Proceedings of Asia International Conference on Tribology 2018, pp. 487-488, September 2018

Surface roughness of AISI 4340 alloy steel in dry and cryogenic milling

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Keywords: Surface roughness; alloy steel AISI 4340; machining

ABSTRACT – This study investigates the effect of machining parameters on the surface roughness in milling AISI 4340 with cutting speeds of 160- 240 m/min, feed rate of 0.05- 0.15 mm/tooth and depth of cut of 0.1- 0.5 mm under dry and cryogenic conditions using a carbide cutting tool. The results found that the Ra measured for dry and cryogenic conditions were 0.20-0.38 µm and 0.18-0.27 µm respectively. The (ANOVA) analysis found that the feed rate has significant influence and the utilization of the cryogenic technique helps to improve the surface roughness up to a maximum of 24% as compared with the dry milling.

1. INTRODUCTION

Nowadays, manufacturing industries are increasingly growing towards high-quality product. This quality is directly influenced by the surface integrity, dimensional accuracy, burr, etc. The AISI 4340 steel is mainly used as a component for aircraft, aerospace components such as bush, shaft, valve, and components that resistance to chemical reaction. In addition, it is also widely used in automotive industry [1]. Stipkovic et. al [2] found that in machining hardened AISI 4140 alloy steel, the higher feed per tooth combined with higher cutting depth generated bad surface finish. Previous studies on the cryogenic method commended its positive impact on machining performance. Musfirah et. al [3], had proven that the utilization of the cryogenic technique improves the surface roughness to a maximum of 88%. This paper investigates the effect of machining parameters in dry and cryogenic conditions on the surface roughness of AISI 4340 as it directly indicates the product quality.

2. METHODOLOGY

The miling process was performed using AISI 4340 using SPINNER CNC milling machine. The machining process was carried out using insert carbide with detail cutting tool geometry in Figure 1.

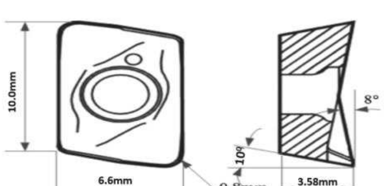

Figure 1 Cutting tool geometry for DNMA432.

Through detail literature review of past studies on machining AISI 4340 [3,4] dry cutting condition was established as shown in Table 1. For cryogenic machining only 4 trials were conducted as shown in Table 2. It was based on lowest cutting speed and depth of cut.

Table 1 Experimenl run for dry cutting condition.

Trial	Cutting speed, v m/min	Feed rate, f mm/tooth	Depth of cut, D mm
1	180	0.10	0.3
2	180	0.15	0.5
3	180	0.20	0.7
4	200	0.10	0.5
5	200	0.15	0.7
6	200	0.20	0.3
7	220	0.10	0.7
8	220	0.15	0.3
9	220	0.20	0.5

Table 2 Experimental run for cryogenic condition.

Trial	Cutting speed, v m/min	Feed rate, f mm/tooth	Depth of cut, D mm
1	180	0.10	0.3
2	200	0.10	0.5
3	200	0.20	0.3
4	220	0.15	0.3

The measurement of surface roughness value was conducted using Mitutotyo portable surface roughness model SJ-310. The equipment is used to measure the arithmetic value of Ra. The measurement process is according to ISO 4288: 1996. Total measurement length and cut off length is 4 mm and 0.8 mm respectively.

3. RESULTS AND DISCUSSION

Table 3 shows the measured Ra in dry cutting conditions. The analysis of variance (ANOVA) indicates that the feed rate has significant influence on the surface roughness with 79.77% contribution followed by the depth of cut (9.76%) and cutting speed (8.87%). This result is in agreement to a study by Fratila & Caizar [5], when face milled aluminium alloy. The machined surface roughness was measured for both dry and cryogenic methods at selected cutting conditions. Comparisons of Ra values for selected dry and cryogenic conditions are shown in Table 4.

Table 3 Measured surface roughness under dry cutting condition.

Test	Cutting speed, V m/min	Feed rate, F mm/tooth	Depth of cut, D mm	Surface roughness (µmm)
1	180	0.10	0.3	0.287
2	180	0.15	0.5	0.299
3	180	0.20	0.7	0.350
4	200	0.10	0.5	0.252
5	200	0.15	0.7	0.203
6	200	0.20	0.3	0.321
7	220	0.10	0.7	0.218
8	220	0.15	0.3	0.261
9	220	0.20	0.5	0.382

Table 4 Comparison of average surface roughness values for dry and cryogenic machining.

Test	Cutting speed, V m/min	Feed rate, F mm/tooth	Depth of cut, D mm	Cutting conditi ons	Surface roughness (µmm)
1	180	0.10	0.3	dry	0.287
				cyro	0.251
4	200	0.10	0.5	dry	0.252
				cryo	0.191
6	200	0.20	0.3	dry	0.321
				cryo	0.274
8	220	0.15	0.3	dry	0.261
				cyro	0.238

From these results, it is clear that in comparison to dry machining, cryogenic machining can deliver a better surface finish. Similar finding was reported by Jerold and Kumar [6] during machining of AISI 105 steel. In this study, the achieved surface roughness produced during cryogenic machining ranged ≤ 0.28 µmm. The Ra of the cryogenic machined surface was improved by about 24 % compared to the dry milling, as shown in Figure 2 for test 4.

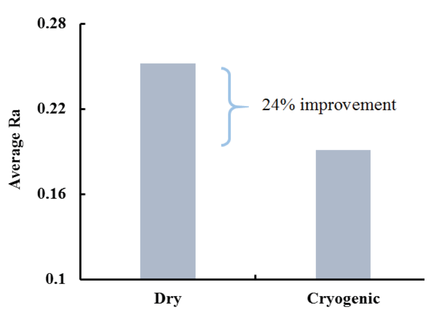

Figure 2 Comparison of a for dry and cryogenic conditions or for test 4.

Rough surface finish in the dry cutting is most probably due to the adhesive effects at the workpiece-tool interface caused by the high temperature [7]. Besides, the phenomenon of flank build-up, built-up edge, or even a dead metal zone that usually forms at the edge of the radius of the insert [8], which are commonly associated with high cutting temperatures, might also contribute to the high surface roughness. The application of the cryogenic cooling technique which effectively reduced the cutting temperature, lessened all the effects mentioned above. In general, the experimental results revealed that cryogenic cooling could improve the surface roughness by up to 24%.

4. CONCLUSION

From the results obtained, it can be concluded that the feed rate has the significant influence on the surface roughness. Furthermore, the utilization of cryogenic cooling proved to be more effective for improving the surface roughness of the machined surface.

ACKNOWLEDGEMENT

The authors would like to thank the Government of Malaysia and Universiti Kebangsaan Malaysia for their financial support under FRGS/1/2016/TK03/UKM /01 /1 and GUP-2017-048 grants.

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