Analysis of Tool Life by using Experimental Calculations & Ansys

Akshaykumar Kore[1], Digambar Date[2], Vikramsinh Mane[3]

[1]*M-Tech Student Dept. of Mechanical Engg. College of Engineering, Osmanabad*
[2] *HOD Dept. of Mechanical Engg. College of Engineering, Osmanabad*
[4] *Principal College of Engineering, Osmanabad*

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Abstract -There are many factors that affect the life of single point cutting tool such as cutting force, temperature, feed rate, depth of cut, speed etc. We will be analyzing effect of these factors on single point cutting tool life using ANSYS software. Cutting forces acting on cutting tool are determined analytically at different depth of cut. Modelling of single point cutting tool is done by PRO-Engineer software. The model is then imported in ANSYS software and meshing is done. Then the temperature readings and the forces calculated at different depths of cut are given as an input to the software. The software analyzed the model by finite element analysis at various forces and calculated the stresses developed at the tip of the tool and also the deformation of the tip of the tool. In Finite element analysis of single point cutting tool the maximum stresses are developed at the tip of tool which is the main cause of failure.

***Key Words*: Single point cutting tool, Tool Life, Ansys, Catia, etc.**

1. INTRODUCTION

Manufacturing is one of the primary wealth-generating activities for any nation - the growth of manufacturing has led to undeniable advances, not only in providing an abundance of material processions, but also in creating the economic basis for genuine improvements in the quality of life. It has been accepted that, in general, the nation intensively engaged in manufacturing enjoy a higher standard of living, as it is expressed by the per capita output of the economy. Manufacturing should be competitive not only locally but also on a global basis since the proportion of manufactured goods in the export trade of a nation can be taken as a measure of the nation's economic development. The only way to make manufacturing competitive is to attain a high level of profit. Since 40% or so of the selling price of a product is manufacturing cost, maintaining high level of profit often depends on reducing manufacturing cost of the manufacturing processes, metal cutting or machining is often claimed to be the most important process in engineering manufacturing because the vast majority of manufactured products require machining at some stage in their production, ranging from relatively rough or non-precision work, such as cleanup of castings or forgings, to high-precision work involving tolerances of 0.0025 mm or less. An obviously efficient machining operation with lowest possible machining cost is a key issue of competitive manufacturing and the nation's economy.

1.1 Tool Life

Tool life can be described as the amount of time that a cutting tool can be used until the flank wear has reached the tool life criteria, as shown in Figure-1. The diagram shows the influence of the cutting speed on the cutting tool life, where a lower value of cutting speed will wear the cutting tool in a lower rate increasing the amount of time that can be used until the tool life criteria is reached, thus increasing the tool life.

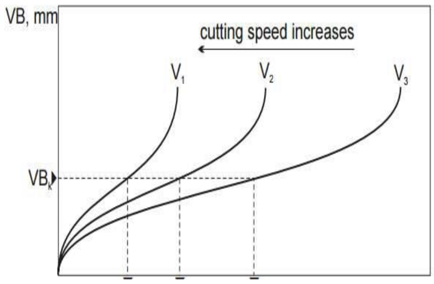


Fig -1: Relationship between flank wear criteria and the tool life for diff. cutting speed

Methods of calculating Tool Life

While simple tool life equations can be solved via handwritten mathematics and manual calculation, today's computer-executed analysis is necessary to solve equations of complex models in an amount of time that is practical within a production environment. Digital calculations are very reliable, but manufacturers should maintain a critical attitude towards the results, especially when machining advanced workpiece materials and employing extreme machining parameters. Overall, progress in tool life model development has brought academic theory and practical application into close alignment.

1. The Archard model

Modelling of wear processes is not limited to metal cutting applications. In the 1950s, British engineer John F Archard developed an empirical model for the rate of abrasive wear between sliding surfaces based on deformation of the asperity, or roughness, of the surfaces. According to his equation

$$Q = KWL / H.$$

Here, Q is the wear rate, K is a constant wear coefficient, W is the total normal load, L is the sliding distance of the surfaces, and H is the hardness of the softer of the two surfaces. The model basically states that the volume of material removed due to abrasive wear is proportional to friction forces.

