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Analysis of Single Point Cutting Tool Using ANSYS

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Abstract::- This paper highlights the effect of the temperature and cutting forces generated on the tip of the Single Point Cutting Tool (SPCT) while working. In a experimental work, temperature measurement is done by using thermocouple at various depth of cut and it found that the temperature increases with increase in depth of cut. Cutting forces acting on cutting tool are determined analytically at different depth of cut. Modeling of single point cutting tool is done by PRO-Engineer Wildfire-4 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. Also the maximum deformation takes place at the tip of tool which blunts the tool, is the cause of failure.

Keywords: *Single Point Cutting Tool (SPCT), temperature, cutting forces, stresses, ANSYS.*

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I. Introduction

In today's CIM environment and competition age the main attention of manufacturer is a cost reduction. When it is not possible to reduce the fixed cost, it is necessary to concentrate on variable cost like electricity, cutting fluids, cotton waste, oil grease, welding rods, cutting tools etc.

Of all the factors the cost of cutting tool is very high. Tools of H.S.S, carbide, diamond tip are costing very high. Therefore it is necessary to pay attention to increase the tool life. As the tool life increases, the variable cost decrease.

In exact mechanism of metal cutting briefly stated is that a cutting tool exerts a compressive force on the work piece. Under this compressive force the material of the work piece is stressed beyond its yield point causing the material to deform plastically and shear off. The sheared material begins to flow along the cutting tool face in the form of small pieces called chips .The flowing chips causes the wear of cutting tool.

Heat is produced during shearing action. The heat generated raises the temperature of tool, work and chips. The temperature rise in cutting tool tends to soften it and causes loss of intensity in the cutting edge leading to its failure. This temperature during metal cutting is maximum at the tip of the tool, is to be measured by experimental set up and this experimental temperature is given as input to the software and analyzes the stresses and deformation on the single point cutting tool. Hence the FEM is capable of providing this information, by creating the geometric model required for the finite element using software like PRO-Engineer and analyzing the model using software like ANSYS. PRO-Engineer generates the three dimensional model of tools and analysis can be performed using ANSYS on the tool easily. Also the forces acting on the tool due to the workpiece are responsible for deformation of tool and the tip of the tool displaces in XYZ direction.

During the metal cutting process heat is produced due to shearing action and it raises the temperature of the tool. Due to this temperature the tool gets soften at the tip and various stresses and deformation is take place in the tool. It is essential to measure this temperature experimentally at various depth of cut. Also to find out the effect of forces acting on the tip of the tool.

II. Literature Review

Wear of a cutting tool in a machining operation is highly undesirable because it severely degrades the quality of machined surfaces and causes undesirable and unpredictable changes in the work geometry. From a process automation point of view, it is therefore necessary that an intelligent sensing system be devised to detect the progress of tool wear during cutting operations so that worn tools can be identified and replaced in time.[1] (Sundaram S., Senthilkumar P., Kumaravel A. and Manoharan N., *"Study Of Flank Wear In Single Point Cutting Tool Using Acoustic Emission Sensor Techniques"*, ARPN Journal of Engineering and Applied Sciences, VOL. 3, NO. 4, AUGUST 2008.)

The life of a tool is important in metal cutting since considerable time is lost whenever a tool is replaced or reset. Cutting tools loose it's sharpness as usage continues and their effectiveness decrease over time. At some point during the life-span of the tool, it is necessary to replace, index or re-sharpen and reset the tool. Tool life is a measure of the length of time a tool will cut effectively. The life of cutting tool depends upon many factors, such as the microstructure of the material being cut, metal removal rate, the rigidity of the setup and effects of cutting fluid (David and Agapiou, 2000; Krar, 1995). The correct choice of cutting velocity can enhance tool life but at the same time, the tool should be used to its maximum capacity.[2] (Kadirgama K., Abou-El-Hossein K. A., Mohammad B., Noor M. M. and Sapuan S. M., "*Prediction of tool life by statistic method in end-milling operation*", Scientific Research and Essay, Vol. 3 (5), pp. 180-186, May, 2008.)

