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.

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. [1] 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 factors for analyzing the major factor like executing effect of the cutting tools. It is observed that Tool wear have adverse effects on surface quality & eventually it also affects the dimensions of the work piece. 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. (Figure.1)

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. [2] 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.

**Figure 1:***

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 [3] 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.(Figure.2)

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. (Figure.3)

**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.

\[
T = \frac{Z}{A} \frac{1}{V} \frac{1}{b} \frac{1}{t}
\]

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.

**Abrasive & Crater Wear**
Dislodged abrasive grains of tool which undergoes mechanical abrasive wear.

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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. (Figure.4) 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. [4] In operation, the weaker interface bonding of different CBN and alumina based cutting tools main lead to adhesion and high wear rate. (Figure.5)

Tool Binder Investigation and Effects of Binders

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. [5] CBSNR 252509 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. (Table.1) 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.[6] 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. (VB =0.4mm). (Figure.6), (Table.2)

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...

Table 1.

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

Table 2.

| Details of composition and proteins of cutting tool materials |
|-------------------------------------------------------------|
| Details of the tool material                                |
| Unit            | Tool A | Tool B | Tool C | Tool D |
| Composition     | Al₂O₃  | Al₂O₃  | Al₂O₃  | Al₂O₃  |
| Al₂O₃ (96.5%)   | (70%)  | (70%)  | (70%)  | (80%)  |
| Inert specification | CNGN  | CNGN  | CNGN  | CNGN  |
| 120708-T        | 120708-T | 120408-T01020 | 120408-T01020 |
| Density g/cm³   | 4.02   | 4.25   | 4.26   | 3.74   |
| Vickers hardness | HV     | 1730   | 1930   | 1800   | 2000   |
| Rupture strenght | GPₚ   | 300    | 400    | 400    | 390    |
| Fracture toughness | MPam⁰  | 4.5    | 4.5    | 4.0    | 8.0    |
| Thermal conductivity | W/mK | 16     | 20     | 24     | 18     |
constant size of the grain of 1mm. [7] 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. [Figure 7] Keeping track of time of about 50 to 400s and the flank wear was observed. [8] It was seen that with feed rate of 400 m/min of cutting speed it was low and 1800m length of cut. All of this study is adequate and possible due to the cutting forces that are measured at the time of machining. [Figure 8] The use dynamometer is taken in action to measure the longitudinal force measurement while turning operation.

From different studies we came to an conclusion that the wear properties for steel is diffusion and chemical wear for the PCB. [12] 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. [13] A lot more studies have shown focused effect on the grain size on the tool life. [14] For machining at different feed rates, the plot of measured diameter for the tools with different speeds. [15]

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