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Tool Life and Tool Wear for CBN and Alumina based Ceramic Tools

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Abstract: In present times there are still many issues in the field of micro-machining for materials which are hard to machine like short tool life and rapid tool wear of the machining tools. Considering titanium alloy TI-6AL-4V in study some standard procedures and conditions were followed which were ISO standard in life testing for milling and in turn it was used to predict tool wear of tungsten carbide for micro end milling and groove milling. Some factors like cutting-edge radius, tool volumetric change and Flank wear rate determines the tool wear.

I. INTRODUCTION

While doing machining of alloys which are Heat resistant comes into picture the demand for increasing productivity has turned out to use of some other materials used in making tool such as cubic boron nitride (CBN) or ceramics. However, in the automotive industry in the wear of those tools and hard turning is not sufficiently known in aerospace materials CBN tools are mostly used. There are wear data that are making use of multiple regression analysis (MRA) to evolve various tool wear models using mathematical approach.

One of the essential tool life factor for analyzing the major factor like executing effect of the cutting tools. It is observed that Tool wear have adverse affects on surface quality & eventually it also affects the dimensions of the workpiece. There are some tool wear criteria and when tool reaches that, it can't be used further as cutting edge won't work and fail. There are some notable wear like wear land, notch wear and crater wear.

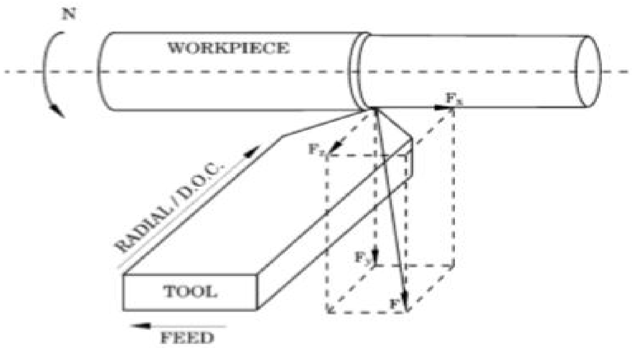


Fig. 1. Cutting force components in turning operations.

Currently, so many research in this field during past period of time and have greatly contributed to our-understanding of the issues. Still there are not proper relationships about cutting and tool's geometry. Apart from all the advancement in the field there are some complexities which are still prevailing like processes of machining which involve extreme conditions of increasing temperature and strain-rates. And all of this mostly happens due to lack to adequate data.

In order to achieve proper cutting design tools & adequate cutting environment, and also for tool change strategies.

Material removal in micromachining based on micromachining capabilities is very much restricted to material removal process, where without affecting the quality of the finished product directly affect tool cutting radius and material properties.

For machining hard objects such as cast iron were hardness vary a lot, in such cases alumina based ceramic composites are widely used. There are different ranges of hardness, extreme temperature alloy, stainless steels posses very high hardness and good chemical stability. Mixed cutting tools of alumina ceramic and whisker reinforced cutting tool made of alumina ceramic, Aluminum oxide-based ceramic are majorly put up in the category of plain carbon steels.

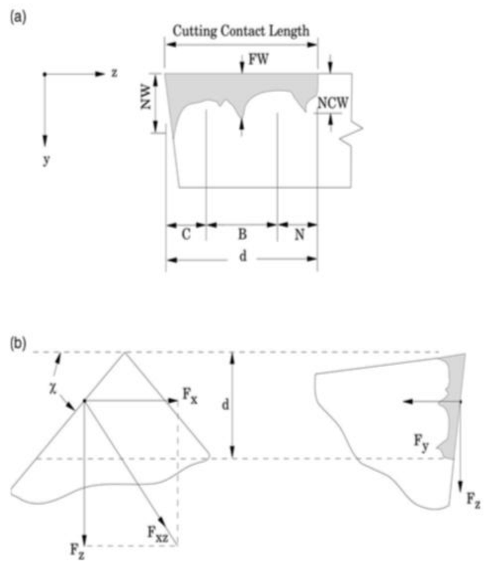
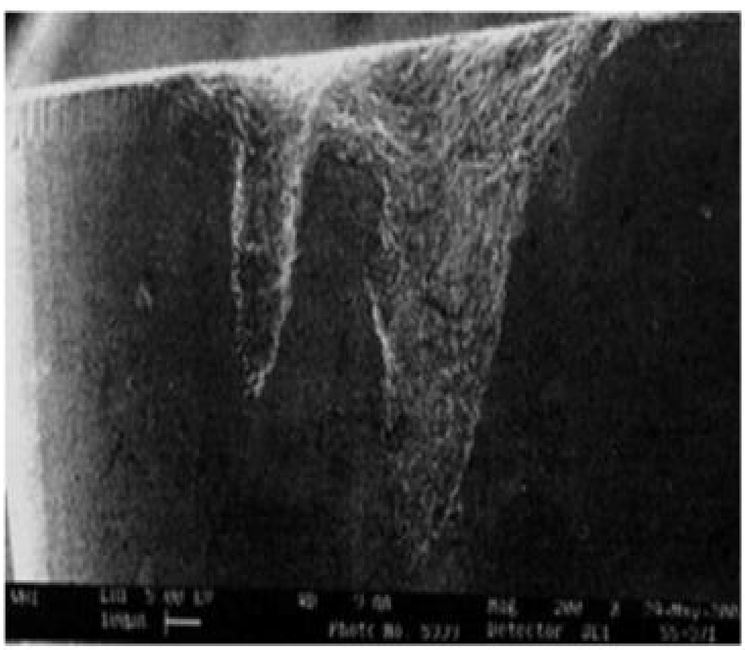


