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OPTIMIZATION OF FEED RATE BY THE VARIATION OF RAKE ANGLE IN SINGLE POINT CUTTING TOOL

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Organizations that engage in excellent human resource training and development tend to achieve benefit both short-term and long-term.Now a day's fast-paced, competitive industry, training has become a buzzword. Different values of induced forces are observed as a result of the variation in the rake angle of the tool and feed rate of the process. The effect of forces is measured by induced stress in the tool. For this study, three types of stress viz. Von-Mises, Max Principal, and Max Shear Stress are considered. The aim of this study is to investigate whether the increase in rake angle significantly reduces stresses and does not compromise on tool strength. A total of 30 sets of values of forces developed due to variation in rake angle and feed rate are considered and these values are obtained for six distinct values of rake angles (0º,3º,6º,10º,12º,18º) and feed rates (0.027, 0.042, 0.084, 0.108, 0.132). A simulation for stress developed on the cutting tool was carried out in ANSYS Workbench 17.2. The simulation model was created in Solid Works and the results obtained indicate a considerable reduction in stress values asthe rake angle increases irrespective of the decrease in lip angle and decrease in tool cross-section area.

Keywords:_Training and Development, Orthogonal turning, Rake angle,SPCT._

INTRODUCTION

The forces acting on the tool are shown in Figure.1. One important aspect of the orthogonal cutting process is that there does not exist any force in the direction perpendicular to the relative motion of the tool and workpiece. These developed forces act at the tip and on the sharp cutting edges of the tool. The magnitude of these forces is directly dependent on the parameters like feed rate, cutting speed, depth of cut, and rake angle of the tool. The location of the cutting tool is critical in metal cutting operations.

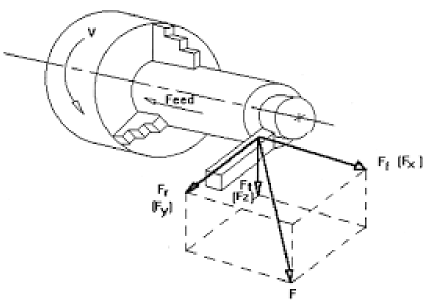

Figure1. Various Forces on Single Point Cutting Tool

Its location is used as a basis to classify the cutting operations in two types viz. orthogonal cutting and oblique cutting.

The orthogonal cutting additionally known as two-dimensional metal cutting has its cutting edge oriented parallel to the workpiece. In the turning process, the workpiece is rotated about its axis while the tool traverses laterally along its length. During the process, the tool removes the material in the form of layers (chips) which creates three types of cutting forces on the tool i.e., the tangential force, the feed force, and the radial force.

RESEARCH PROBLEM

The main parameters involved in metal cutting or machining are mentioned as follows:

- Feed rate: It can be described as the amount of lateral movement of the tool against the workpiece. The unit of the feed rate can be mm/rev or mm/mm. In the unit, the numerator is related to the tool while the denominator is related to the workpiece.

- Cutting speed: It is the rate of cutting edge's relative motion on the material of the workpiece.

- Depth of cut: It is the value of distance the tool is fed into the workpiece's surface.

- The geometry of the tool: The geometry of the tool is related to its various angles. The angles are denoted by the tool signature. Geometry and material type of workpiece.

IMPORTANCE OF CUTTING FORCES

Rake angle is the angle measured between the rake surface and the reference plane (πR) or workpiece's perpendicular surface. Rake angle is the most important aspect while designing a cutting tool. It is provided on the tool to enable the chip flow during the machining away from the workpiece. Other than its primary function,[1] it can improve the sharpness of the tool and also reduce the cutting forces and power requirements. Rake angle is classified into three types viz. positive rake angle, zero rake angle, and lastly negative rake angle [2].

A positive rake angle is used when the tool has to machine ductile workpiece and form a continuous chip. It also helps to avoid built-up edge (BUE) formation. However, a positive rake angle can indirectly affect the strength of the tool by decreasing the lip angle.

