Dry condition Turning of AlN-TiC Tool Inserts Contrived from Electric Discharge Plasma Activated Sintering

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Abstract

This paper deals with the fabrication of developed AlN-TiB2 based ceramic insert and comparative evaluation of the performance of the developed ceramic insert with commercially available Al2O3-TiC ceramic inserts. Nitriding process is utilised to make Aluminium nitride (AlN) and TiC (Titanium carbide) powders are produced by in-situ reaction of Potassium tetra Fluoroborate and Potassium Fuorotitanate along with Aluminium alloy, by liquefying the Aluminium-TiC composite in heavy denser acidic liquid. The AlN-TiC based ceramic insert is prepared by Electric Discharge Plasma Activated Sintering (ED-PAS) of 30% TiC (Titanium carbide) particles and 67% AlN (Aluminium nitride) with some additive Al2O3 (3%). Sintering is carried out at maximum temperature of 15600ºC with a load of 60 Mega Pascal with eight minutes of sintering. The sintering is conceded in a vacuum atmosphere. The sintered ceramic insert has high hardness and extraordinary toughness of nearly 14.7 GPa 6.5 MPa.m1/2respectively. The performance is evaluated by machining experiments made out on hardened EN 24 (Euro Norm 24) steel. The developed Aluminium nitride insert displayed resistance to wear and delivered superior surface finish compared to market available TiC ceramic inserts. Tool dynamometer was used to monitor the cutting forces in the lathe to relate the recorded parameters with the tool wear. Scanning Electron Microscopy is used to study the tool wear more accurately and the SEM images are in favour of the results.

Keywords: Ceramic insert, AlN-TiB2, Electric Discharge Plasma Activated Sintering, EN24, Dry turning

1. Introduction

The advanced ceramic cutting tools have very high wear resistance, good mechanical and hot hardness. Chemically they are more stable than high speed steels and carbides thus have fewer tendencies to react with work material and to form built up edge. Because of their high strength, extremely high resistance to wear and cratering, capabilities of running at high speed and low thermal conductivity, ceramic and ceramic composites remains attractive candidate material for cutting tool applications. The unique chemical and mechanical property of the ceramic inserts can offer increased metal removal rate, extended tool life and also have ability to machine hardened materials like stainless steel and hardened steel. Innovative ceramic engineering on high-temperature structural ceramics has resulted in an impressive array of high-performance ceramic cutting tools which have had a major positive impact on manufacturing and productivity, particularly with regard to metal cutting.

Alumina toughening is the significant advancement in ceramic engineering, which has increased the fracture toughness of ceramic tools considerably. It is also to be noted that self-lubrication (dry turning) of ceramic insert reduces both production cost and human hazards. Several authors reported the ceramic insert usage in dry machining [2-8].The admixture of alumina based improved ceramic composites useful as a cutting tool [9-10]. Mixed particles can be milled using planetary ball mill to increase sintering efficiency. It also reduces particle size thus increase the composite strength [11-12]. Difficult to sinter powders can easily consolidated by plasma activated sintering than conventional hot pressing and they also provide near net shape geometry [13-14].

In the present study AlN-TiB2 ceramic insert is fabricated by Electric Discharge Plasma Activated Sintering (EDPAS) and their performance is evaluated by machining hardened steel (EN24). The cutting force, surface finish and flank wear are evaluated after machining. SEM images are included to support the results. The hardness and toughness of the developed insert is higher than the existing one.

2. Experimental Method

Commercially available high purity atomized Aluminium powder is taken to react with high purity nitrogen in the production of high purity AIN powder. The Direct Nitridation has advantage of low cost due to simple reaction system. Even though the reaction starts at a temperature of 4750C, the direct nitridation process takes about 15000C to complete the process. The reason behind this is that the large heat of nitrogen makes the unreacted aluminium to melt and react to produce aluminium nitride. Perfect nitridation of aluminium requires heating at high temperature for a long time [15].