2. **The Taylor model**

In the early 1900s American engineer FW Taylor developed a tool life model that included factors relevant to metal cutting Taylor observed that increasing depth of cut had minimal effect on tool life. Increasing feed rate had somewhat more effect, while higher cutting speeds influenced tool life the most. This prompted Taylor to develop a model focused on the effect of varying cutting speeds. The equation for Taylor's basic model is

$$v_C * T_m = CT,$$

Where, v_C is cutting speed, T is tool life, and m and CT are constants with CT representing the cutting speed that would result in a tool life of one minute.

1.2 Objectives

1) To predict tool life, cutting forces, power produced and results were compared with the FEA analysis approach.
2) To analyse the Single point cutting tool under different parameters (Depth of cut, Feed and speed).
3) To compare the results of the two materials with respect to their better performance

2. Mechanics of Machining

A number of theories have been developed to investigate the mechanics of the machining process. These machining theories assume that plastic deformation occurs in the work material at a constant flow stress while the chip formation process can be represented by a shear plane AB (Figure-2). It was also assumed that the frictional conditions at the tool/chip interface could be represented by an average coefficient of friction, as for normal sliding friction. Having failed to give an adequate explanation of how work material properties and cutting conditions influence the machining process, the above machining theories have been of little practical help in reducing the number of empirical results for cutting forces, tool-life, temperatures, surface finish, etc. which are needed in selecting optimum machining conditions.

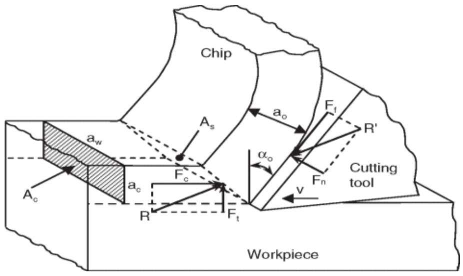


Fig -2: Mechanics of machining

2.2 Types of Metal Cutting

In metal cutting operation, the position of cutting edge of the cutting tool is important based on which the cutting operation is classified as orthogonal cutting and oblique cutting Orthogonal cutting Fig.3(a) is also known as two-dimensional metal cutting in which the cutting edge is normal to the work piece. In orthogonal cutting no force exists in direction perpendicular to relative motion between tool and work piece. Oblique cutting Fig.3 (b) is the common type of three-dimensional cutting used in various metal cutting operations in which the cutting action is inclined with the job by a certain angle called the inclination angle.

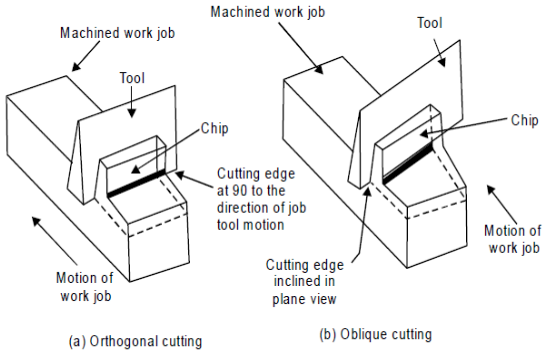


Fig -3: Types of metal cutting

2.2 Nomenclature of single point cutting tool

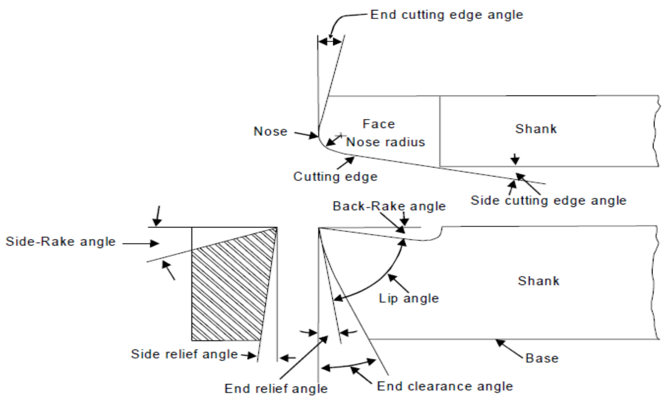


Fig -4: Nomenclature of single point tool

(i) Back rake angle

It is the angle between the face of the tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge.

