Finite Element Analysis of Deformation of Single Point Cutting Tool

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Abstract—Design of single point cutting tool is very important as change in different angles of single point cutting tool may result in variation in cutting force resulting in machining of work piece and its finishing. This paper emphasizes on how deformation in a standard single point cutting tool and shows which the regions under different stress regions are. Here cutting force as well as the thermal effect due to high temperature are considered for deformation.

Keywords—Deformation, single point cutting tool, stress region

I. Introduction

SINGLE point cutting tool (SPCT) is the most used tool of machining industry. SPCT is used in different machines gives different rate of accuracies and surface finish of final work piece. When SPCT is used in Computer /numeric Controlled machines the precision of cut and surface finish are almost the expected. But when SPCT are used in general Lathe machines the precision and surface finish are not good enough. But since CNC machines are costing more than general purpose lathe, in small scale industries where costing is one of the factor there normal lathe are only used. Turning operation is the most basic operation used to decrease the diameter of work piece fixed on rotating spindle while the SPCT held stationary on tool mounting. When SPCT is used in lathe there are different problems faced by the SPCT. There are three zones created in the total system. Primary deformation zone where major of the plastic deformation takes place. Secondary deformation zone between chip and tool interface results in secondary plastic deformation because of friction between chip and tool. Tertiary deformation zone between tool and the work piece due to frictional rubbing. [1] Heat generated because of friction in rubbing is distributed between the three zones majorly taken by secondary zone that is the chips. Heat generated makes the work piece softer resulting in little decrement in cutting force but this heat also affects in deformation of cutting surface of SPCT.

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[1] It is studied that power consumption, heat generation and end finishing depends on mechanical and chemical properties of work piece cutting tool material, cutting environment and cutting tool geometry and rake angle of the tool.[3] Size of tool is determined by width and height of shank and overall length of tool.

Different surfaces present in SPCT:

Cutting Edge: It is the edge of SPCT responsible for separation of chip from work piece. Total cutting edge includes side cutting edge, nose radius and end cutting edge.

Flank Surface: This are the surfaces adjacent to cutting edge.

Shank: It is the main body of tool which is held in the holder.

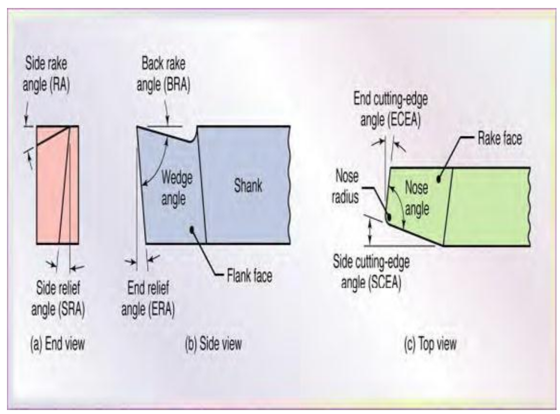

Fig. 1 Different Cutting Tool Angle [4]

There are different angles present while designing tool. Below are SPCT angles:

1. Side Rake angle
2. Back Rake angle
3. Side Relief angle
4. End Relief angle
5. Side Cutting-edge angle
6. End cutting-edge angle

Tools are made up of different material. The tool materials are expected to have different material properties like high hardness, toughness, coefficient of thermal expansion and high wear resistance. Tool material are selected as per different application. For this example we will be using High Speed Steel (HSS) material. Usually high speed steel consists of 1.5%- 2% Carbon, 18% Tungsten, 4% Chromium, 1% Vanadium and rest is iron. HSS tools are generally used for

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high speed cutting that means high cutting velocity ranging from 15-30 m/min. The type of HSS used is 40CrMnMo7. [2]

Properties of 40CrMnMo7:

Elastic modulus: 2.050000031e+011 N/m^2

Poisson's ratio : 0.28

Shear modulus: 7.9e+010 N/m^2

Mass density: 7800 kg/m^3

Tensile strength: 992000000 N/m^2

Yield strength: 821000000 N/m^2

Thermal expansion coefficient: 1.1e-005 /K

Thermal conductivity: 14 W/(m·K)

Specific heat: 440 J/(kg·K)

Above values are obtained from solidworks material module.

