Design And Analysis Of Single Point Cutting Tool By Using ANSYS R15.0

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Abstract : The cutting forces at single point cutting tool-tip interface is determined, generated in high-speed machining operations. An investigation of cutting forces acting on the tool is carried out by subjecting it to the maximum possible working stress during a cutting operation. It is also determined that change in cutting speed and depth of cut has the maximum effect on increasing cutting forces. By varying the material the effect of those on cutting forces are compared with the theoretical results and FEA results. In this report, an FEM simulation technique is utilized to investigate the physical cutting and deformation of tip of single point cutting tool under the influence of cutting forces.

IndexTerms -. Shear area, Young's Modulus, Young's Modulus, Thrust force, Shear Force, Overall correlation, Section modulus, Ansys R15.0.

I. INTRODUCTION

Cutting is the separation of a physical object or a portion of a physical object into two portions, through the application of an actually directed force. However, any sufficiently sharp object is capable of cutting if it has a hardness sufficiently larger than the object being cut, and if it is applied with sufficient force. Cutting is a compressive and shearing phenomenon, and occurs only when the total stress generated by the cutting implement exceeds the ultimate strength of the material of the object being cut. The stress generated by a cutting implement is directly proportional to the force with which it is applied, and inversely proportional to the area of contact. Hence, the smaller the area (i.e., the sharper the cutting implement), the less force is needed to cut something. A cutting tool or cutter is any tool that is used to remove material from the work piece by means of shear deformation. Cutting may be accomplished by single point or multipoint tools. Single point tools are used in turning, shaping, planning and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the work piece without the rest of the tool dragging on the work piece surface. The angle of the cutting face is also important plus the speeds and feeds at which the tool is run.

II. OBJECTIVES

- To analyse the Stress distribution on the Single point cutting tool for prescribed cutting forces.
- To analyse the Single point cutting tool under different parameters (Depth of cut and speed).
- To compare the results of the two materials with respect to their better performance.

III. Methodology

- Modelling: Modelling of Single point cutting tool is done by CATIA V5 R21 as per the geometrical considerations.
- Meshing: Meshing is done by using ANSYS R15.0 workbench. It is necessary to understand how the structure is likely to behave and how elements are able to behave.
- Boundary conditions: Fixing the end face of the Single point cutting tool and applying force on the cutting edge.
- Analysis: Analysis is done by using ANSYS R15.0 workbench.
- Comparison of results.

Table 1 Cutting Forces for Different Depth of Cut

Cutting force in N	Depth of cut in mm		
	0.2	**0.5**	**1.0**
P_X	4.932	12.33	24.66
P_Y	3.28	8.22	16.44
P_Z	16.4	41.10	82.20

Table 2 Geometrical of single point cutting Tool

Table 3 Cutting Forces for Different Speed

Cutting force in N	Speed in rpm		
	33	51	82
P_X	101.04	81.423	40.221
P_Y	268.79	236.421	190.314
P_Z	333.54	297.243	266.832

Parameter	Specifications
Length of the tool	100 mm
Width of the tool	50 mm
Height of the tool	50mm
Side rake angle	6.59°
Back rake angle	9.84°
Side relief angle	3.8°
Side cutting edge angle	2.73°
End cutting edge angle	34.89°

IV. Data Reduction

Properties of Chromium Steel and Tungsten Carbide are listed below,
E_s =Young's Modulus of Chromium Steel = 2×10^{11} N/m^2
E_t =Young's Modulus of Tungsten Carbide = 6×10^{11} N/m^2
ρ_s =Density of Chromium Steel = 7972 kg/m^3
ρ_t =Density of Tungsten Carbide = 15600 kg/m^3
γ_s =Poisson's ratio of Chromium Steel = 0.3
γ_t =Poisson's ratio of Tungsten Carbide = 0.22
(1) For Chromium Steel (0.2 mm Depth of cut)

To find shear stress acting on the shear plane.

As per the standard AISI 410 steel, for depth of cut 0.2mm, the chip thickness ratio is given by r_c=0.45,

$$\tau_s = \frac{F_s}{A_s} \quad (1)$$

To find the shear area, A_S

$$A_S = b \times \frac{h}{\sin\emptyset} \quad (2)$$

$$A_S = (0.2\times10^{-3}) \times \frac{0.2\times10^{-3}}{\sin(25.23)}$$

$$A_S = 9.38 \times 10^{-8}\ m^2$$

Where: $\emptyset$ = Shear angle, degrees

$$\emptyset = \tan^{-1}\frac{r_c\times\cos\alpha}{1-r_c\times\sin\alpha}$$

$$\emptyset = \tan^{-1}[\frac{0.45\times\cos 6.59}{1-0.45\times\sin 6.59} = 25.23^o$$