If a tool life can be predicted only on the basis of measurements of the flank and crater wear of the tool, the changeable circumstances caused by new tools and all related unknown wear appearances would demand that we consider tool wear as a collection of different kinds of wears located at the tool tip, difficult to separate in the form of ordinary locations. This phenomenon is especially explicit in finish machining and high-speed cutting (HSC) operations, where the emphasis should be placed on the reliability of the cutting process, tool life and required surface roughness. The advantages of this process lie not only in the speed of machining (lower costs) but also in attaining the lower, prescribed surface roughness.[3] (Dolinsek S., Kopac J., "Mechanism and types of tool wear; particularities in advanced cutting materials", Journal of Achievements in Materials and Manufacturing Engineering, VOLUME 19, ISSUE 1, November 2006.)

High speed machining is one of those main methods of increasing production efficiency and shorten machining times. High speed machining (HSM) has become a common trend supplied in manufacturing industry since the successful development of high speed spindle and modern material techniques. But wear happens during the cutting operation of the cutting tool. Since tool wear may cause poor dimensional accuracy, as well as deterioration of surface integrity of the workpiece, and even cause damage of workpiece if neglected. Therefore the variation of tool wear of the tools during high speed machining process must be known. If the quantity of tool wear is learned, it is possible to make tool compensation for maintaining workpiece accuracy. And the replacement time of the tool can be determined, in order to prevent the occurrence of workpiece damage.[4] (Lin W.S., "*The reliability analysis of cutting tools in the HSM processes*", Archives of Materials Science and Engineering, Volume 30, Issue 2, April 2008, Pages 97-100.)

III. Methodology

Experimental Setup: - Figure 1 shows the temperature measurement set up. The set up consist of tool, thermocouple, and temperature indicator connected to the A.C supply. The readings are taken while turning a M. S. bar on Lathe machine.

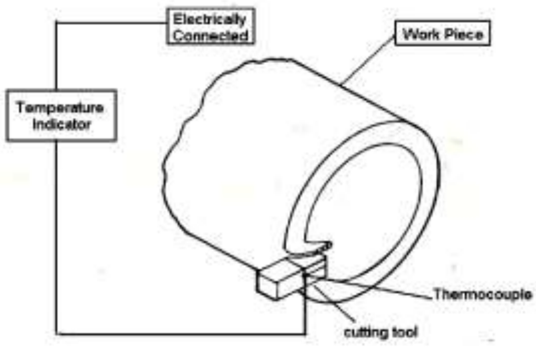

Figure 1:-Temperature Measurement in Metal Cutting

In the procedure of temperature measurement first take tool of proper specification. And select the tool material for cutting tool is HSS (High speed steel). For assemblage of thermocouple with tool, hole is made on the side face of the tool by using "Electro Discharge Machining". The diameter of the hole is similar to the diameter of the thermocouple which is to be fixed in the tool. The thermocouple is connected to temperature measuring indicator through wire cable. Temperature indicator work on A.C. supply. When the alternating current is 'ON' that time temperature indicator showed reading at room temperature. The thermocouple used for measurement having the range of 1000 ^{0} c. Assemble the set up properly and used for the temperature measurement.

After preparing the set up, it is mounted on the lathe machine. Before starting the cutting appropriate material for cutting was selected (Mild steel) and the diameter of the work piece was 50 mm and length was 90 mm. Then tool was set up properly and metal cutting is started. Cutting process increases with increasing the temperature from the room temperature. If the metal cutting process is started for the depth of cut 0.2 mm, keeping cutting speed and feed at constant value and take the temperature reading for that depth of cut 0.2 mm is 120 ^{0}c. In this way readings of temperature were taken at same value of feed and speed at different depth of cut. While taking readings, some point should be kept in mind, that during cutting temperature increases with respect to the feed, at the end of cut final temperature is to be noted and take the maximum value of that temperature. In this way temperature reading were taken for different depth of cut.

The result during the experimental work are shown in table 1. And also the graph is plotted. It is observed that as the depth of cut increases there is a rise in temperature.

