Wear mechanisms of coated tungsten carbide when machining inconel 718 under cryogenic and dry conditions

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ABSTRACT – Inconel 718 is an aerospace material that is difficult to cut due to its high generated cutting temperature. This study is using dry and liquid carbon dioxide as a coolant to cut inconel 718. The cutting tool used is coated tungsten carbide. Parameter used in this experiment are Vc=70 and 110 m/min, f=0.075 mm/rev and a_p=0.1 mm. Results show that the cryogenic machining reduces the wear progression of the nose wear. The main wear criteria is catastrophic fracture at highest speed. Cryogenic machining reduced the fracture and chip welding on the rake face of the tool.

1. INTRODUCTION

Inconel 718 is one of the well-known superalloy materials that is hard to machine. Pusavec et al. [5] stated that the heat generated while cutting this material promotes to rapid tool wear which shortens the tool life. Thus, as a sustainable solution to solve the heat generated issue, cryogenic machining method has been introduced.

Apart from cryogenic machining as a solution to improve the machinability of inconel 718, the cutting tool also plays a vital factor to improve its machinability. Li et al. [3] found that coated tungsten carbide could deliver performance to machine such material along with its economic price. Currently, the use of coated tungsten carbide has been given attention to cut inconel 718 through cryogenic machining as previous studies [1,4]. However, much studies focusing on the use of liquid nitrogen (LN_2) instead of liquid carbon dioxide (CO_2) as the cryogen for cutting this material. Moreover, the study of the wear mechanism for the coated tungsten carbide is still insufficient.

Therefore, this study will be focusing on the wear mechanisms of the coated tungsten carbide under high - speed machining of inconel 718 using cryogenic (CO_2) and dry condition.

2. METHODOLOGY

This experiment is conducted under turning process of bar an inconel 718 workpiece with dimension of Ø100mm x 150 mm length using CNC machine, HURCO TM8i. The measured average hardness of the aged inconel 718 grade AMS5663 is 44.8 HRC. The cutting tool is a PVD TiAlN coated tungsten carbide, CNGG120408FS grade KC5010 from Kennametal and inserted into a tool holder, DCLNR2525M12 from Sandvik.

The liquid carbon dioxide is delivered to the cutting area directly from the highly compressed tank at a pressure of 57 bar. The carbon dioxide initially in liquid phase inside the tank but as it released to the atmospheric environment, it will change phase to dry ice. Katja Busch et al. [2] stated that this phase change refers to the Joule-Thomson effect and the theoretical temperature of the dry ice that could be achieved is as low as -78.5°C. The dry ice delivered to the cutting area by using a single nozzle, which is positioned at the flank face of the cutting tool as in Figure 1.

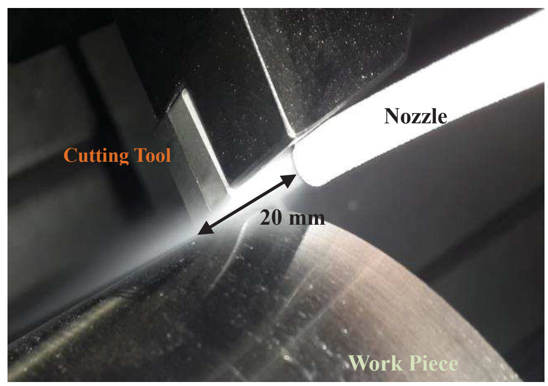

Figure 1 Position of the nozzle.

The machining parameter used in this experiment is shown in Table 1. The same parameter used for both cryogenic and dry condition.

Table 1 Machining parameter.

Parameter	Value
Cutting speed, V_C (m/min)	70,110
Feedrate, f(mm/rev)	0.075
Depth of cut, a_p (mm)	0.1

3. RESULTS AND DISCUSSION

3.1 Wear progression

Comparison of the wear progression between the cryogenic and dry condition shown in Figure 2. From the comparison, it shows that the increase in cutting speed will fasten the wear of the cutting tool under cryogenic and dry condition. However, with the cryogenic condition, it slows down the progression until the cutting tool achieved fracture. The wear criterion found in this study is catastrophic fracture under cryogenic and dry at highest speed, 110 m/min.

