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Research Article

Effect of Cutting Parameters on Tool Life

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Abstract

In metal cutting operations, it is desirable to study the tool wear, dimensional accuracy, surface roughness and the cutting parameters that affect the tool life. Flank wear of cutting tools is often considered as the tool life criterion because it determines the diametric accuracy of machining, its stability and reliability. The present work shows how the life of the cutting tool can be calculated taking into account the cutting parameters such as cutting speed, feed and depth of cut, workpiece material, power of the machine, the dimensional tolerance of the part, the geometry of the cutting tool, operating conditions of the machine tool and the finishing surface etc. The tool life of cutting tool insert was investigated by the dimensional tolerance set for the workpiece. In order to study the tool life, model of cutting tool insert is built by the Pro-e Wildfire 5.0, and model file is imported into ANSYS Workbench 14.5 software so as to carry out the post-processing by the finite element and subsequently tool life is analyzed.

Keywords: *Cutting Parameters, Cutting Force, Tool Wear, FEA, Tool Life.*

1. Introduction

The selection of proper cutting tool is an important parameter in the machining process of a part in production. It performs the cutting action that helps in getting required surface finish and accuracy of the part. In order to perform these tasks the tool should possess some special characteristics. Some of the important characteristics are hardness, toughness, wear resistance and chemical stability or inertness with respect to the workpiece material (S. Kalpanjian, 1995). It helps to withstand wear resistance and serve for long period of time to produce more number of components with same accuracy. Machining is an important part of metal manufacturing process to achieve desired shape, good dimensional accuracy and aesthetic requirements. In modern machining process while using the CNC machine tools the cutting tool with various types of tool inserts will play a vital role in machining process and in improving the surface finish. Many cutting tool manufacturing organizations globally with their rich experience of research and development, invented different ways of enhancing the life of cutting tool in order to optimise the rate of the production and to reduce the cost of production, which is the objective of the manufacturing Industry.

1.1. Tool Wear

Cutting tools are subjected to rubbing process and they are in metal-to-metal contact, between the chip and work piece, under conditions of very high stress at high temperature. The situation is further provoked due to the existence of extreme stress and temperature gradients near the surface of the tool. During cutting, cutting tool remove the material from the component to achieve the required shape, dimension and finish. However, wears are occurring during the cutting action, and it will result in the failure of the cutting tool. When the tool wear reach certain extent, the edge change or tool has to be replaced to guarantee the ordinary cutting action known as tool life. Under high temperature, high pressure, high sliding velocity and mechanical or thermal shock in cutting area, the cutting tool has normally intricate wear appearance, which consists of some basic wear types such as crater wear, flank wear, thermal crack, fatigue crack, breakage of inserts, plastic deformation etc. In order to find out suitable way to slow down the wear process, many research works are carried out to analyze the wear mechanism in metal cutting. It is found that tool wear is not formed by a unique tool wear mechanism but a combination of several tool wear mechanisms.

In metal cutting tool wear mechanism includes abrasive wear, adhesive wear, delamination wear, solution wear, diffusion wear, oxidation wear, electrochemical wear, etc. Among them, abrasive wear, adhesive wear, diffusion wear and oxidation wear are very important (Cho S. S., Komvopoulos K., 1997). An investigation is carried out for the performance of uncoated and coated carbide tools of ISO grade K10 with a 3μm thick monolayer of TiN

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when continuous turning AISI 8620 steel(Renato Franc¸oso de Avila *et al*, 2006). For this purpose a topographic analysis was employed to assess the crater wear volume evolution. The experimental work shows the results of dry turning using CVD multi-layer coated cemented carbide tools (I. Ciftci, 2006). The effect of cutting speed and feed rate variation on tool life and possible tool wear modes of failure are found in milling operation (K.A. Abou-El-Hossein, Z. Yahya, 2005). Analysis is carried out for wear and failure mechanism of cemented carbide tools in milling process using SEM analysis (H. Shao, L. Liu, H.L. Qu, 2007). They predicted that the tool wear progression follows a three-stage wear pattern that is abrasive, , adhesive and diffusive wear appear in different stages.