Table 1: - temperatures at various depth of cut

Depth of cut (mm)	Temperature (^{o}C)
0.2	120
0.5	160
1.0	200
2.0	450
2.5	550

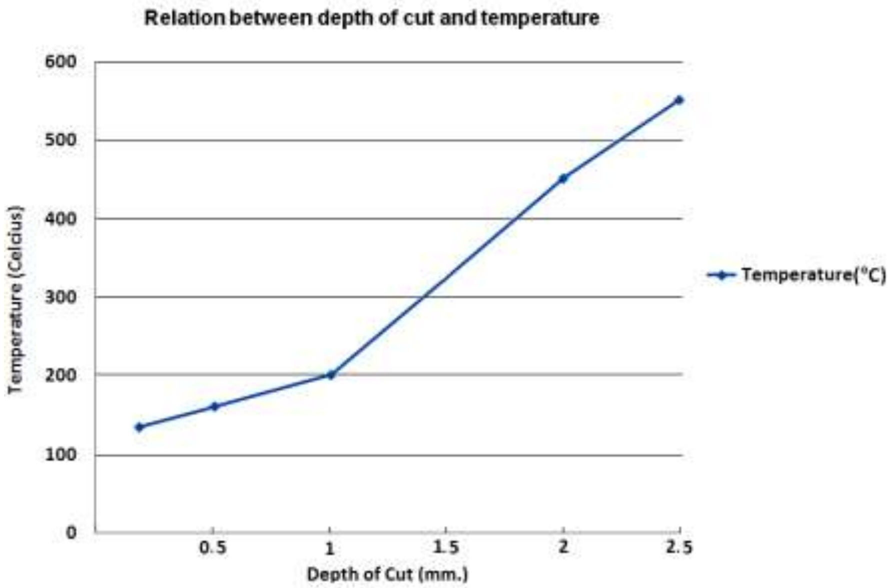

Figure 2: - graph of temperature vs. depth of cut

Determination of cutting forces acting on the cutting tool:

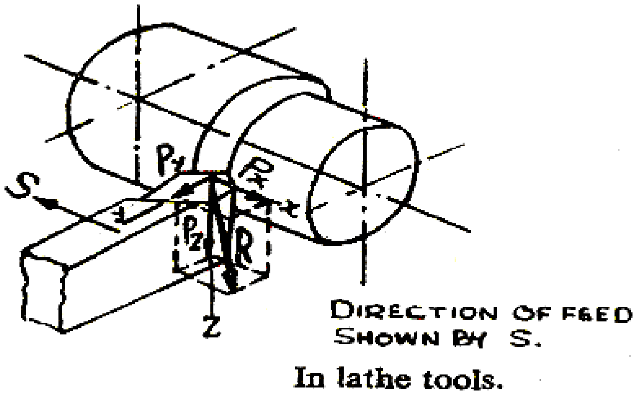

Figure 3: - components of cutting forces

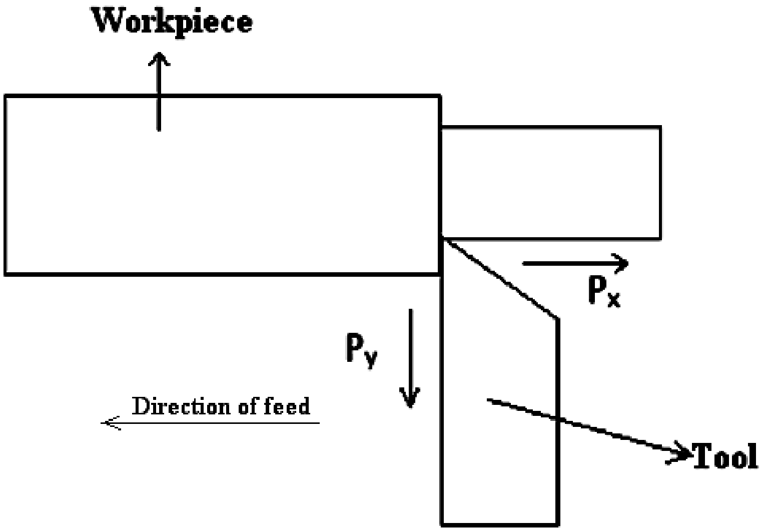

Figure 4: - top view of cutting action

In any metal cutting operation in a lathe there acts a force 'R' on the tool. This force 'R' can be resolved into three components.

P_y = in the horizontal plane, perpendicular to the direction of the feed (thrust force);

P_x = in horizontal plane against the direction of feed (feed force);

P_z = in vertical plane, perpendicular to both P_y and P_X (cutting force);

Empirical formula determining the Pz can be expressed as under

$$P_z = C_p \times t^x \times S^y \times K$$

Where,

C_p = coefficient, characterized by the work material and condition of working such as tool, coolant.

t = depth of cut

S = feed in mm/revolution

K = overall correlation, consisting of actual condition of working and tool angles, which varies from 0.9 to 1.0.