Fig. 2. Force system and wear distribution on the cutting edge. (a) Flank wear elements and (b) force system.

While turning, there so many chances of catastrophic tool failure which can be and must be avoided so that it doesn't damage, the tool and/or the machine tool and it is important as it can cause obstacle in Material removal in micromachining based on micromachining capabilities is very much restricted to material removal process, where without affecting the quality of the finished product directly affect tool cutting radius and material properties. Out of which these two, effective tool life is often used to define by the end of flank wear. Flank wear has influence on component stability, dimensional accuracy and surface quality of the material while it's machining.



Notch wear in Ti[C, N] mixed alumina ceramic cutting tool (tool C) on machining martensitic stainless steel.

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II. TOOL WEAR/LIFE RELATIONSHIP

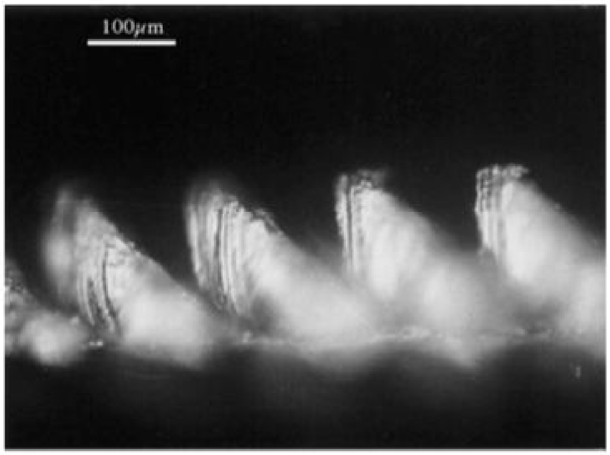
The Taylor's equation is very well known and is used to find tool life expectancy which provides a good approximation.

$$T\ Z^{A_t}\ (1)\ V^{bt}$$

This formula is very useful and very widely used in operations. PCD & PCBN tools as well as for machining WC this equation is used which is mostly used for high speed steel tools. But this equation in some cases doesn't prove well like change in dominant wear mechanism with different cutting conditions.

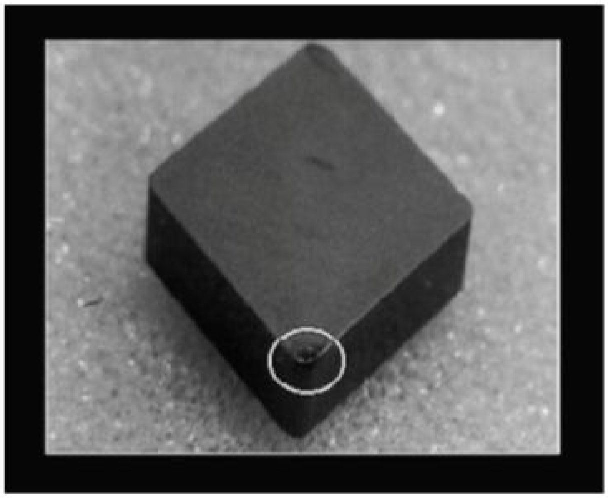
III. ABRASIVE & CRATER WEAR:

Dislodged abrasive grains of tool which undergoes mechanical abrasive wear as there are hard abrasives contained in the work material. For avoiding this it is very essential that micro cutting process the chip doesn't accumulate at the cutting tool tip and leave immediately. This wear is very much closely related to the hardness distribution density of the abrasive and shape as well as distance of the cut.