(ii) Side rake angle

It is the angle by which the face of tool is inclined sideways. This angle of tool determines the thickness of the tool behind the cutting edge.

(iii) End relief angle

It is the angle that allows the tool to cut without rubbing on the work- piece. It is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measured at right angles to the flank.

(iv)Side relief angle

It is the angle that prevents the interference as the tool enters the material. It is the angle between the portion of the side flank immediately below the side edge and a line perpendicular to the base of the tool measured at right angles to the side.

(V)End cutting edge angle

It is the angle between the end cutting edge and a line perpendicular to the shank of the tool. It provides clearance between tool cutting edge and work piece.

(vi)Side cutting edge angle

It is the angle between straight cutting edge on the side of tool and the side of the shank. It is also known as lead angle.

3. Selection of Material

In our experimental tests, we have used tungsten carbide material for cutting tool & two different materials for workpiece i.e Alluminum alloy & medium carbon steel.

1. Tungsten Carbide (For Cutting Tool)

Tungsten carbide cutting tools have the characteristics of high hardness, high strength, high wear resistance and high modulus of elasticity, as well as good impact toughness and corrosion resistance.

2. Medium carbon steel (For workpiece)

Medium or High carbon steel contains 1 – 1.5% carbon is used as material for general machining work since 1870. Some additives (cromium and tungsten) are required to improve wear resistance. The steel begins to lose its hardness at about 250°C. Medium carbon steel has generally low carbon content (0.30% to 0.60%) This particular scope of carbon is joined with a procedure of extinguishing i.e. cooling the steel from the external surface to the internal and then treating it to make a structure that has reliable rigidity all through the body.

3. **Alluminum Alloy (For Workpiece)**

In machining, Aluminium alloy is one of the most widely used engineering materials due to their relatively lower specific weight and corrosion resistance compared to steel. Besides, they are also relatively easier to machine. Aluminium alloys have been found to provide the highest degree of machinability compared to other lightweight metal such as titanium and magnesium alloys.

4. Theoretical calculations

Here we have assumed the aluminum and medium carbon steel have been turned using the tungsten carbide tool insert and decided to optimize the cutting parameters for that material combination only. In practice typical values of exponents and constants for tungsten carbide tool and aluminum as workpiece are n=0.33, a=0.6, b=0.15 and C=80. As we know the specific cutting pressure value of aluminum from that we get the cutting force and from selected RPM value calculate the cutting speed and finally cutting power requirement.
Following table shows the calculations done with varying feed, depth of cut and speeds for different material

1. Alluminium Alloy (Workpiece Material)

Table -1: By varying speed, feed, and depth of cut

Speed	Feed	DOP	C	n	a	b	Tool Life	Power	Cutting Force	Feed Force	Radial Force
(m/min)	(mm/rev)	(mm)	-	-	-	-	(Min)	KW	KN	KN	KN
55.42	0.1	0.25	80	0.33	0.6	0.15	375.60	19.28	20.86	5.21	10.43
63.34	0.11	0.3	80	0.33	0.6	0.15	193.9	23.15	21.92	5.48	10.96
71.26	0.12	0.35	80	0.33	0.6	0.15	108.0	27	22.73	5.68	11.36
79.18	0.13	0.4	80	0.33	0.6	0.15	63.88	30.51	23.11	5.77	11.55
87.10	0.14	0.45	80	0.33	0.6	0.15	39.64	34.71	23.90	5.97	11.95