$K = K_c \times K_\phi \times K_\sigma \times K_m$

K_c = Correction coefficient for coolant. (Air)

K_ϕ = Correction coefficient depending upon the entering angle. (90^O)

K_σ = correction coefficient depending upon the back rack angle. (8^O)

K_m = correction coefficient depending upon the material.

For Depth of cut = 0.2 mm

Feed = 0.286 mm/revolution

C_p = 225

x = 1.00

y = 0.75

$$P_z = C_p \times t^x \times S^y \times K$$

$$= 225 \times 0.2^{1.00} \times 0.286^{0.75} \times 0.935 = 16.45 \text{ N}$$

The components approximately connected by the following expression

$P_x / P_z = 0.3$

$P_x = 0.3 \times P_z = 0.3 \times 16.45 = 4.936$

and

$P_y / P_z = 0.2$

$P_y = 0.2 \times 16.45 = 3.29$ N

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Table 2:- cutting forces at different depth of cut

Cutting forces (N)	Depth Of Cut (mm)				
	0.2	**0.5**	**1.0**	**2.0**	**2.5**
P_x	4.936	12.339	24.68	49.36	61.70
P_y	3.29	8.226	16.45	32.91	41.130
P_z	16.45	41.13	82.275	164.55	205

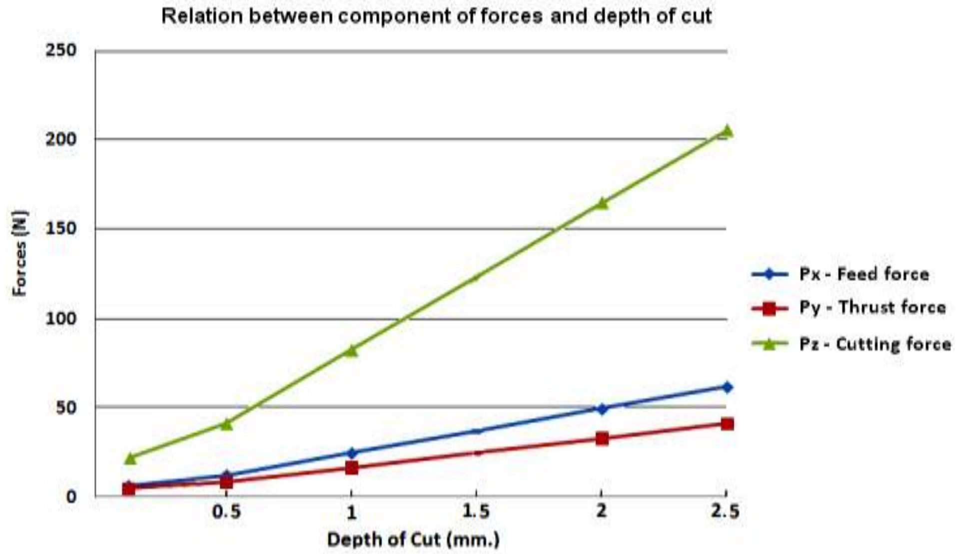

Figure 5:-graph of components of cutting forces vs. depth of cut

Modeling of single point cutting tool in Pro-Engineer software:

Modeling is the art of representing the object or system. The geometric modeling is defined as the complete representation of a structure with graphical and non-graphical information. It generates the mathematical description of the geometry and non-geometry of a structure in the computer database and an image of an object on the graphics screen.

Pro-Engineer Wildfire 4.0

Pro-E Wildfire 4.0 has been developed by Parametric Technology Corporation (PTC)of U.S.A. This is a CAD/CAM/CAE software but we are using this for only 3-D part modeling (CAD) of Water monitor trailer. This CAD includes.

1. Sketcher
2. Part Modeling(part design)
3. Advanced Part Design
4. Surface Design
5. Assembly Design
6. Drafting and Detailing.

Part Modeling

Pro/ENGINEER Part enables you to design models as solids in a progressive three-dimensional solid modeling environment. Solid models are geometric models that offer mass properties such as volume, surface area, and inertia.