II. Modeling

Different parameters like different angle, type of work piece, cutting velocity, feed rate and mainly type of machining operation are to be considered while designing tool. Generalized parametric values were selected to model the tool. Solid works software is used for modelling the single point cutting tool. Here work piece is considered to be made up of cast iron which is hard in nature, so low cutting speed of about 5 m/min is set. Feed rate is 2 mm for every cycle. Size of tool is 80x80x80 mm. Shank size is kept as 100x100x300 mm.

Different angle values:

Side Rake angle: 8

Back Rake angle: 0

Side Relief angle: 5

End Relief angle: 5

Side Cutting-edge angle: 5

End cutting-edge angle: 5

For modelling the tool in solid works first shank was designed by creating square of then extruding by mm. On the front surface smaller sized of was created then extruded giving different edges. Then with different cutting sketches in different planes were created as shown in figure. This sketches were then cut extruded as needed giving ready single point cutting tool with different edges and surfaces.

III. Solution Setup

Turning operation of Cast Iron is kept in mind while setting up solution parameters for single point cutting tool. There are two cases that will be considered for the current analysis. First being the case of new single point cutting tool as shown in figure .Here the force acts at the tip of the tool in downward direction as shown. Second case is of the used tool. As shown in figure that a cut section plane is formed. The force then acts normal to the section plane. For both the cases common parameters considered are:

Force acting on the tip or the cut-section plane =900 N

Temperature at the flank surfaces = 150^{o}C

Temperature at the other flank surface = 50^{o}C

The above values are generalized values referred from some previous papers.

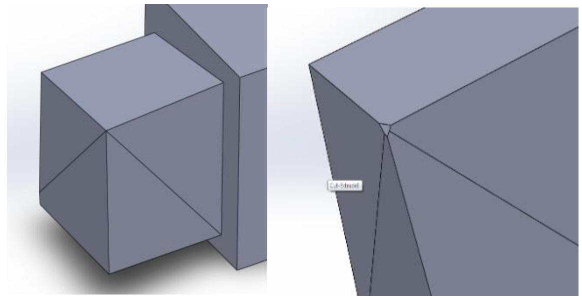

Fig. 2 Fresh Tool with pointed tip; Used Tool

As shown in figure pink arrow shows force distribution and blue arrow shows temperature distribution. Green arrows shows the fixtures that is the tool is fixed at that part. Here we can see green arrows in the shank**.**

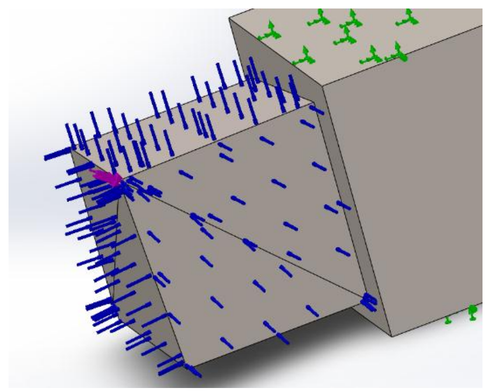

Fig. 3 Force and Temperature setup

IV. Result And Discussion

A tip with displacement of and stress of is formed because of force acting on the tool. For the other case the stress areas are sown in figure:

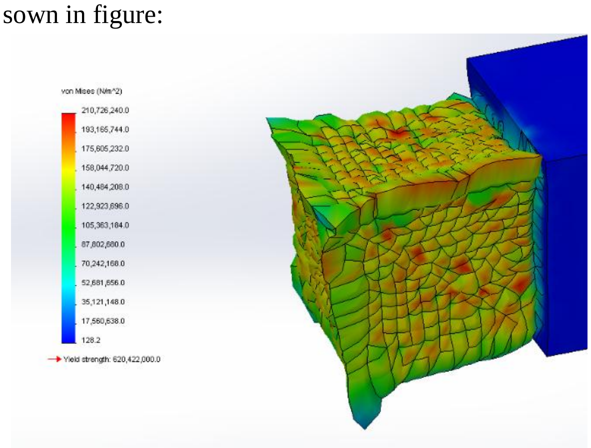

Fig. 4 Von Misses Stress Distribution in used SPCT

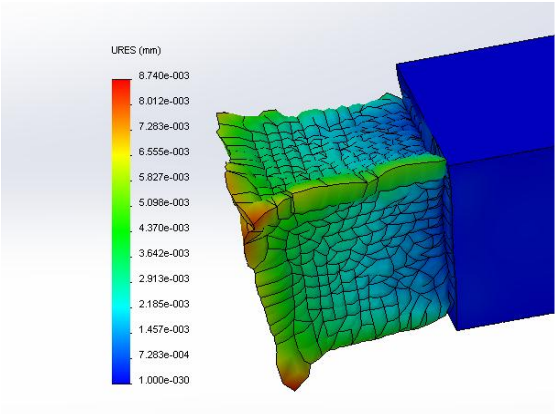

Fig. 5 Displacement in used SPCT

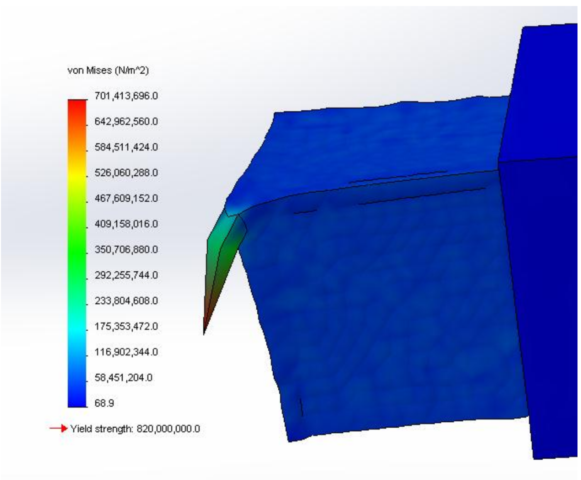

Fig. 6 Stress Distribution in new SPCT

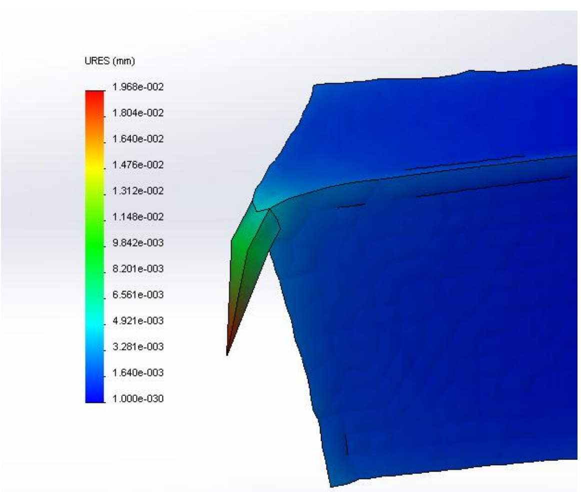

Fig. 7 Displacement in new SPCT

Figure 2 shows stress distribution at different points along the tool compared to high stress tip in figure 5.Since the Stress is distributed at different points so the deformation in this is less compared to the high stress tip tool. In Figure 3 and figure 5 where deformation is shown in terms of displacement. As stress is evenly distributed in used tool so deformation or displacement in used tool will be less as shown in figure 3 and because of high stress tip formation more deformation or displacement will occur in new tool. Hence used tool will become slowly blunt compared to used tool.

V. Conclusion

From results it is concluded that when a new tool is used the high stress regions developed are less and displacement at the tip is more as much as 0.01968 mm. For the used tool the high stress areas are more and displacement at the tip is lesser as 0.008740 mm as it is blunt at the tip. More stress regions means more power hence used tool requires higher power to machine compared to fresh tool. Based on the finding if power is the main concern and hard materials are to be machined then tool with pointed tip is preferred.

Reference

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