1.3. Tool Life

In manufacturing field tool life measured in terms of time, no of components produced, length of path travelled depending on the application. Evaluation of tool life in machining operation is a key job. Some time it needs skill of operator also. According to DIN 6583 standard, the tool life criterion under the influence of tool life conditions, tool life parameters are used. Tool life parameters are time, quantities and paths achieved in chipping under specified conditions until a tool life criterion is reached.

These parameters include [DIN6583]

- Tool life,
- Tool life travel path,
- Tool life volume, and
- Tool life quantity

The wear takes place at cutting edge surfaces represents tool life, which can be measured directly or indirectly by various means. In direct method wear is measured by seeing rake and flank surfaces under microscope (Viktor P. Astakhov, 2006). Indirect methods for determining wear are correlating with process parameters such as surface finish of workpiece, cutting forces, temperature, vibration, cutting conditions, torque, strain and snapshot images of the cutting tool etc in different ways. Out of these direct wear measurement is mostly convenient and accurate. It has been discussed that the direct and indirect methods of tool wear measurement using various tool wear sensors and chemical analysis of tool particles carried by chip, weighing of the tool before and after machining (G.F. Micheletti, W. Koenig, HR Victor, 1976).The methodology to predict the tool wear evolution and tool life in orthogonal cutting has been developed using FEM simulations (Yung-Chang Yen et.al. 2004). Whereas some research work shows how the life of the cutting tool can be calculated taking into account the cutting parameters once known the parameters of Taylor algebraic structure (N G de Mattos *et al*, 2011).

2. Tool Life Evaluation Methodology

In this work the tool life is calculated analytically by using Taylors Algebraic Structure for different cutting speed and feed rates and the results are compared with software results. The objective of this work is to analyze the tool life of the single point cutting tool insert used in the turning operation of AISI1038 steel.

2.1. Analytical Methodology

The algebraic structure of Taylor proposed, in this research, is the one shown in Eq. 1.

$$T = C \cdot V^{A} \cdot f^{B} \cdot ap^{D} \cdot VB^{E} \quad (1)$$

Where: T is the cutting time [min]; V is the speed [m/min]; f is the feed [m/rev]; a_p is the depth of cut [mm]; VB is the flank wear [mm]; and C, A, B, D, E are the algebraic structure parameters of Taylor. To determine the parameters of the algebraic structure Taylor the following cutting conditions were used: cutting speed = 100, 140, 180 and 220 [m/min], feed = 0.2, 0.3, 0.4, 0.5 and 0, 6 [mm/rev] and depth of cut of 1.5; 3.0 and 5.0 [mm] for AISI 1038, and these parameters cutting were combined in different ways. The 227 values of flank wear (VB) were measured at eight different cutting conditions [10]. The cutting tool was tungsten carbide, TNMG 160408-FU having grade CU25, with rake angle γ= -6°, clearance angle α= 6° and cutting edge angle χ= 75°. The Taylor parameters were by multiple regression and its values are shown in Eq.2.

$$T = 1.86 \cdot 10^{6} . V^{-1.92} \cdot f^{-0.78} \cdot ap^{-0.20} \cdot VB^{2.22} \quad (2)$$

The tool wear and tool life is calculated for different cutting speed, feed and depth of cut. The cutting tool was tungsten carbide, TNMG 160408-FU having grade CU25, with rake angle γ = -6°, clearance angle α= 6° and cutting edge angle χ= 75° for turning of AISI1038 workpiece material. The following cutting conditions were used: cutting speed of range 190 to 275 [m/min], feed range 0.18 to 0.35[mm/rev], depth of cut of the range from 0.5 to 3.0[mm] and flank wear as 0.48mm for AISI 1038.

Table 1 Tool life T [min] for Workpiece Material AISI 1038 Steel

SR.No	Cutting Speed V (m/min)	Feed f (mm/rev)	Depth Of Cut ap (mm)	Cutting Force K_c (N)	Tool Life T (min)
1	190	0.18	0.10	57717	67.26
2	210	0.21	0.15	22380	42.84
3	230	0.24	0.20	11919	29.89
4	250	0.27	0.25	7309	21.93
5	270	0.30	0.27	4873	16.67
6	275	0.35	0.30	3417	13.76

The Table 1 shows the numerical values of tool life for the various machining parameters that is cutting speed, feed and the depth of cut, that have been selected for the measurement of flank wear and tool life.