2. Medium carbon steel (Workpiece Material)

Table -2: By varying speed, feed, and depth of cut

Speed	Feed (f)	DOC (d)	C	n	a	b	Tool Life	Power	Cutting Force	Feed Force	Radial Force
(m/min)	(mm/rev)	Mm	-	-	-	-	min	KW	KN	KN	KN
53.6621	0.1	0.25	80	0.33	0.6	0.15	370.2254	17.23	17.9822	4.2413	9.1254
60.5268	0.11	0.3	80	0.33	0.6	0.15	188.2587	21.54	18.2254	4.5857	9.9625
68.9822	0.12	0.35	80	0.33	0.6	0.15	103.5487	24.99	20.3254	4.6522	10.4054
77.0254	0.13	0.4	80	0.33	0.6	0.15	76.8747	28.02	21.9878	4.7812	10.5898
84.9935	0.14	0.45	80	0.33	0.6	0.15	63.8747	32.12	22.5452	4.8954	10.9725

Again calculation also done at various combinations of speed, feed, depth of cut to calculate the optimum cutting parameter for aluminum & medium carbon steel as workpiece and tungsten carbide as a tool material. Table no 1 & 2 gives the detailed results of analytical calculations.

5. FEA Modeling & Analysis of Tool

Finite element analysis (FEA) is the process of simulating the behavior of a part or assembly under given conditions so that it can be assessed using the finite element method (FEM). FEA is used by engineers to help simulate physical phenomena and thereby reduce the need for physical prototypes, while allowing for the optimization of components as part of the design process of a project.

5.1 Model Description

In this FEA analysis as static analysis was done by applying the cutting forces on the tool edge. So, the complete tool geometry has not been modeled. Only tool insert geometry has been imported in the ANSYS 18.2 student version.

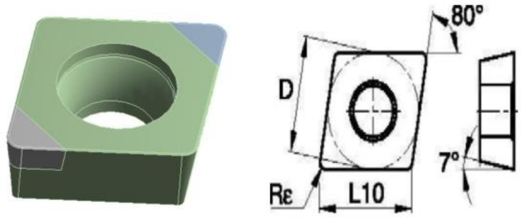


Fig -5: Carbide tool insert

5.2 Meshing

Geometry of the element is complex so Hex meshing is time consuming so Tetrahedral elements having mid side nodes is used. Workbench uses by default Solid 187 element for tetrahedral element having midside nodes.

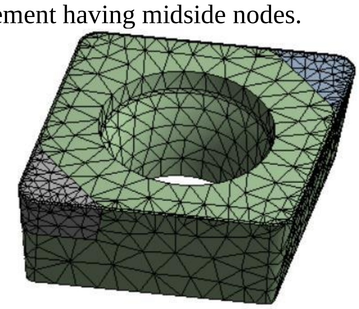


Fig -6: Carbide tool insert

5.3 Boundary and Loading Conditions

Fixed boundary conditions defined where insert is bolted to tool shank.

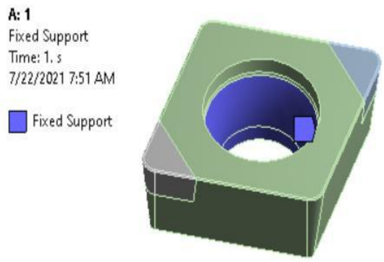
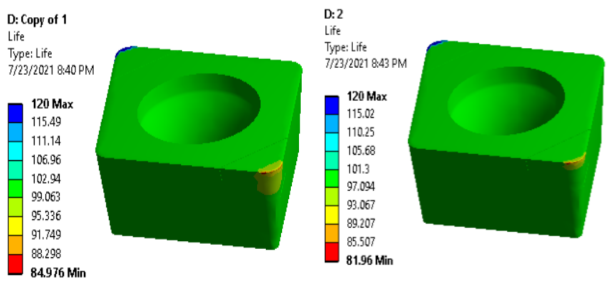


Fig -7: Fixed support

Cutting force, Radial Force and Axial force is applied at the edge where the cutting tool edge touches the workpiece during the turning operation.

