STUDIES ON CUTTING PARAMETERS IN MILLING OPERATIONS OF TITANIUM ALLOYS

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Abstract: Titanium and its alloys are the most widely used metals in the aircraft, jet – engine, racing –car, chemical, petrochemical, marine components, and racket motor cases. Effect of various parameters such as cutting speed, federate and depth of cut on the machining process are studied. In this paper to find an appropriate cutting tool for machining titanium alloys, performance of cubic boron nitride tools, and to evaluate the performance of the different cutting tool materials in terms of tool wear, tool life and cutting forces.

Key words: Machining, titanium alloys, cutting speed, tool life

1. INTRODUCTION

Titanium alloys are considered as difficult –to-machine materials because of their low thermal conductivity (i.e., 20 W/mK), high chemical reactivity, high strength –to-weight ratio and low modulus of elasticity (i.e., E=12.7 x 10^4 MPa). Its mechanical properties can be better than those of many alloy steels, and thus it has a very high specific strength. Even, advanced cutting tool materials like polycrystalline diamond (PCD) and cubic boron nitride (CBN); also pose difficulties in machining titanium and its alloys. The CBN layer provides very high wear resistance and cutting-edge strength. The predominant reason for tool wear in the machining of titanium alloys with these CBN compacts is diffusion dissolution of the binder material, i.e., cobalt, into the chip [1]. High purity polycrystalline binder less sintered bodies of CBN (BCBN) compacts are free from the abovementioned effects of binder and exhibit excellent mechanical properties, superior thermal stability, and thermal crack resistance, which are essential to the selection of a cutting tool material for high-speed machining. In this paper [2], the recently developed BCBN compacts have been found to show significantly improved performance in the machining of gray cast iron. In this study, an attempt has been made to compare the performance of CBN, BCBN and PCD tools when high-speed machining of a Ti-6Al-4V alloy.

2. EXPERIMENTAL SETUP

The experiments were performed using a three-axis CNC vertical milling machining with a maximum feed rate of 50m/min and spindle speed of 15-25000rpm. BCBN inserts, CBN inserts and PCD inserts have been used to perform full immersion milling through the center of the Ti-6Al-4V (ASTM B 265 Grade 5) work pieces. It has a built-in high –pressure coolant supply system (40 bar).

3. RESULTS AND DISCUSSION

The cutting tests cover a range of cutting speed (V_c= 250-400 m/min), feed rate (f=0.05-0.2mm/tooth) and depth of cut (a_p= 0.05-0.2 mm) to evaluate the performance of the different cutting tool materials in terms of tool wear, tool life, cutting forces, and the surface finish produced. In the previous studies [3,4], that high-pressure coolant enhanced tool life by improving coolant penetration into the tool tip interface, when machining difficult-to-cut materials. Consequently, all the tests were carried out using high-pressure coolant.

3.1 The Effect of cutting parameters on tool life

At a cutting speed of 400m/min, feed rate of 0.05 mm/tooth and depth of cut of 0.05 mm as shown in fig 1.It shows the time domain chart for the flank wear of the tool. It can be seen that BCBN and PCD tools exhibit distinctly longer tool life than CBN tools used.

Figure 1 Variation of flank wear with machining time (cutting speed Vc=400m/min, feed rate, f =0.05 mm/tooth, depth of cut, a= 0.05mm). Flank wear as a function of machining time at a cutting speed of 400 m/min, feed rate of 0.75mm/tooth and depth of cut of 0.05mm as shown in fig 2.It is observed that the flank wear of BCBN tools is uniform and progressive when using higher fed and low depth of cut. Initially, the wear of PCD tool is higher than BCBN tools but its wear rate is gradually reduced.

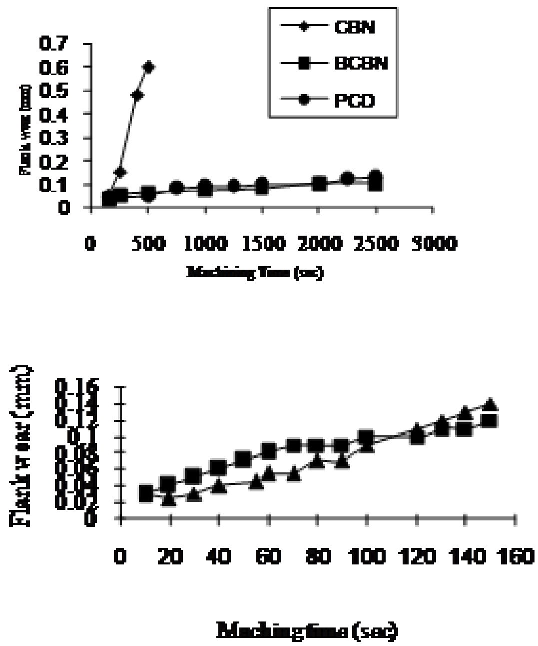

Figure 2 Variation of flank wear with machining time (cutting speed Vc=400m/min, feed rate f=0.75 mm/tooth, depth of cut =0.05mm)

The cutting speeds were varied from 150 m/min to 500 m/min while keeping feed rate 0.05 mm/tooth and depth of cut 0.05 mm. Fig 3 shows that the tool life of conventional CBN tools is the lowest and even decreases with an increase in the cutting speed.