A negative rake angle is used for machining hard and brittle materials. The chips formed by these tools are non-continuous and broken. Due to its negative value, tool strength is more and it can bear a higher load. A negative rake angle does have some detrimental effects such as high deformation of chip material during its shearing process and requirement of high force and power since the negative angle decreases tool edge sharpness. Also, the high frictional force generated on the rake face during machining has a tendency of BUE.

LITERATURE REVIEW

Kosaraju, Anne, & Ghanta (2011) performed an experimental study to understand the effect of varying rake angle and feed rate on forces acting on SPCT. The experimental results showed that with the increase in feed rate, forces acting on the tool increased whereas they decreased as the rake angle increased. Rathod &Razik(2014)investigated the effect of temperature generated on a SPCT during the high-speed machining operation. Experimental and simulation data were compared and results indicate that the key factors accountable for heat generation are feed rate, tool's cutting speed, and depth of cut. Shambharkar, Kawale, &Choudhari (2016) performed an experimental and analytical study on SPCT to examine the effect of varying temperature and depth of cut on cutting forces. The results from the analytical study were compared with theoretical values and it was revealed that a sudden temperature rise weakens the tool near the tip area and promotes its failure. Kurekar&Khamankar(2017) performed an experimental and FEM analysis on SPCT to examine the outcome of cutting force and thrust force on the tool, and the comparative study showed that the cutting force affected the tool more than the thrust force[3]. Shih (1996) created a plane-strain FEA method to employ it on a model of SPCT and hence, to investigate the effect of different back rake angles on the metal removal process. The outcomes from the study suggested that the dynamic coefficient friction will have less impact on cutting with a large value of back rake angle. Mahnama&Movahhedy (2012) combined a FEM model for chip generation in orthogonal turning with a dynamic framework for machine tool arrangement to accurately predict chatter and machine stability. Krishnan, Thakur, &Garg(2015) did a comparative study of FEM and theoretical analysis on deflection in SPCT due to machining parameters like feed rate, depth of cut, and tool's geometrical parameters or tool angles viz. side clearance angle and side rake angle. The analysis was carried out by varying the two geometrical parameters. The results indicated a decrease in tool deflection to some degree with increment in the side rake angle. The tool's deflection in axial direction decreased with increment in theside rake angle. But in the case of tangential deflection, it decreased with an increment in the side cutting edge angle. Radial deflection increased in both cases. Daniel, Terfa, & Kingsley(2017) conducted an experimental study on the effect of varying feed rateand rake angle on machining forces in orthogonal turning operation. Around 12 experiments were conducted and for three different values of rake angle (-5^o, 0^o, 5^o) and four values of feed rate (0.1, 0.17, 0.24, 0.31 mm/rev). Results showed that the thrust force came out to be higher than the cutting force whereas the radial force was negligible. The values of forces increased with an increase in feed rate and decreased with increments in rake angle. Baldoukas et. al. (2008) performed an experimental study to observe the effects of rake angle, depth of cut, and type of workpiece material on the main cutting force and pattern or form of the chip for the orthogonal metal turning process. They removed chips from the machining process during the experiment, that were later collected and analyzed with important calculated forces to determine the optimum rake angle for each type of material. The results from the experiment denoted that the main cutting force increased with an increase in the depth of cut.

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METHODOLOGY

A FEM simulation is carried out on a SPCT to analyse the effect of forces by considering stress induced in the tool.

The first step is to model the cutting tool on which analysis will be performed. The cutting tool is modelled in Solid works CAD software. The tool is a High-speed tool and the tool signature is 0-7-7-7-15-15-0.5. In this particular study, the rake angle and feed rate are varied and the corresponding values of forces and are used to determine respective stresses. Six values of rake angle (0˚, 4˚, 8˚, 12˚, 16˚, 20˚) and five feed rates (0.022, 0.044,0.088, 0.108, 0.132) are considered. Fig. 2 shows the cad model of 4º rake angle SPCT. Correspondingly six cad models of the cutting tool are designed for different rake angles.

