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Wear mechanism of carbide cutting tools in machining process

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ABSTRACT – Carbide cutting tool is widely used in machining process due to its availability. It is also cheaper than the majority of better performance cutting tool such as cubic boron nitride (CBN), polycrystalline diamond etc. In addition, the carbide cutting tool has substantial hardness and toughness that is suitable to be applied in intermittent cutting compared to the ceramic cutting tool. This paper presents the case study of wear mechanism experienced on edge of the coated and uncoated carbide tools in machining process (turning and milling). It was observed that the tools failed primarily due to wear on the two main areas of flank and rake faces for machining Inconel 718, and titanium alloy. Therefore it can be concluded that the mode of failure for the carbide cutting tools was similar regardless of the machining operations. The failure is believed to be due to the mechanical properties of the carbide materials such as brittleness rather than the type of machining operations.

1. INTRODUCTION

The cutting process occurs when a small volume of material around the cutting edge is removed either in continuous or intermittent cut. This cutting edge/work-piece interface determines the performance of the tool, the machinability of the material and the quality of the machined surface. During the cutting process, many events occur at the said interface that cannot be observed by the naked eye. They are tool vibration, tool wear, metal flow, and increasing temperatures, which could only be estimated through analytical and experimental methods. Wear rate is defined as the volume or mass material removed per unit time or per unit sliding distance and is a complex function of time [1]. The initial period during which wear rate changes is known as the 'run-in' or 'break-in' period. Wear during run-in depends on the initial material structure and properties and on surface conditions such as surface fluids [2]. Wear of cutting edge is caused mainly by load, friction, and high temperature. Wear mechanism could be classified as adhesion, abrasion, diffusion, oxidation, and fatigue[3].

In machining process, most of the mechanical energy used to remove material becomes heat, which generates high temperature in the cutting region. The higher the cutting speed, the faster the heat generation and higher temperature resulted. The new challenge in machining is to use high cutting speed in order to increase productivity. This is the main reason for rapid tool wear. This paper presents the wear mechanism that caused the failure of carbide tool which commonly occurred on the cutting edge of carbide tools in machining various materials of inconel alloy and titanium alloy.

2. METHODOLOGY

Machining experiments were conducted to study the effect of machining parameters on the wear mechanism and failure mode of carbide cutting tools in milling and turning operations.

Milling was carried out for block of double aging Inconel 718 using tungsten carbide with multi-layer PVD TiAlN/AlCrN grade ACK 300. The tungsten carbide insert was 10 mm diameter, with tool geometry of relief, radial rake, and axial rake angles of 11^{o}, 0^{o}, and -3^{o} respectively. The approach angle was 90^{o}.

Turning was carried out for a cylindrical bar of alpha-beta (α-β) titanium alloy Ti-6Al-4V extra-low interstitial (ELI). A carbide insert with the International Standards Organization (ISO) designation of CNGG 120408-SGF-H13A was used in the machining experiments. The cutting tools used were uncoated, straight tungsten carbide chip breakers with a rhombic shape.

Tool wear measurement was done using a Mitutoyo toolmaker's microscope, 30x magnifications with repeatability ± 3 μm. In order to eliminate any influence of previous cutting effect on work piece, every new layer will be faced/turned using a non-test insert. The tool wear on the flank face was measured after a specific pass interval; the cutting tool would be discarded from the tool holder in order to observe and measure the progression of wear. The wear measurement requirement would then depend on the rate of wear growth. The measured parameter to represent the progress of wear was the maximum tool wear VBmax. The machining was stopped when VBmax = 0.3 mm. This is according to ISO 8688-2-1989, tool life failure for end mill, and ISO: 3685, 1993 for turning. The detailed investigation of wear mechanisms were carried out using scanning electron microscope (SEM).

3. RESULTS AND DISCUSSION

3.1 Wear Mechanisms of Coated Carbide in Milling of Inconel 718

Both uniform (VB) and localised flank wear (VB3) were observed during experiment, at initial stage of cutting time, the growth of flank wear rise steadily with the increase of cutting length. Fig. 1 shows detail of the tool damage during initial stage, which consists of abrasive wear on the flank and rake face causes thinner coating. Sliding force of chip flow and feed force during cutter rotation cause delamination on both sides. Hence, exposed the WC-Co base material. Further repetitive load during interrupted cutting causes pitting on the unprotected cutting edge.