Optical micrograph of saw tooth type of martensitic stainless steel chip.

It is most certain that mostly, flank wear is primary wear factor for determining the tool life of the Alumina based ceramic tools, but other wear factors like abrasive and crater wear are also play a vital role in determining the life of the tool. In operation, the weaker interface bonding of different CBN and alumina based cutting tools main lead to adhesion and high wear rate.



Photograph of SiC whisker reinforced alumina ceramic cutting tool showing crater wear region.

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IV. TOOL BINDER INVESTIGATION AND EFFECTS OF BINDERS

A. Experiment on CBN Inerts

In an experiment 27 CBN inserts which were first of cutting tests set was conducted which also included various kinds of binders, CBN content grain size. The chosen height of the CBN layer was decided as 0.7mm. CBSNR 2525M09 was considered as the tool holder. The varying ranges of the CBN content were somewhat between 50-95% and the sizes of the grain were varying between 2-8mm.

Chemical composition of Inconel 718 (in % of mass)

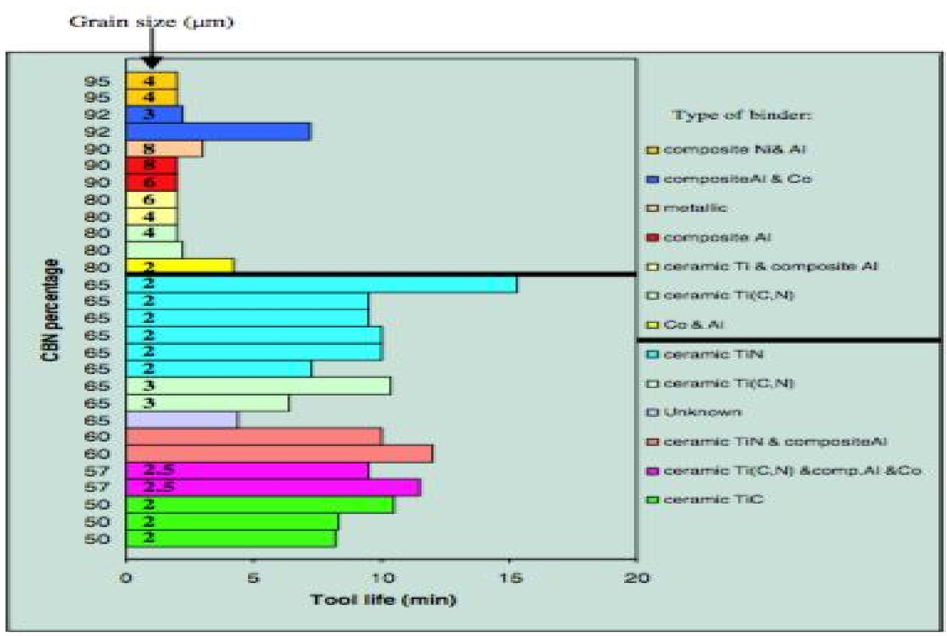
Inconel 718: NC 19 Fe Nb					
Ni 50–55	Cr 17–21	Co 1 max	Mo 2.8–3.3	Al 0.3–0.7	C 0.02–0.08
Si 0.35 max	Mn 0.35 max	Fe rest	Cu 0.2 max	S 0.015 max	P 0.015 max
B 0.006 max	Nb + Ta 4.8–5.5	Ti 0.7–1.15			

The outcome of this experiment was that the tool was worn and the considered flank wear was 0.3mm.Al2O3, carbide and nitride was the component of the binder called ceramic.

The above experiment conducted shows the relation of binder and CBN content on the tool life of the material. From the studies and experiments conducted it is observed that the longest tool lives are outcome of low CBN content(lesser than 65%). For content(more than 80%), the expected tool lives are approximately to 3 min. on taking average. The fig. below shows us that the binder is composed of composite of Al and Co. which is a *ceramic. Also from this fig. we can observe the graphical representation of the effect of content in CBN & Binder on tool lives.* (V_B =0.4mm).

