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Cutting Response of Single Point Cutting Tool using FEA

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Abstract - *In machining process, the geometry of cutting tool is one of the major parameter on impacting the quality of manufacturing process of a component. The tool geometry consists of various cutting angles and faces which have significant role in Machining different surfaces and components. With the advancement in computer technology, FEA gives an opportunity to have a detailed examination of all cutting tool angles and faces on the finish component (workpiece). In this paper a single point cutting tool is modeled in Solid-works software and then the model is imported in ANSYS 18.1, where analysis has been carried put. By subjecting the real boundary condition to cutting tool geometrical parameter on stress and tool deformation has been examined.*

Key Words: FEA, Stress, Deformation, Tool.

1. INTRODUCTION

(Design and manufacturing of cutting tools occupies a crucial role in any manufacturing system, as machining processes continue to hold a large share of product shape and form realization activities. The mathematical modeling of any cutting tool begins with the modeling of a single point cutting tool (SPCT). Conventionally, cutting tools have been defined using principles of projective geometry and the definitions have been limited to few standard shapes of the cutting tools. They are not unified and find a very limited use in computer based manufacturing and engineering analysis. [1]

Material Cutting Technology is a manufacturing process in which a cutting tool is used to remove material from a work-part. So that the remaining material becomes a desired final shape and size by a controlled material-removal processes. The machining process is controlled by detail drawing. Machining is a family of processes. Machining common features are the use of cutting tools to form chips that are removed from the work-part. In manufacturing, metal parts frequently require machining. The cutting action itself is a shear deformation on the work-part. Machining can be applied to a wide variety of work materials all solid metals, plastics and plastic composites, woods and even most ceramics in spite of their high hardness and brittleness etc.

To remove material of the work-part (to perform cutting operations) and relative motions are required between the cutting tools and work-part. The relative motion is a combination of a primary motion called the Cutting Speed (v) and a secondary motion called the Feed (f). In addition, the penetration of the cutting tools below the original work surface is called the DOC (Depth of Cut (d)) The cutting conditions can be defined as combination of the Speed, Feed, and DOC. [2]

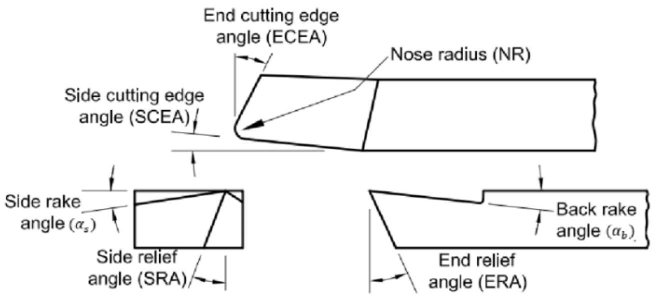

Fig. 1 The angles of a single-point cutting tool.

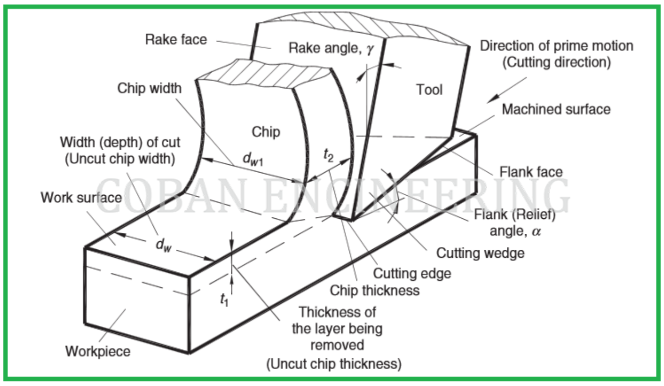

Fig. 2 shows as an example for orthogonal cutting process. [2]

2. LITERATURE REVIEW

Sewailem and Mobarak [3] demonstrated that the wearing of a cutting tool is affected by many factors, example, the material, the cutting conditions, the geometry and the cutting forces. Merchant [4] identified the most significant factors associated with tool wear as being the magnitude of the cutting force, the temperature at the tool workpiece interface, the surface finish of the workpiece, the dimensional accuracy of the component, the occurrence of vibration, and the noise level. Luttervelt and co-workers [5,6] analyzed the effect of various cutting parameters on the chip flow direction, indicating that the direction depended not only on the geometry of the tool and the cutting conditions (feed-rate, depth of cut) but also on the curvature of the workpiece.