To find the shear forces F_s,

$$F_s = F \times \cos(\phi+\beta-\alpha) \quad (3)$$

$$= 17.47 \times \cos(25.23+55.36-6.59) = 4.817\ N$$

Where, β = Friction angle, degrees

$$\beta = \alpha + \tan^{-1}\frac{F_f}{F_t}$$

$$\beta = 6.59 + \tan^{-1}\frac{4.93}{3.28} = 55.36^o$$

Substitute the values of (2) and (3) in equation on (1)

$$\tau_s = \frac{4.187}{9.38\times10^{-8}} = 5.126\times10^7\ Pa$$

To find the equivalent stress,

From the DDHB, Volume 1 [Dr. Lingaiah K.], Page No. 2.16, Equation No. 2.99,

$$\sigma = \frac{F}{A} + \frac{M_b}{Z} \quad (4)$$

To find F,

$$F = \sqrt{P_x^{\ 2} + P_y^{\ 2} + P_z^{\ 2}}$$

$$F = \sqrt{(4.932)^2 + (3.28)^2 + (16.44)^2}$$

$$F = 17.47\ N$$

$$M_b = P_z \times \text{Distance}$$

$= 16.44 \times 8.5\times10^{-3}$

$= 0.13974$ N-m

Z = Section modulus

$Z = \frac{I}{Y} = \frac{1.637\times10^{-12}}{\frac{10\times10^{-3}}{2}}$

$= 3.274 \times 10^{-10}$ m^3

[The total contribution of moment of inertia is of three sections as calculated (16.376×10^{-10}m^4) in the tool geometry and it is the multiplier of the 0.1 - 0.2 percent of correction factor (K) of inertial affects (sectional parameter- Area moment of inertia)].

i.e., Total I = $0.001\times(16.3768363\times 10^{-10})$

$= 1.637\times 10^{-12}$ m^4.

Substitute the values of F, A, M_b and Z in the equation (4)

$\sigma = \frac{17.47}{9.38\times10^{-8}} + \frac{0.13974}{3.274\times10^{-10}}$

$\sigma = 6.1224\times10^{8}$ Pa

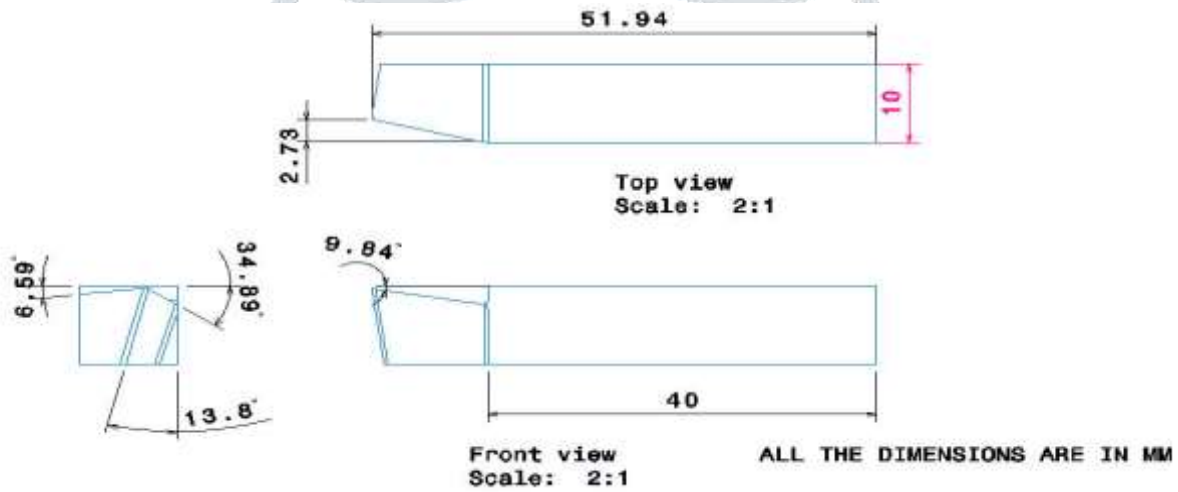

Fig 1 Modelling of Single point cutting tool

V. Results and Discussion

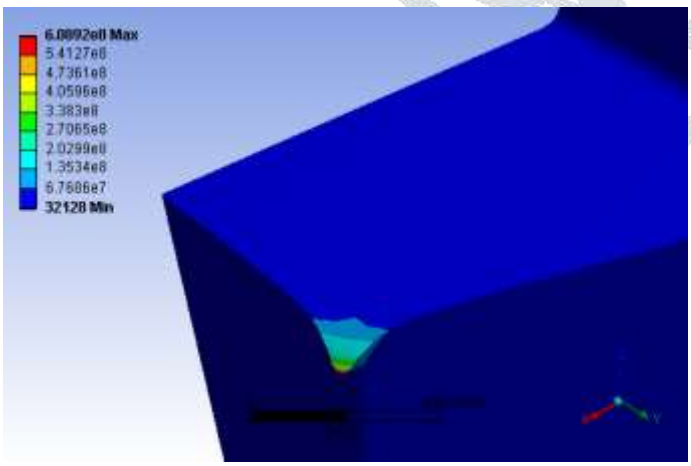

Fig. 2 Equivalent Stress of Chromium Steel tool (0.2 mm DOC)