2.2. FEA Analysis of Tool Insert

The FEA analysis is carried out by using ANSYS Workbench 14.5 for evaluation of cutting tool life. In order to achieve this, the modeling is done by using Pro-e Wildfire 5.0. The objective of this work is to compare analytical results with FEA data for the tool life.

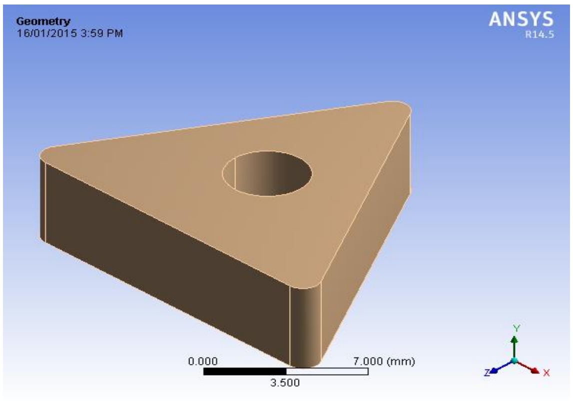

Fig.1 Geometry of Tool Insert

Fig.1 describes the 3D model of cutting tool insert considered for tool life simulation. The 3D model is developed in Pro-e Wildfire 5.0 and imported in ANSYS Workbench 14.5.The material properties assigned to the model are shown in Table 2.

Table 2 Mechanical Properties of TNMG 160408-FU tool insert

SR. No	Name of the Material Property	Value
1.	Young's Modulus(Gpa)	530
2.	Poisson's Ratio	0.24

Fig.2 shows the meshing of 3D model of tool insert by using SOLID45 3D elements in ANSYS Workbench 14.5.Then in the next step boundary conditions are applied as shown in Fig.3 and 4. The boundary conditions are like this, tool insert is fixed that is all Degrees of freedom equal to zero at central hole indicated by purple colour. Similarly the second condition i.e. cutting force is applied at the tool tip curved surface and is indicated by red colour.

In the next step tool life simulation is done at different cutting speeds and cutting forces. Fig. 5 shows the tool life of magnitude 67.423 min. at cutting speed 190 m/min and cutting force 57717 N indicated by green colour. For cutting speed 210 m/min and cutting force 22380 N, the magnitude of tool life obtained is of magnitude 42.406 min. shown in fig.6. Fig.7 shows the tool life of magnitude 29.735 min. at cutting speed 230 m/min and cutting force 11919 N. The tool life of magnitude 21.842 min. is obtained at cutting speed 250 m/min and cutting force 7309N shown in Fig.8. Fig.9 shows the tool life of magnitude 16.97 min.at cutting speed 270 m/min and cutting force 4873 N. In Fig.10 tool life of magnitude 13.839 min. is obtained at cutting speed 275 m/min and cutting force 3417 N.