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The Model of the SPCT generated by Pro-E Wildfire 4.0 software

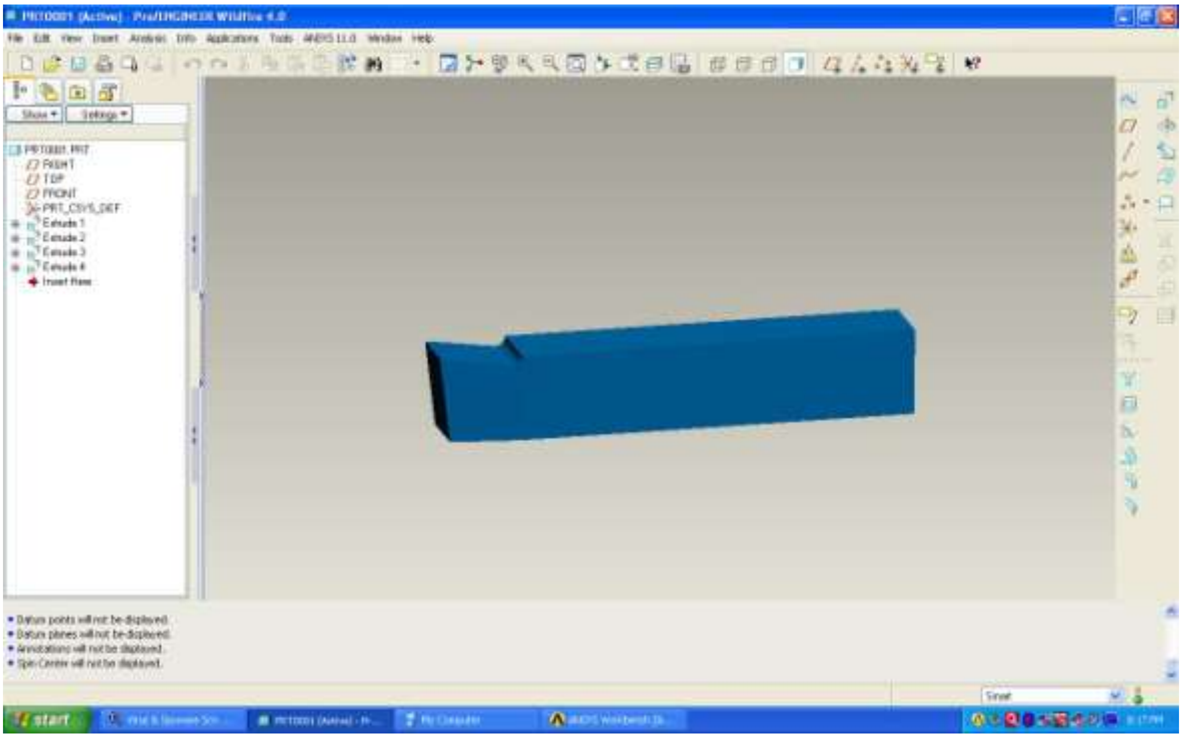


Figure 6:- model of single point cutting tool.

This model is then imported in ANSYS software for meshing and analysis.