5.4 FEA Results

1. FEA result of Alluminium Alloy



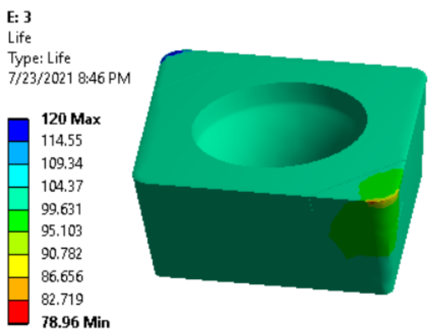


Fig -8: Tool life in minutes Varying Depth of cut at N = 1000 RPM and feed = 0.13 mm/rev (a) d=0.25 mm (b) d=0.3 mm (c) 0.35mm

2. FEA result of Medium carbon steel

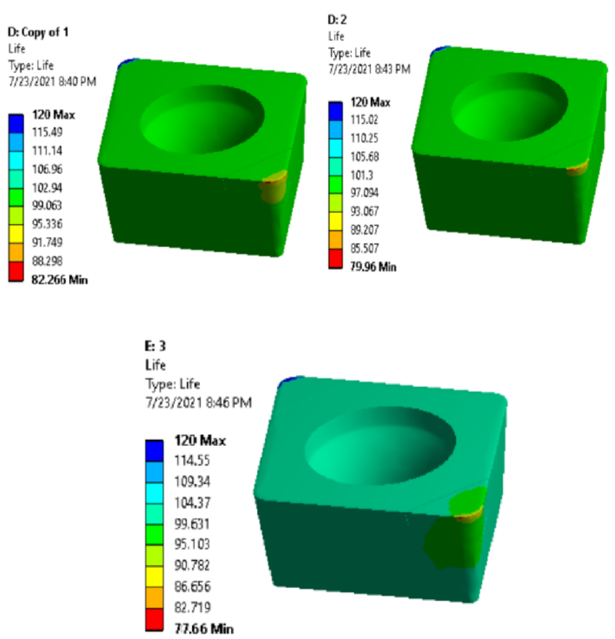


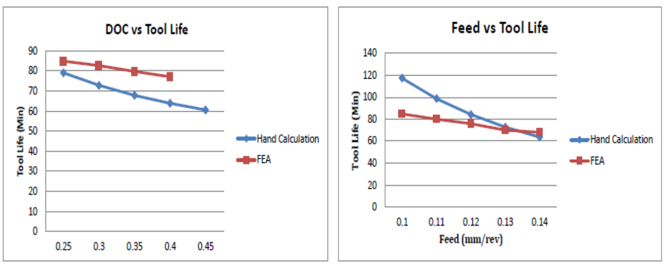
Fig -9: Tool life in minutes Varying Depth of cut at N = 1000 RPM and feed = 0.13 mm/rev (a) d=0.25 mm (b) d=0.3 mm (c) 0.35mm

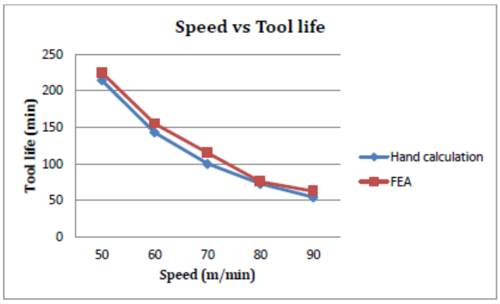
6. RESULT AND DISCUSSION

In this work aluminum alloy & medium carbon steel are taken as a work material and tungsten carbide as tool material. By varying the different parameters like depth of cut, speed and feed at different conditions the tool life, surface finish, cutting force and other parameters were calculated.

Following plots of Graph shows the tool life variation with depth of cut and feed.