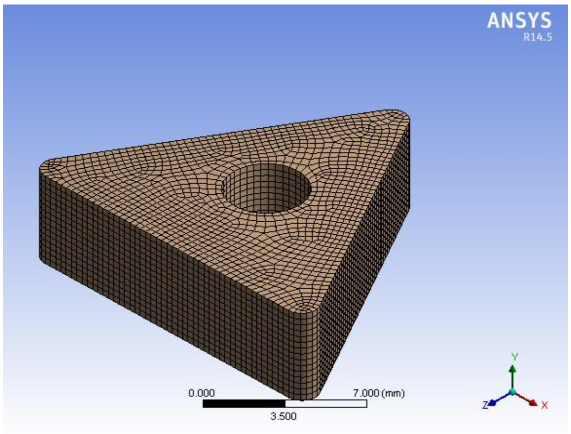

Fig.2 Mesh Model of Tool Insert

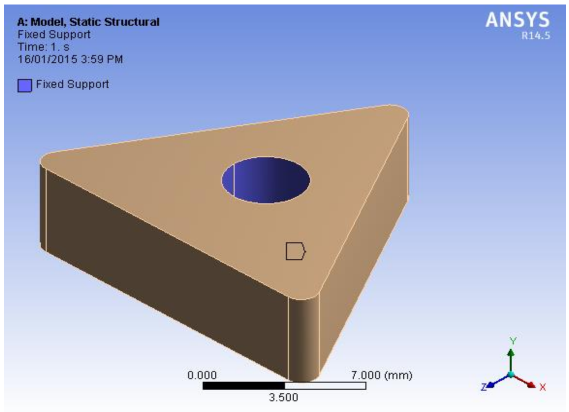

Fig.3 Boundary Condition of Tool Insert

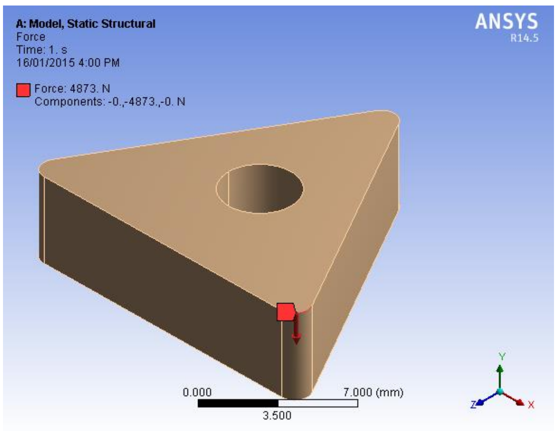

Fig.4 Cutting Force at tip of Tool Insert

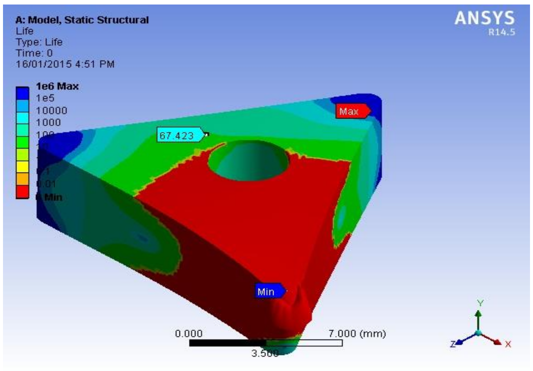

Fig.5 Tool Life at cutting speed 190m/min and cutting force 57717 N

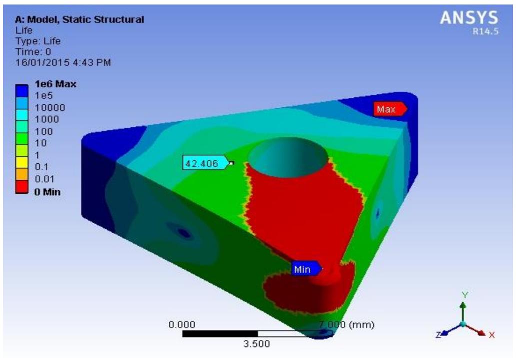

Fig.6 Tool Life at cutting speed 210 m/min and cutting force 22380 N

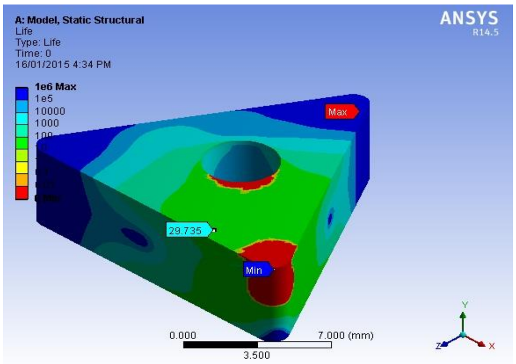

Fig.7 Tool Life at cutting speed 230 m/min and cutting force 11919 N

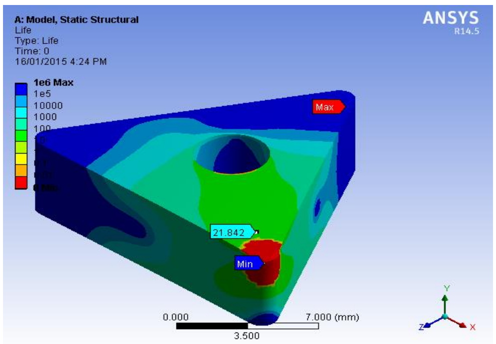

Fig.8 Tool Life at cutting speed 250 m/min and cutting force 7309 N

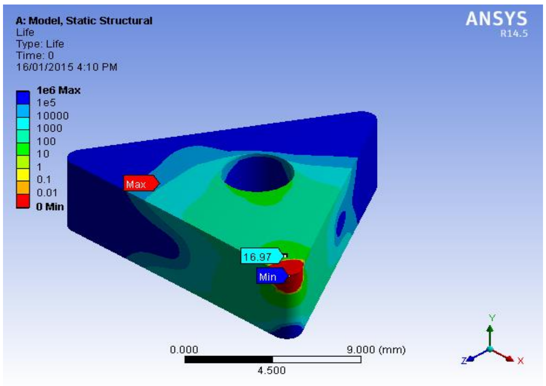

Fig.9 Tool Life at cutting speed 270 m/min and cutting force 4873 N

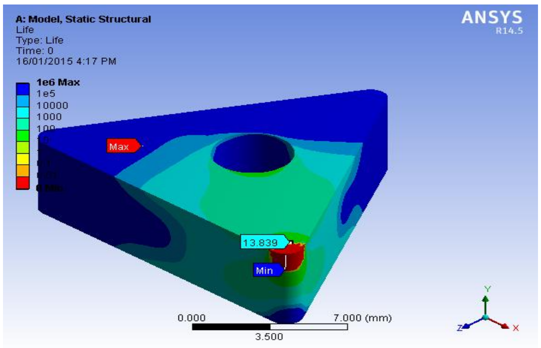

Fig.10 Tool Life at cutting speed 275 m/min and cutting force 3417 N

3. Results and Discussion

To study the effect of cutting parameters on tool life, the cutting speed is varied from 190 m/min to 275 m/min, feed is varied from 0.18mm/rev to 0.35 mm/rev, Depth of cut is varied from 0.10 mm to 0.30 mm and corresponding tool life is calculated analytically. Similarly, cutting force is varied from 57717 N to 3417 N and tool life is obtained by FEA in ANSYS Workbench 14.5. Table 3 shows the comparison between analytical and FEA Tool Life results.