The reaction between molten Al and the mixture of KBF4 and K2TiF6 (salt-metal) produces in situ TiC particles. The process parameters involved are reaction time and reaction temperature is about 30 min and 7500C respectively. Thus the produced materials are used for making developed inserts are 67% of AlN, 30% of TiC and 3% of Al2O3 (additive).The particle size of AlN, TiC and Al2O3 are 3-5µm, 3-5µm and 4-5µm respectively. Planetary ball milling of mixed powders is conducted with WC (Tungsten Carbide) ball and jar for 18 hours using stearic acid as a milling media to obtain mixed powders and also to prevent agglomeration. Approximate weight of mixed powders poured in Graphite die is about 4 grams. Graphite insulation is made in the graphite die to prevent interaction of powders with the mold. The electric discharge plasma activated sintering is carried out at a temperature of 15600C with heating rate of 1500 C/min with holding time of 8 minutes and uniform compaction load of 60 MPa. The square shaped insert having length of 13 mm each and 4.85 mm thickness after sintering. Figure (1) shows the insert specifications. All the inserts are fabricated according to SNGN (Square Double –sided ceramic) configuration.

T (mm)	A (mm)	R (mm)	B (mm)
4.65	12.0	0.25	2.5

Fig .1 Fabricated Insert Specifications

The fabricated insert performance is tested on hardened steel (EN24) work piece material. The dry turning experiments are

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conducted for different cutting speeds of 11.1m/min, 27.7m/min, 66.8m/min and 246.8 m/min, at constant feed rate of 0.1 mm/rev and depth of cut 0.3 mm for 60 seconds. The developed ceramic inserts are used for various experiments. Cutting forces are recorded with Kistler® dynamometer to correlate them with the tool wear. The mechanical properties of the developed ceramic inserts are tested. The fabricated inserts have high hardness of 16.5 GPa and extraordinary toughness about 7.5 MPa.m1/2.

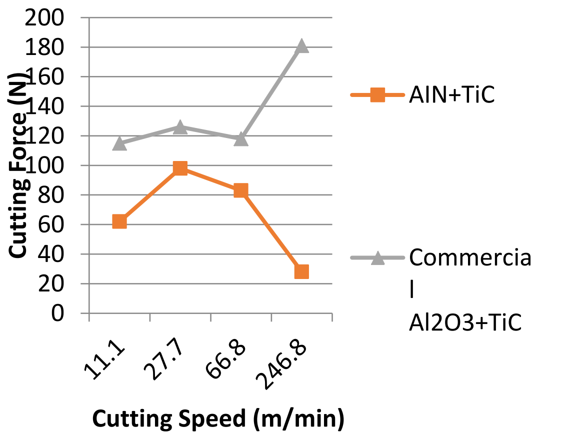

Fig. 2 Cutting Speed Vs Cutting Force

3. Findings and Discussion

The effect of Cutting speed on Cutting force for the dry turning process is shown in Fig. 2. It gives the comparative analysis between commercial insert Al_2O_3 + TiC and developed insert AlN + TiC. From the graph it is obvious that the cutting speed of the process which uses the developed insert is very less compared to the process which uses commercial insert, at any cutting speed. The effect of cutting speed on flank wear of the developed insert is shown in Fig.3. Also a comparative analysis of flank wear on cutting speed of the developed insert and commercial insert are indicated. It clearly shows that at any cutting speed, developed insert flank wear is very less compared to commercial insert.

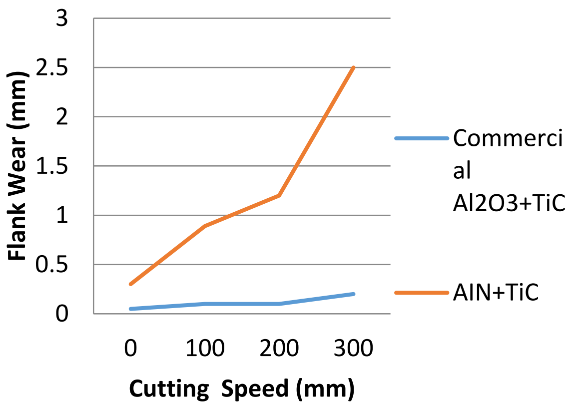

Fig.3 Cutting Speed Vs Flank Wear

Surface roughness of the work piece material which is dry turned by both developed insert and commercial insert is also measured. The effect of cutting speed on surface roughness for developed and commercial inserts are shown in Fig.4. From the graph it is concluded that the surface roughness of the work piece material which is dry turned with developed insert is very less than the surface roughness obtained using commercial insert when the cutting speed is higher than 27.7 m/min.