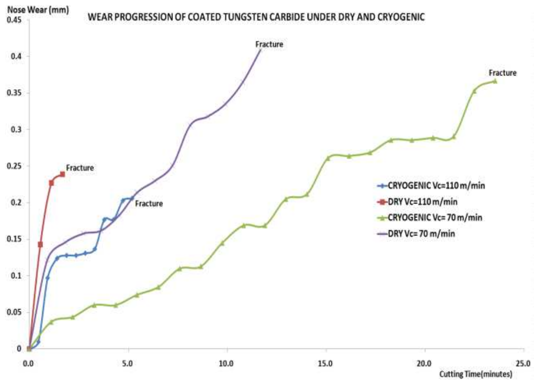

Figure 2 Wear progression under cryogenic and dry condition at Vc = 70 and 110 m/min with constant f=0.075 mm/rev and a_p=0.1 mm.

3.2 Wear mechanism

The cutting tool that has achieved fracture were observed under scanning electron vision. Figure 3 and Figure 4 shows the mechanism of fracture at the edge of the cutting tool. The fractures experienced by the cutting tool under dry condition are gross compared to the cryogenic condition. Moreover, at Figures 3(a), 4(a) and 4(b) show that the material fully adhered to the nose wear region. The built-up edge formed under the dry condition on Figure 3(a).

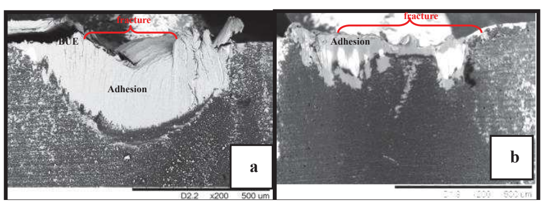

Figure 3 Wear mechanism at Vc=70 m/min for (a) dry and (b) cryogenic from nose view.

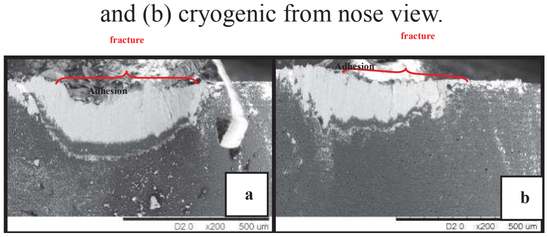

Figure 4 Wear mechanism at Vc=110 m/min for (a) dry and (b) cryogenic from nose view.

Figure 5 and Figure 6 shows the view from the cutting tool edge angle. The chip welded at the rake face of the tool under cryogenic and dry condition. It can be observed that the chip welded under dry condition from figure 5a and 6a are worst than under cryogenic condition from figure 5b and 6b. The built-up layer (BUL) also formed at the fractured edge of the tool under a cryogenic condition at Vc=70 m/min. Apart from that, the adhesion layer formed at the rake face as in figure 5b and 6a. The effect of cutting speed on dry condition does not show much difference.

However, the effect of cutting speed under cryogenic condition shows more adhesion on the nose face at Vc=110 m/min. The built-up layer formed at the fractured edge at Vc=70 m/min.

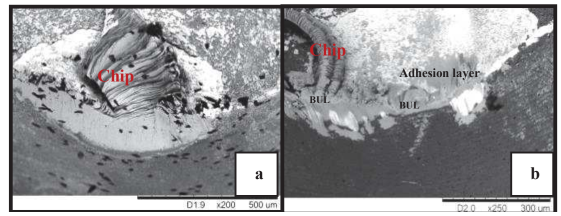

Figure 5 Wear mechanism at Vc=70 m/min for (a) dry and (b) cryogenic from tool edge view.

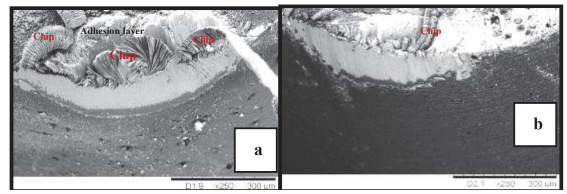

Figure 6 Wear mechanism at Vc=110 m/min for (a) dry and (b) cryogenic from tool edge view.

4. CONCLUSION

For the conclusion, cryogenic machining improves the wear progression and achieve longer cutting time compared to dry. The increase in cutting speed significantly increases the nose wear progression under both conditions. The main wear criterion for this study is catastrophic fracture. In terms of wear mechanism, cryogenic machining reduced the fracture of the cutting edge as compared to a dry condition. Moreover, it is significantly reduced the welding of the chip on the rake face of the cutting tool.

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