Details of composition and properties of the cutting tool materials

Details of tool material	Unit	Tool A	Tool B	Tool C	Tool D
Composition		Al_2O_3 (96.5%), ZrO_2 (3.5%)	Al_2O_3 (70%), Ti[C, N] & ZrO_2 (30%)	Al_2O_3 (70%), TiN (22.5%), TiC (7.5%)	Al_2O_3 (80%), SiC_w (20%)
Insert specification		CNGN 12 07 08-T	CNGN 12 07 08-T	CNGN 12 04 08 T01020	CNGN 12 04 08 T01020
Density	g/cm^3	4.02	4.25	4.26	3.74
Vickers hardness	HV	1730	1930	1800	2000
Transverse rupture strength	MPa	700	620	550	900
Young's Modulus	GPa	380	400	400	390
Fracture toughness	$MPa\,m^{1/2}$	4.5	4.5	4.0	8.0
Thermal conductivity	W/mK	16	20	24	18
Coefficient of thermal expansion	$K^{-1} \times 10^{-6}$	8	8	8.6	6



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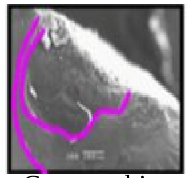
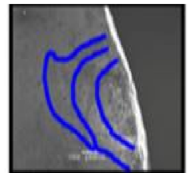
V. STUDY OF CUTTING SPEED EFFECT ON WEAR

Various procedures were conducted to examine which were taken with CBN & alumina based ceramic tools, the outcome of the tests were the CBN & alumina based ceramic composition in the material was under 70% with the constant size of the grain of 1mm. Three CBN were considered for the test: 35%,50% and 65% along with different cutting speeds: 300,350,400 m/min. the provided feed rate was 0.5mm/rev and depth of cut is 0.6mm. Keeping track of time of about 50 to 400s and the flank wear was observed. It was seen that with feed rate of 400 m/min of cutting speed it was low and 1800m length of cut.

Progressive Wear (1)



Catastrophic Wear (2)

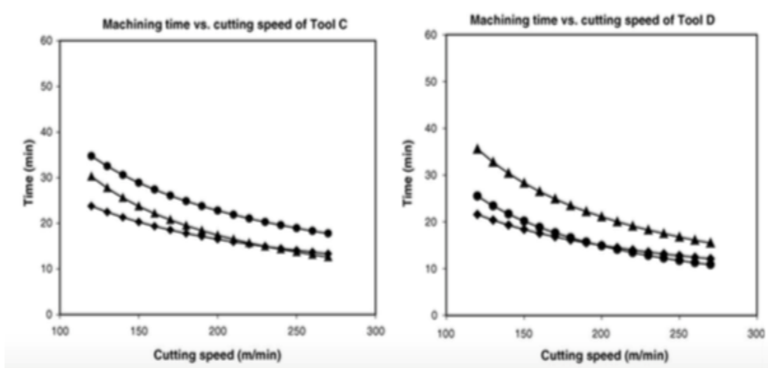


Chipping (3)

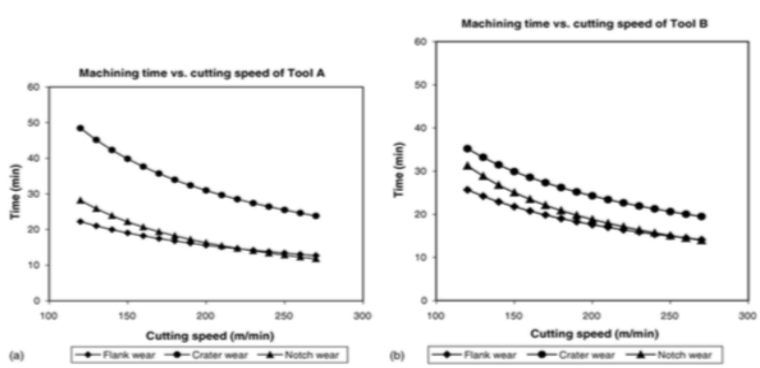
All of this study is adequate and possible due to the cutting forces that are measured at the time of machining. The use dynamometer is taken in action to measure the longitudinal force measurement while turning operation.

VI. CONCLUSION

This investigation of the effect on mixed cutting tools of alumina ceramic and whisker reinforced cutting tool made of alumina ceramic, Aluminum oxide-based ceramic are majorly put up in the category of plain carbon steels and concluding the study of parameter for rejecting the tool used for micro-milling machining for the material with are hard to cut. Volumetric tool loss, finished surface roughness, cutting-edge radius, flank wear rate were the major factors that affected the tool wear rate.



At initial stage there is instantaneous tool wear which is cased due to very high stresses developed in the material, majorly at the tip of it. Wear rate is more or less linear in the secondary stage and in the final stage wear rate might casuse sudden increament in the temperature and the pressure at the cutting point due to high forces resulting in fast resulting in catastrophic failure. Crater wear leads to weakening of the tool. Because of flank wear there are brittle and discontinuous chips and it increases with the increasing speed. Measurement of the tool life can be done using tool wear criteria and when tool reaches that, it can't be used further as cutting edge won't work and fail.