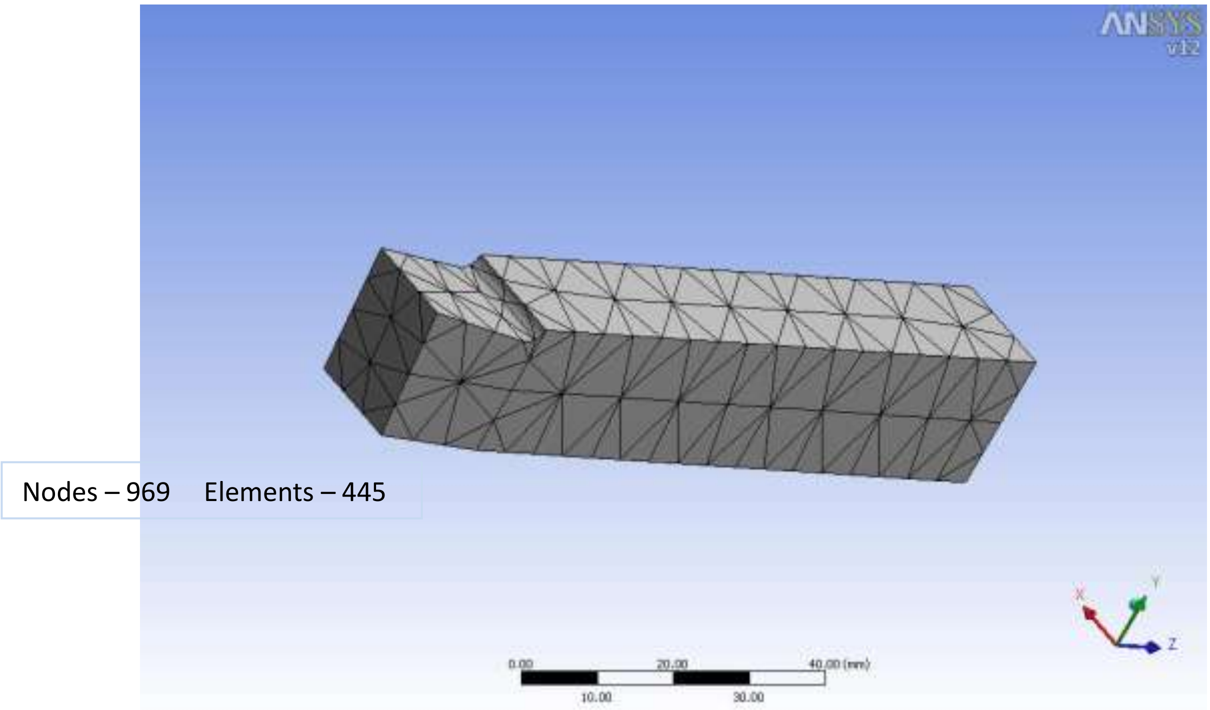


Figure 7:- mesh model made by ansys software

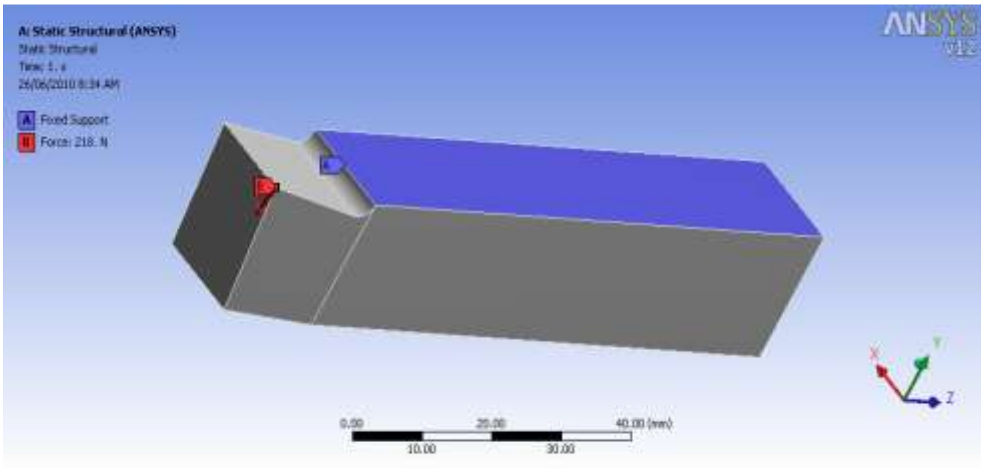
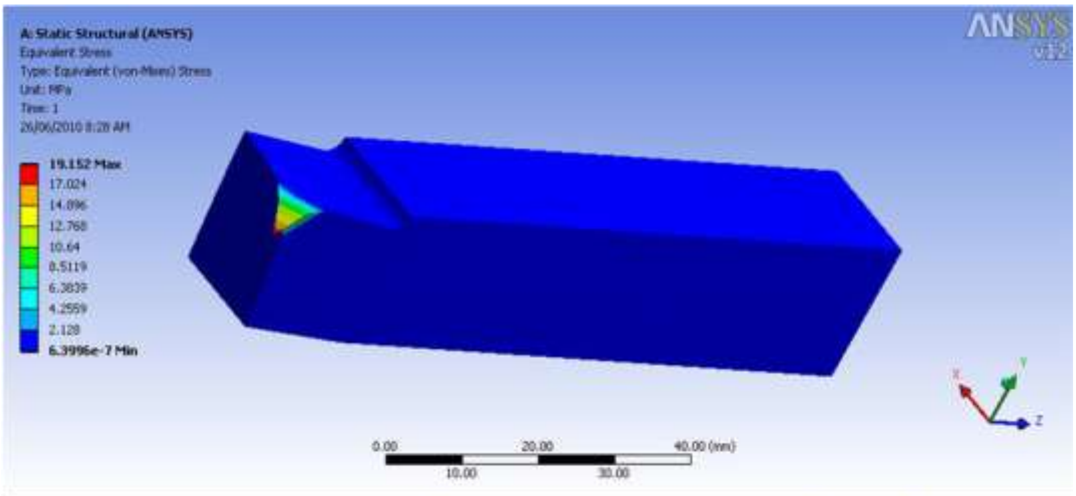