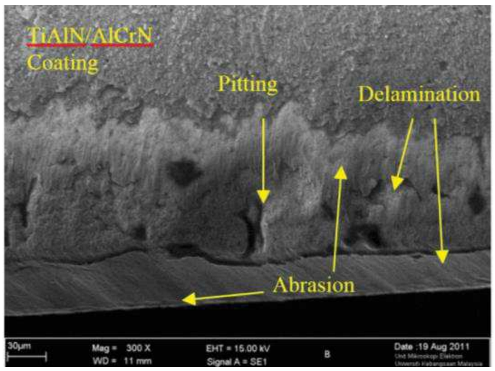

Figure 1 Several failure modes during machining of Inconel 718.

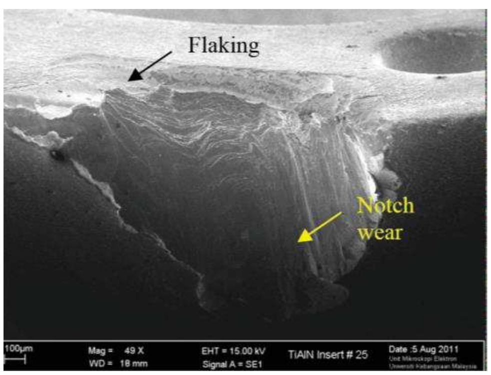

Figure 2 Failure mode observed during catastrophic failure.

3.2 Wear Mechanisms of Coated Carbide in Turning of Titanium Alloy Ti-6Al-4V ELI

At the initial cutting process, the uniform wear on the flank face, nose and rake face were clearly seen. Further cutting caused the wear width on the nose to increase faster than that on the flank and rake faces. Flank wear, nose wear, and crater wear were formed on their respective areas as shown in Fig. 3, as well as temperature-activated wear mechanisms, which adhesion and dissolution-diffusion became predominant. These type of wear mechanisms occurred mostly at the high cutting speed where the temperature generated exceeded the chemical dissolution temperature 1100°C of tungsten carbide. The cutting edge of an insert is subjected to a combination of high stresses, high temperatures, and perhaps chemical reactions, which cause the tool wear due to one or several mechanisms [3].

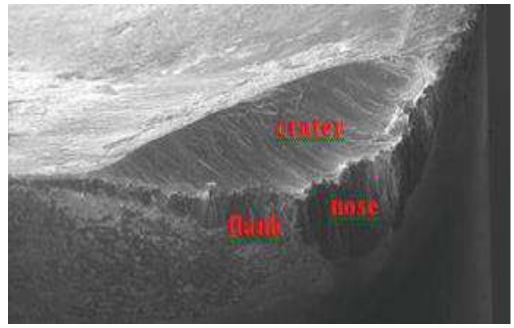

Figure 3 Wear on the uncoated carbide tool edge when turning Ti-6Al-4V ELI.

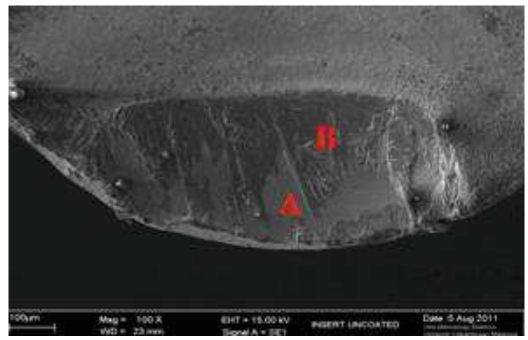

Figure 4 Crater wear on the top rake face of the tool; A) smooth wear area due to diffusion mechanism; B) melted titanium alloy.

4. CONCLUSIONS

From the observation using SEM on the wear experienced on the cutting tools, it can be concluded that the tools failed primarily on two main areas of flank and rake faces for cutting the Inconel 718, and titanium alloy. Wear such as crater, nose wear, abrasion, notching, fracturing, cracking were observed. This finding indicated that the mode of failure for the carbide cutting tools were similar regardless of the turning or milling operations, since the failure was mainly determined by the carbide tool properties such as toughness, hardness and brittleness properties, and the machined work piece material. Furthermore due to the removal of the coating material, the cutting tool fails similar to that with the uncoated tool.

5. REFERENCES

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