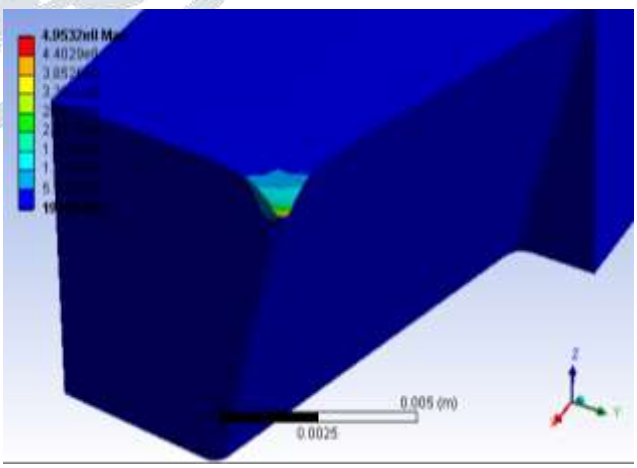

Fig. 3 Equivalent Stress of Tungsten Carbide tool (0.2mm DOC)

The Fig.2 and Fig.3 show the equivalent stress of the Chromium Steel and Tungsten Carbide tool respectively. From these results we can observe that the stress induced in Tungsten Carbide is less than the Chromium Steel tool for the depth of cut of 0.2 mm.

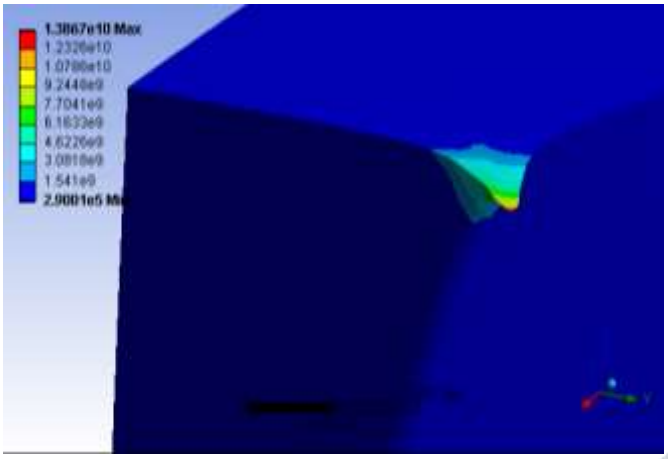

Fig. 4 Equivalent Stress of Chromium Steel tool (33 rpm Speed)

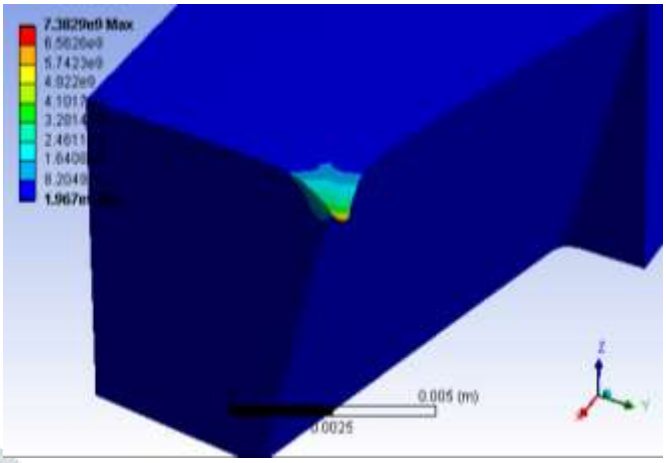

Fig. 5 Equivalent Stress of Tungsten Carbide tool (33 rpm Speed)

The Fig. 4 and Fig. 5 show the equivalent stress of the Chromium Steel and Tungsten Carbide tool respectively. From these results we can observe that the stress induced in Tungsten Carbide is less than the Chromium Steel tool for the speed of 33 rpm.

