affect the increase of shear angle. In addition, the material hardness also affects the shear angle, where the harder carbon steel and alloy steels, the more significant of the shear angle increases.
- The increase in feed rate values will have implications in surface roughness values. It means that the higher the feed rate, the higher or more coarse the surface roughness. The hardness level of the material affects the surface roughness value. The harder the carbon steel and the alloy steel, the better the quality of surface roughness.

- In general, the material hardness level affects the shear angle of the chip and surface roughness. Favourable chip will produce fine machining surface roughness when compared to unfavorable chip.

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