Table 3 Comparison of Tool Life Results

SR. No	V (m/min)	F (mm/rev)	ap (mm)	Analytical T (min)	FEA T (min)	% Difference
1	190	0.18	0.10	67.26	67.42	0.24
2	210	0.21	0.15	42.84	42.41	1.00
3	230	0.24	0.20	29.89	29.73	0.51
4	250	0.27	0.25	21.93	21.84	0.41
5	270	0.30	0.27	16.67	16.91	1.42
6	275	0.35	0.30	13.76	13.84	0.60

The effect of cutting speed on tool life is as shown in Fig.11.

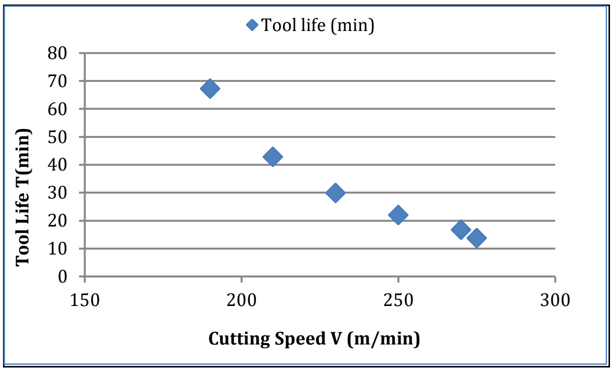

Fig.11 Effect of Cutting Speed on Tool Life

Conclusions

From the above results and discussion it is concluded that

1) The maximum tool life obtained in FEA analysis is 67.423 min. and analytically it is 67.259 min.
2) From this it is concluded that the results obtained analytically and by FEA, the difference in tool life is not more than 2%.
3) Thus, finally it can be observed that we must select the cutting parameters, which are cutting speed, feed rate, and depth of cut, in such a way so as to have the optimum tool life at the tool tip so that the minimum tool wear is encountered.
4) Thus we could have the longest tool life and better machining economy.

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