Table.4 Comparison of Equivalent Stress for Depth of Cut

Sl. No.	Material	Depth of Cut, mm	Equivalent stress, Pa
1.	Chromium Steel	0.2	6.089×10^{8}
		0.5	15.223×10^{8}
		1.0	30.44×10^{8}
2.	Tungsten Carbide	0.2	4.953×10^{8}
		0.5	8.227×10^{8}
		1.0	25.16×10^{8}

Table 5 Comparison of Equivalent Stress for Speed

Sl. No.	Material	Speed, rpm	Equivalent stress, Pa
1.	Chromium Steel	33	13.862×10^{9}
		51	12.321×10^{9}
		82	10.82×10^{9}
2.	Tungsten Carbide	33	7.328×10^{9}
		51	7.461×10^{9}
		82	6.061×10^{9}

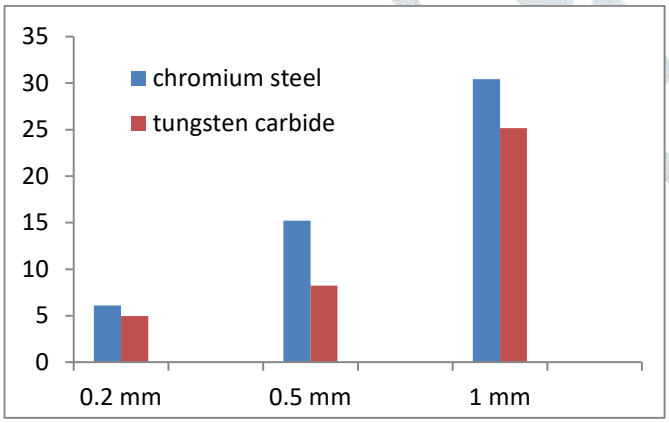

Fig.6 Comparison of Equivalent Stress v/s Depth of Cut

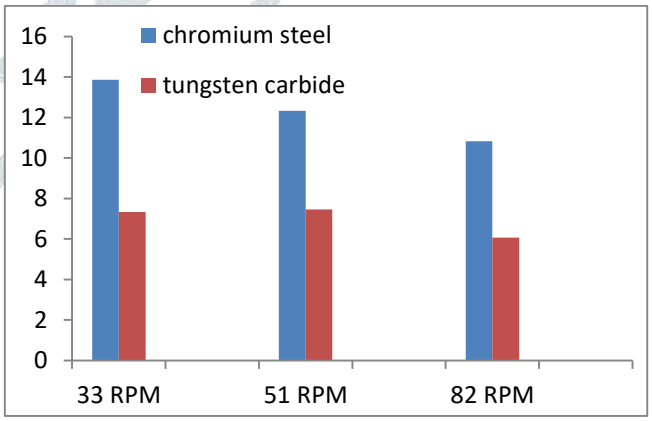

Fig. 7 Comparison of Equivalent Stress v/s Speed

The Fig.6 shows the comparison between equivalent stress and depth of cut. In that we can observe that the equivalent stress induced in Chromium Steel tool material is comparatively 18.65% higher than that of Tungsten Carbide tool material for the depth of cut of 0.2 mm, 0.5 mm and 1.0 mm. The result shows that the performance of Tungsten Carbide is better than Chromium Steel tool material.

The Fig.7 shows the comparison between equivalent stress and speed. In that we can observe that the equivalent stress induced in Chromium Steel tool material is comparatively 35.52% higher than that of Tungsten Carbide tool material for the depth of cut of 33 rpm, 51 rpm and 82 rpm. The result shows that the performance of Tungsten Carbide is better than Chromium Steel tool material.

VI. Conclusion

- From the result, the equivalent stress induced in Chromium Steel tool material is comparatively 18.65% higher than that of Tungsten Carbide tool material for the depth of cut of 0.2 mm, 0.5 mm and 1.0 mm
- The shear stress induced in Chromium Steel tool material is comparatively 23.25% higher than that of Tungsten Carbide tool material for the depth of cut of 0.2 mm, 0.5 mm and 1.0 mm.
- The equivalent stress induced in Chromium Steel tool material is comparatively 35.52% higher than that of Tungsten Carbide tool material for the depth of cut of 33 rpm, 51 rpm and 82 rpm.
- The shear stress induced in Chromium Steel tool material is comparatively 33.2% higher than that of Tungsten Carbide tool material for the depth of cut of 33 rpm, 51 rpm and 82 rpm.
- As we mentioned in the objectives, it is concluded that the performance of Tungsten Carbide is better than Chromium Steel tool material.

VII. Scope for Future Work

The following recommendations are made for future work in this area:-

- For analysis the tool material can be taken as Ceramics, Cemented Carbide and Carbon Steel etc.
- Design and Analysis of Single point cutting tool can also be carried by changing cutting parameters such as Rake angle, Feed etc.
- The working procedure can be carried out for tool wear and vibration for further analysis.

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