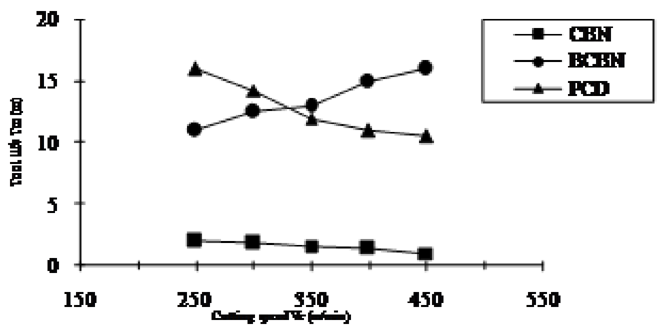

Figure 3 Effect of cutting speed on toll life (feed rate f=0.05 mm/tooth. depth of cut a =0.05mm)

The tool life of PCD tools is longer at low cutting speeds and decreases with increase in the cutting speed. The toughness of the BCBN tools is higher than PCD and CBN tools even though the PCD tools posses higher hardness.

3.2 The Effect of cutting parameters on cutting forces

Fig 4 shows that three components of the resultant cutting force-Fx, Fy, and Fz are higher for CBN tools and it appears to be low at a cutting speed of 350m/min. There is no significant changes in the cutting forces were observed with cutting speed for PCD tools. Only the tangential cutting force Fz shows slight variation with cutting speed in the case of BCBN tools. For BCBN tools, all three components of the cutting force decreased with the increase in cutting speed .The behavior of cutting forces is intimately correlated to the frictional characteristics at the chip tool interface. Since the thermal conductivity of the CBN tool is lower, the tool wear is higher, which increases the friction between the tool and the chip . This leads to the increased cutting forces. The cutting forces are less with less feed rate and low depth of cut and they were not much affected by the increase in cutting speed.

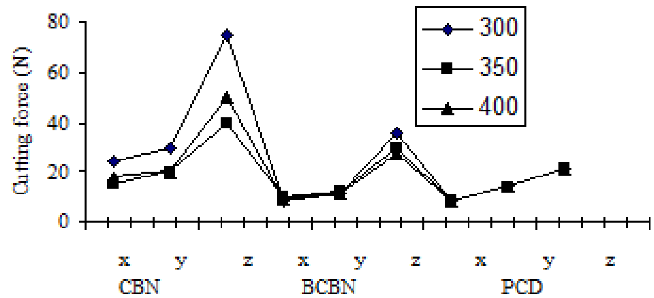

Figure 4 Effect of cutting speed on cutting force (Cutting speed, Vc= 300, 350, 400 m/min, feed rate, f=0.05mm/tooth, depth of cut, a =0.05mm)

3.3 Effect of cutting parameters on surface roughness

By machining of Ti-6Al-4V alloys with CBN, BCBN, and PCD tools, the surface finish is obtained in the reasonable range of 0.12µm - 0.5µm. At higher cutting speeds, BCBN tools produce the best surface finish. The surface finish improves with the increase in cutting speed for PCD and BCBN tools. At lower cutting speed with low feed and depth of cut, the tool tends to rub on the surface rather than cutting, which deteriorates the surface finish. The improvement in surface finish with the use of high-pressure coolant is probably attributed to better lubrication. The coolant supplied at high pressure reduces the tool-chip contact area and also the frictional force at the tool-chip interface.

4. CONCLUSIONS

From this paper, the following conclusions can be made:

- The BCBN tools show significantly improved tool life, better surface finish, and lower cutting forces.
- The PCD Tools are chemically active with titanium alloys at higher cutting temperatures.
- High-pressure coolant produces better lubrication and more efficient cooling at the chip-tool interface.
- The BCBN tools are free from the binder element cobalt that readily reacts with titanium. Chips produced by BCBN tools show no diffusion of the tool materials. This results in longer tool life of BCBN tools.
- The BCBN tools are more suitable cutting tool materials for machining titanium alloys, both economical and functional aspects.

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