The FEM simulation is carried out on ANSYS workbench 17.2. The no. of FEM simulation carried out are 30, 5 simulations for each value of rake angle. The 5 simulations correspond to the 5 values of feed rates. The forces which are input values for simulation are referred from [5]. The forces and appropriate boundary conditions are applied and results are evaluated.

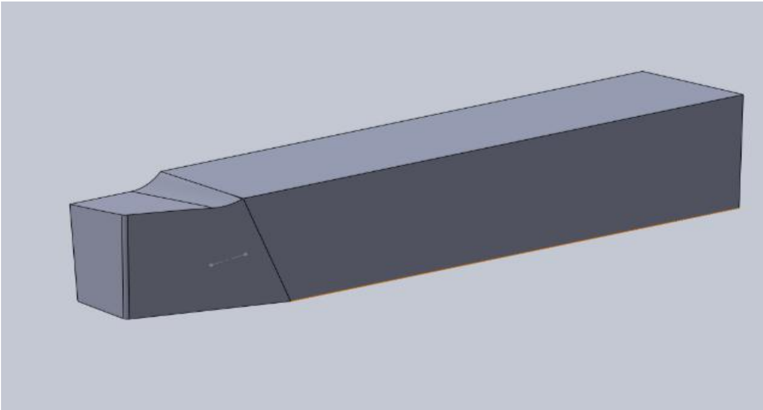

Figure2. CAD Model of SPCT

The material used for the tool is HSS and for the workpiece is EN8. Table 1 has the mechanical properties of both materials. These values are the input parameters during the simulation.

RESULTS AND DISCUSSION

The input values for simulation are shown as per in Table 2. The table shows feed rate, rake angle, and its corresponding forces. Three forces namely Feed force, cutting force and radial force are observed. These values are considered to be acting on the cutting edge and edge of nose radius. The simulation results are shown in fig.3. The values from table 2 are represented in graphical format. The line graphs as shown in fig.4 shows the plots of stress to feed rate for a particular rake angle. These graphs show that the value of all three stresses increases as the feed rate increases. Von-Mises have the highest value followed by Max

Shear and lastly Max principal Stress. It is observed by comparing these graphs that a smaller rake angle has a high value of stresses and it starts to descend relative to each other as the rake angle increases. From the graph of 8º rake angle, the max shear and max principal have a flat trend whereas vonmises have the highest value for 0º amongst all the other values of rake angles. The stresses start to decrease from 12º,16º and are significantly reduced in 20º. The lowest values are observed for 20º.

The graph as shown in fig.3 are plots of stress vs rake angle. For the plot of Von-Mises vs Rake angle, the different curve line is for different values of feed rate. The lowest feed rate has correspondingly lower induced stresses. The highest value is observed at 0º and the curve descends to meet the lowest value at 20º. The stresses in the plot of Max principal stress vs Rake angle have its highest value at 4º for all feed rates and it descends to give the lowest value at 20º. The stresses in the plot of Max Shear vs Rake angle show high variation near 8º value. The max shear stress attains the lowest value at 8º followed by a steep increase for further values of angle. Here 20º is the second lowest value for max shear.