The orthogonal cutting model shown in Fig. 2 is a very well established, fundamental tool of the 2D ductile cutting that can be applied to many types of machine operations such as turning, drilling and milling [7,8]. The assumptions of this model assume that the tool has a perfectly sharp edge and that a continuous chip is produced with no built-up edge [8]. The resultant of the cutting forces between the tool and work piece can be expressed by either the forces applied to the tool face (NC and FC), the forces applied on the shear plane (NS and FS), or the horizontal and vertical forces (FP and FQ). The rake angle a is the angle between the line perpendicular to the cutting direction and the tool face and is shown as a positive angle in Fig. 2. Merchant [9] presented an orthogonal cutting force model that is derived from the resultant force between the tool face and the chip, which is equal to the resultant force between the work piece and the chip along the shear plane.

Kashiway and Elbestawi [10], investigated the effect of cutting temperature on the integrity of machined surface. It has been shown that cutting temperature has a major effect on the integrity on the machined surface. The undesirable surface tensile residual stresses were attributed to the temperature generated during machining. Therefore, controlling the generated tensile residual stresses relies on the understanding of the effect of different process parameters on the cutting temperature.

B. Findes, et al [11], studied the influence of cutting speed, feed rate and depth of cut on cutting pressures, cutting force and on cutting temperature, when machining AISI H11 steel treated to 50 HRC work piece material with mixed ceramic tool. The results show that depth of cut has great influence on the radial cutting pressure and on cutting force. The cutting pressure and cutting force increase with an increase in depth of cut and feed rate. It was found that increase in cutting speed increases cutting zone temperature rapidly.

W. Grzesik [12], His work related to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip/tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions. Results showing how the tool chip interfacial friction influences the temperature distribution fields as the effect of using coated tools are the main. A good agreement was achieved, especially for uncoated and three-layer coated tools, between predicted and experimental values of cutting temperatures.

W. Grzesik, M. Bartoszuk et al. [13], the aim of this study was to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting condition.

Meenu and KomeshSahu [14]They developed an optimization method of the cutting parameters (cutting speed, depth of cut and feed) in dry turning of AISI D2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate (MRR). The experimental layout was designed based on the Taguchi's L9 (34) Orthogonal array technique and analysis of variance (ANOVA) was performed to identify the effect of the cutting parameters on the response variables. The results showed that depth of cut and cutting speed are the most important parameter influencing the tool wear. The minimum tool wear was found at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Similarly low w/p surface temperature was obtained at cutting speed of 150 m/min, depth of cut of 0.5 mm and feed of 0.25 mm/rev. Whereas, at cutting speed of 250 m/min, depth of cut 1.00 mm and feed of 0.25 mm/rev, the maximum MRR was obtained. Thereafter, optimal range of tool wear, work piece surface temperature and MRR values were predicted. Finally, the relationship between factors and the performance measures were developed by using multiple regression analysis.

3. OBJECTIVE OF PROJECT WORK

Tool geometrical cutting parameters are strongly influences the tool performance during the operation. So the machining can be improved by the knowledge of effect of various tool signatures on workpiece. Thus the main objectives of this project are as follows:

- To develop a CAD model of single point cutting using Solidworks.
- Modeling and finite element analysis of single point cutting tool.
- Effect of Cutting force and Rack angle of cutting performance.

- Determination of stresses on cutting tool using ANSYS.

4. METHODOLOGY

In order to achieve this, FEA analysis of the single point cutting tool using the analysis (ANSYS). A CAD model of tool has been developed in Solidworks and then imported to ANSYS 18.1. ANSYS 18.1 is a computational technique that enables the estimation of the relative contributions of each of the control factors to the overall measured response. In the present work, only the significant parameters are such back rack angle, cutting force, Von Mises Stress is examined. These parameters are of great use during the optimization of the process variables. Fig. 3 shows Mesh model of imported single point cutting tool.