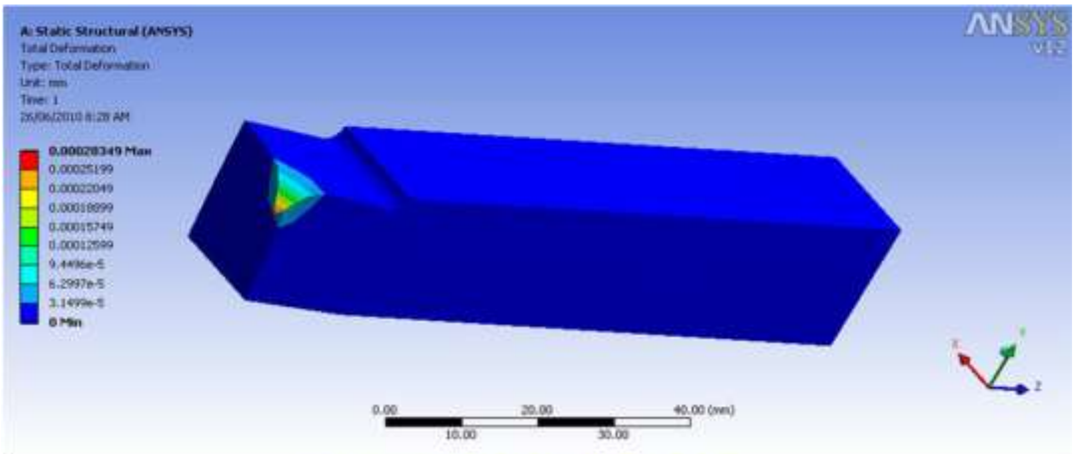
Figure 8:- fixed support given to the tool.

Now, the analysis is performed at various depth of cuts for the forces calculated and the Von-Mises stresses and deformation of the tip in XYZ direction is found out.



Max. Stress → 19.152 N/mm^2 & Min. Stress → 6.339 x 10^{-7} N/mm^2

Figure 9:- von-mises stress at 0.2 mm depth of cut.



Displacement → 2.8349 x 10^{-4} mm

Figure 10:- displacement in xyz direction at 0.2 mm depth of cut.

Similarly, the stresses and deformations are found out by the software. The table showing the stresses and deformation at various depth of cuts is given below.

Table 3:-von-mises stresses and deformation at various depth of cuts.

Depth of Cut (mm)	Von-Mises Stresses (N/mm^2)		Displacement in XYZ direction (mm)
	Maximum	Minimum	
0.2	19.152	6.339	2.8349×10^{-4}
0.5	47.886	1.6×10^{-6}	7.0882×10^{-4}
1.0	95.791	3.2×10^{-6}	14.18×10^{-4}
2.0	191.58	6.4×10^{-6}	28.358×10^{-4}
2.5	238.58	7.921×10^{-6}	35.302×10^{-4}

IV. Conclusions:

The work presented in this paper regarding the project highlights that as the depth of cut increases, the Von-Mises stresses developed in the tool increases. It is the main reason for tool failure.

Also, there is a sudden rise in temperature of the tool tip as the depth of cut is increased which softens the tool from the tip. It adds to the failure of the tool.

The deformation also on higher side with every interval of rise in depth of cut. It is also one of the reason for tool failure.

As the depth of cut is increased further from 2.5 mm to 3.0 mm vibrations are set up in the tool, due to which the geometry of the tool gets affected and the tool becomes unusable.

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