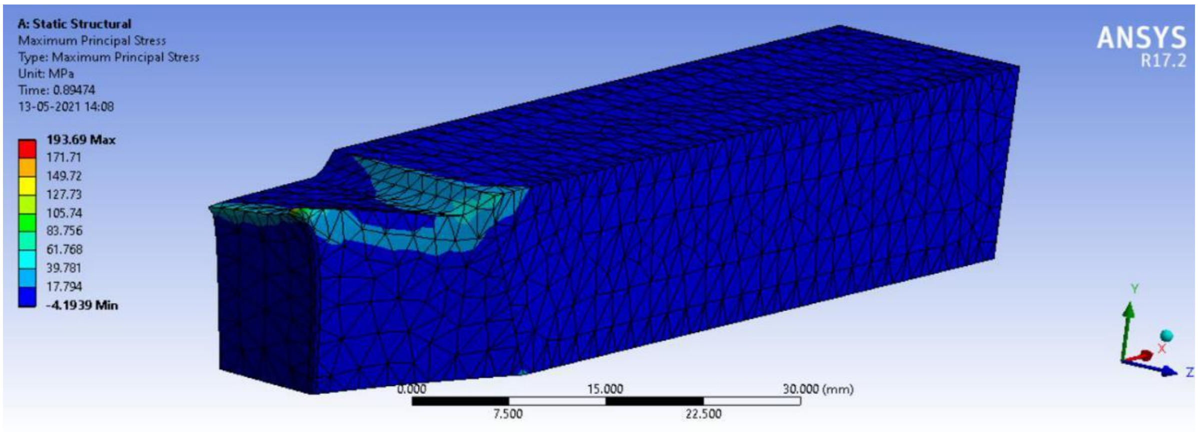

Figure3. FEM Von-Mises Solution

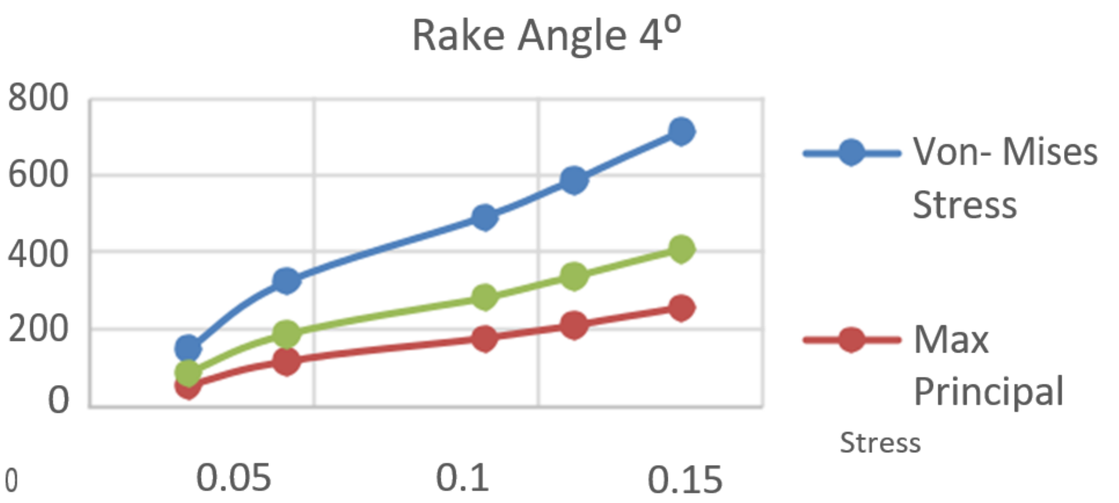

Figure 4. StressesVariation vsFeed Rate at 4º Rake Angle

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The graph in fig.4shown the % variation of stress as rake angle increases. In the case of the graph for Von-Mises and Max principal, the highest positive variation is for 4º and the stress variation is 85% and 132% respectively. Similarly, the highest negative variation is 8º and 20º and the value of variation is -37%, -49%, and -42%, -50% respectively. The plot of max shear stress is different than the previous two. The max and minima occur at 12º and 8º respectively and their values are -84% and 28.5% respectively. All the values of variations are considered for 0.044 and 0.132 feed rate values.The results of the machining of the mild steel are shown; the chip formed is shown and coupled with the chip formed with the abaqus simulation. The type of chip produced in different interactions in machining is shown and the optimum spindle, feed rate and depth of cut are analyzed. For roughing purposes, tools with smooth small size discontinuous chips are preferred, so the carbide is preferred over the cubic boron nitride [5]. The suitable small sized discontinuous chips are obtained at a lower depth of cut of 0.5mm and feed rate 0.15mm/rev.[8] For the finishing and grinding purposes on mild steel, the tool with the fine small thickness short chips which provide a better surface finish, this is obtained at a depth of cut of 0.5mm and feed rate 0.25mm/rev. For cubic boron nitride, the optimum feed rate is 0.15mm/rev at a depth of cut of 0.25mm. [9]

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