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From different studies we came to an conclusion that the wear properties for steel is diffusion and chemical wear for the PCB. The lower speed of the cutting tool will ultimately affect the flank wear, while the high speed like above 25 m/min affects the tool life due to crater wear or notch wear. A lot more studies have shown focused effect on the grain size on the tool life. For machining at different feed rates, the plot of measured diameter for the tools with different speeds.

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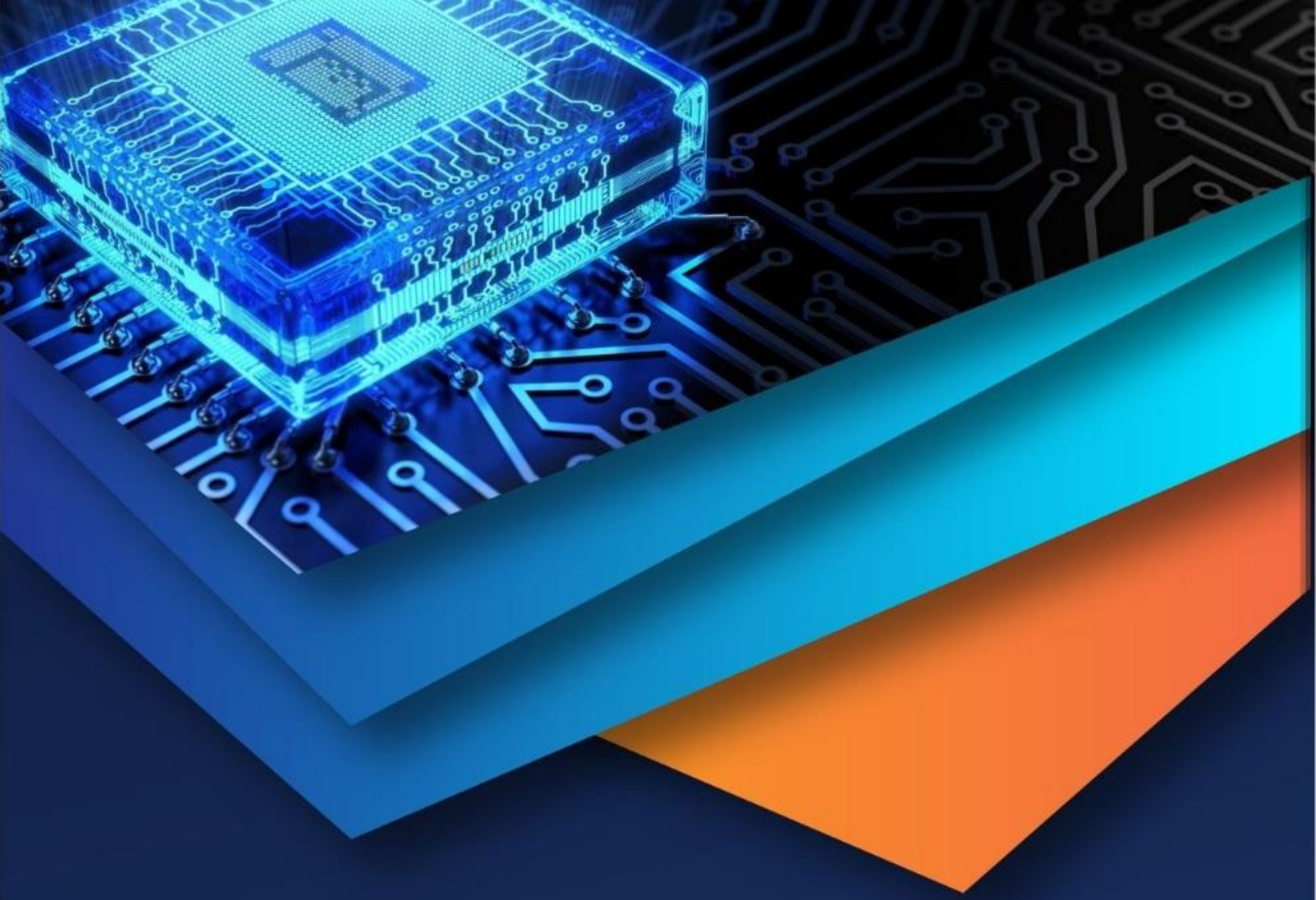

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