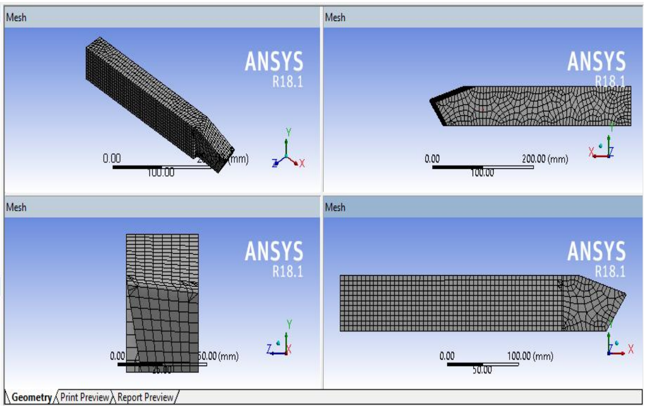

Figure 3. Mesh model of Imported Single point cutting tool

5. RESULT AND DISCUSSION

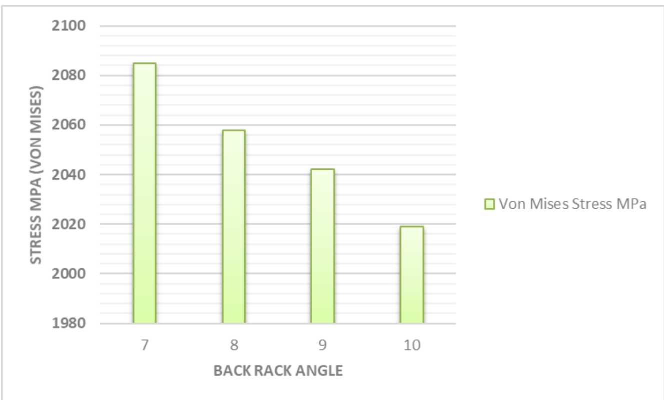

Fig. 4Effect of Back Rack angle on Von-Mises Stress

Fig 4 and 5 shown the effect of a back rack angle on the Von Mises stress and cutting force. It has been observed that an increase in back rack angle decreases the tool stress level significantly. It has also been seen that the cutting force decreases with an increase in back rake angle. Positive back rack angle helps in moving chips away from the machined workpiece as the tool easily penetrates the workpiece and leads to shearing of material rather than compressing, which ultimately improves the cutting efficiency. The same can be evident from the figure 6

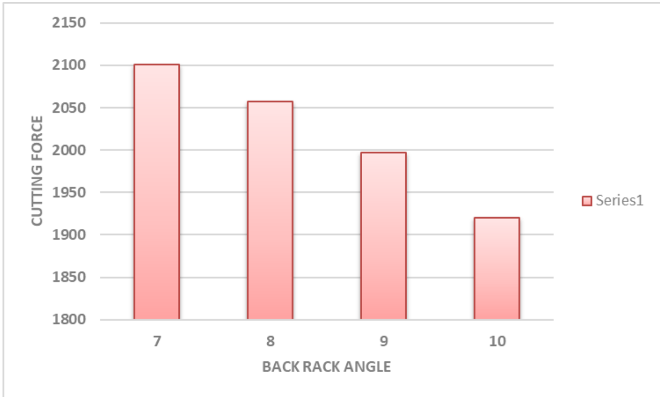

Fig. 5Effect of Back Rack angle on cutting force

From the above, it can be concluded that for cutting harder material positive rake angle is preferred. The chip from the workpiece moves away from the tool due to positive rake angle. Therefore, low tensile strength, as well as non ferrous materials are machined by using a positive rake angle. However, a positive rake angle based tool has also been used for machining long and small diameter shafts or material that is work hardened during machining. Even from the figure 6, we can conclude that during machining hardened material continues chip is generated which desirable in order to maintain the cutting tool under the safer zone and prevents it from failure. Thus it can be proved that for cutting hardened material positive rake angle is used which results in the generation of continuous chip and prevent the cutting tool from failure.

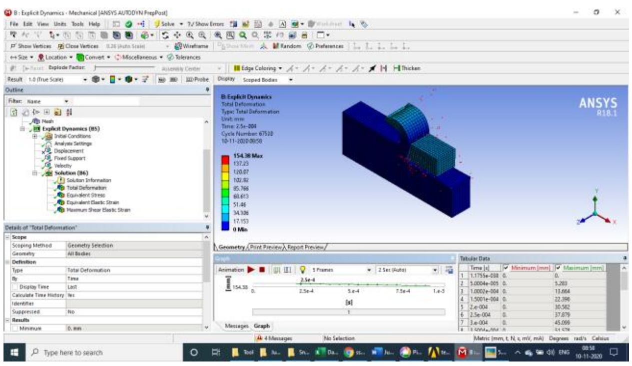

Fig.6 Total Deformation of the Cutting tool

6. CONCLUSION

Based on finite element analysis of cutting tool various conclusions have drawn which are as follows:

- With having positive back rake angle the cutting chips are moves away from work piece.
- Cutting tool stress level decreases as back rake angle increase.
- Increase in relief angle, decreases Von-Mises stress. For machining harder material small relief angle is preferred larger relief angle leads to deterioration of cutting edge and the cutting tool ultimately fails. Increase in back rake angle the cutting forceeventually decreases.

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