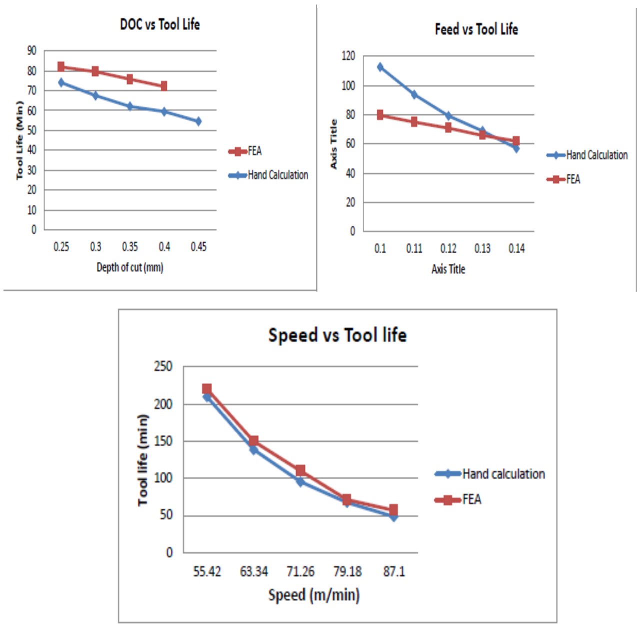
1. Result of Alluminium Alloy





Graph -1: Comparison between depth of cut/feed/speed and tool life

1. Result of Medium Carbon Steel



Graph -2: Comparison between depth of cut/feed/speed and tool life

Table -2: FEA error for varying Speed at Depth of cut = 0.3 mm and feed = 0.13 mm/rev

	Tool Life (min.)					
Speed	Aluminium Alloy		Error	Medium Carbon Steel		Error
	Hand calculations	FEA		Hand calculations	FEA	
m/min	min		%	min		%
55.429164	214.5695	225.2133	4.96	209.8578	222.5487	6.04
63.347616	143.1643	155.1652	8.38	138.4577	151.0254	9.07
71.266068	100.1906	115.1102	14.89	95.2245	110.2587	15.78
79.18452	72.8061	75.7735	4.07	67.2554	69.2457	3.005
87.102972	54.5425	62.6734	14.90	48.2254	55.2147	14.92

The results showed that the tool life is decreasing as the cutting force, MRR and cutting speed increases. Also tool life is decreasing with increase in speed and feed. Same behavior has been observed with theoretical calculation as well as by FEA.

7. CONCLUSIONS

An analytical model developed to calculate the stresses inside the cutting edge of a tool has been proven to be effective. Using this model, a method has been developed in the present work which has been successfully used to predict cutting conditions at which the

Based on the results of these project work, the following have been concluded:

1) At a given depth, it is much more economical to machine using a high-feed/low speed combination than a low-feed/high-speed combination when none of the process constraints are violated.
2) At a given depth/feed combination, the optimum speed for minimum cost criterion is lower than that or maximum production rate criterion due to the fact that tool life for minimum cost criterion is greater than the tool life for maximum production rate criterion.
3) Due to superior wear characteristics of the coated tool, the optimum cutting speeds for this tool are much higher than the corresponding speeds for an uncoated tool used.
4) Due to the power constraint, the *d-f* plane grid point corresponding to the maximum feed/depth combination might be unfeasible when a work material with larger diameter is machined. When that happened, the production cost/time was found to increase considerably.
5) The effect of varying carbon content in work material on the optimum cutting conditions should be considered in practice. It has been shown that the differences of the optimum cutting conditions and the resulting production cost/time due to the maximum allowable variation of carbon content is about *5%*.
6) The optimum cutting conditions given in the above examples compared favorably with those recommended by the tool manufacturers for the tool/workpiece combination considered.

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BIOGRAPHIES (Optional not mandatory)

Prof.Akshaykumar Kore
M.Tech Student Dept. of Mechanical Engg. College of Engineering, Osmanabad, Maharashtra, India