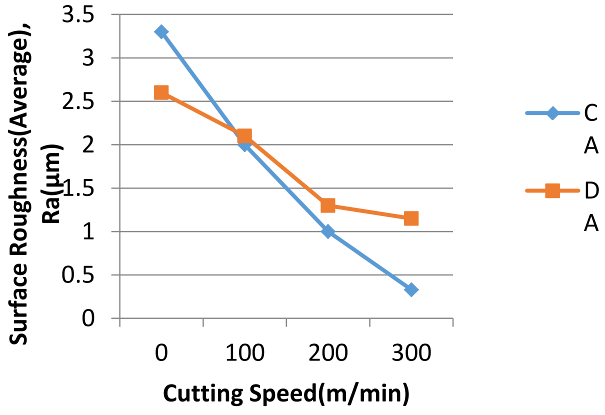

Fig. 4 Cutting Speed Vs Surface Roughness

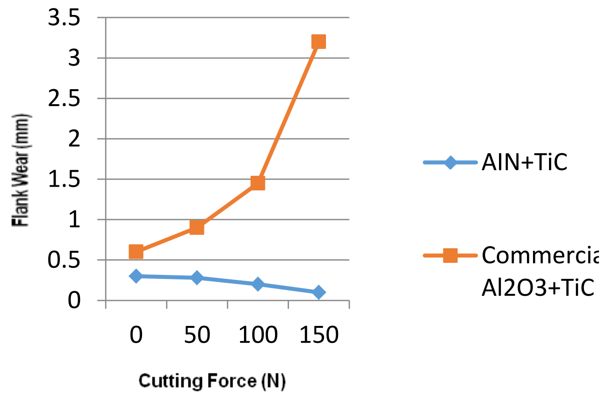

Fig. 5 Cutting Force Vs Flank wear

Fig.5 shows the effect of cutting force on flank wear of both the developed as well as the commercial inserts. From the graph it is evident that the commercial insert flank wear is increasing with cutting force but in developed insert, the flank wear is very less. This may be due to high hardness and toughness of developed insert. To further substantiate the less flank wear of the developed insert, micrographs are taken with the help of scanning electron microscope (SEM). To have a visual comparison of the flank wear between developed insert and commercial insert the SEM images are shown in Fig.6 and 7 respectively.

Fig 6. SEM images of Developed insert (AlN-TiC-Al2O3)

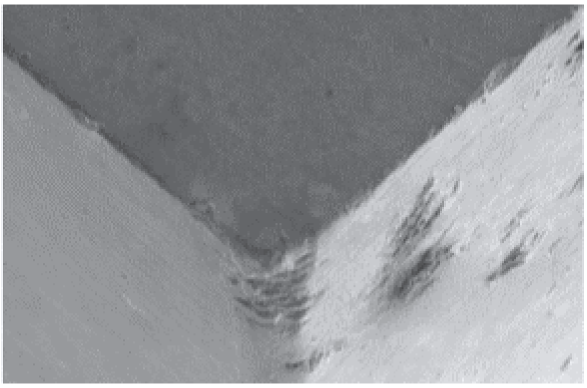

Fig 7. SEM images of Commercial insert (Al2O3-TiC)

4. Conclusion

It is to be noted that the mechanical properties of the developed insert has a high hardness of 14.7 GPa and toughness of 6.5 MPa.m1/2. The following are the dry turned results of hardened steel (EN24) using developed insert AlN-TiC-Al2O3 and commercial insert Al2O3- TiC:

1. Lesser cutting force was found while dry turning of hardened EN24 using prepared inserts when matched to market available inserts at higher speeds of cutting.

2. Lower surface roughness of dry turned EN24 was found in new prepared inserts.

3. Flank wear was very low in prepared inserts than market available insert while

considering cutting speed as well as with respect to cutting force

The all the above results detailed, particularly surface roughness of EN24 and flank wear of the new prepared inserts, it is commended that the developed insert can be replaced in favour of commercial inserts for dry turning applications.

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