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AN ESTIMATION OF EDGE DETERIORATION ON CUTTING TOOL DURING TURNING: OFF-LINE STRESS ANALYSIS APPROXIMATION

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ABSTRACT

Forces occurred during metal cutting have important influences on efficiency of machining as a result of their effect on the tools as well as on the processed materials.

As several experimental set up are designed for the measurement and many model are developed for the calculations of these forces, effect of these forces and other cutting conditions on the tools must also be studied.

In the present study, on the example of parting tool geometry, the effects of cutting forces and several friction coefficients on the stresses have been studied by the finite element method. Their effect on the deterioration of tools have been discussed.

Keywords: Turning, Parting tool, Stress analysis, Finite element method.

TORNALAMADA KESME KALEMİ UCUNUN KÖRLENMESİ İÇİN BİR TAHMİN YÖNTEMİ: GERİLME ANALİZİ YAKLAŞIMI

ÖZET

Kesme işlemi esnasında meydana gelen kuvvetlerin takım üzerindeki etkileri ile bu etkilerin iş parçası üzerinde meydana getirdiği sonuçlar verimli bir kesme işleminin gerçekleştirilmesinde büyük öneme sahiptir.

Kesme sırasında meydana gelen kuvvetlerin ölçülmesi ve hesaplanması için çeşitli ölçüm cihazları ve hesaplama modelleri geliştirilirken bu kuvvetlerin ve diğer kesme koşullarının takımı ne şekilde etkilediği de araştırılmak durumundadır.

Bu çalışmada kesme kalemi geometrisi göz önüne alınarak kesme kuvvetleri ve çeşitli sürtünme durumlarının neden olduğu gerilmeler sonlu elemanlar metodu ile araştırılarak takımın hasara uğramasındaki etkileri üzerinde durulmuştur.

Anahtar Kelimeler: Tornalama, Kesme kalemi, Gerilme analizi, Sonlu elemanlar metodu

1. INTRODUCTION

Machining operations are carried out as a result of relative movements between the cutting tool and parts to be produced. During cutting, two fundamental movement take place: Cutting and translation. Translation is the movement which make the machining of parts by their length or width possible. On the other hand, the cutting movement exists as a result of linear movement of cutting tool and turning movement of the part. Machining process can only be possible if the cutting tool can sustain against the forces exerted by the cutting operations.

Although there are several approximation for modeling the effects among the edge deterioration and wear of the tool, surface quality of machined parts, temperature, mechanical and physical properties of tool and part materials and the forces occurred during machining, no reliable model have been obtained yet [1-3]. This makes the basis of investigations and increasing interest on the experimental, analytical and numerical studies on the metal cutting operations [4-11]. The forces occurred during the chip removal metal forming operations have only shearing (Fs) and radial (Fr) components. These forces have the nature of linearly varying distributed forces [5]. Frictional forces, on the other hand, take place depending on the conditions of use of cutting and cooling fluids. Friction is naturally cause surface forces [5,6].

The cutting forces have been determined as the most important factor of cutting economy and the power required for the entire operations. These forces also have taken the importance as they determine the deterioration and failure of cutting tools. This yields the reliable analyses of stresses on the tools and developing the geometry which gives most suitable conditions for economical machining [6]. Two types of stresses cause the failure of cutting tools: Tensile and compressive type stresses. Tensile stresses take place at the upper face of the tool and cause crater wear while compressive stresses take place at the front face and cause frontal wear. Another type of tensile stress caused failure is the fracture especially for brittle carbide tools. Compressive forces also cause the plastic deformations [4].

The present study concentrates on the stress analysis of parting tool of the turning operations. The geometry and boundary conditions of the tool is given in fig 1. The chip width is 4 mm. 0.2 mm/rev translating speed of the tool for st 60 material yields an Fs of 1500 N for this operation [2]. A 3 mm frictional distance is considered until the cracking and removing the chip from the upper surface of the tool (Fig 2).

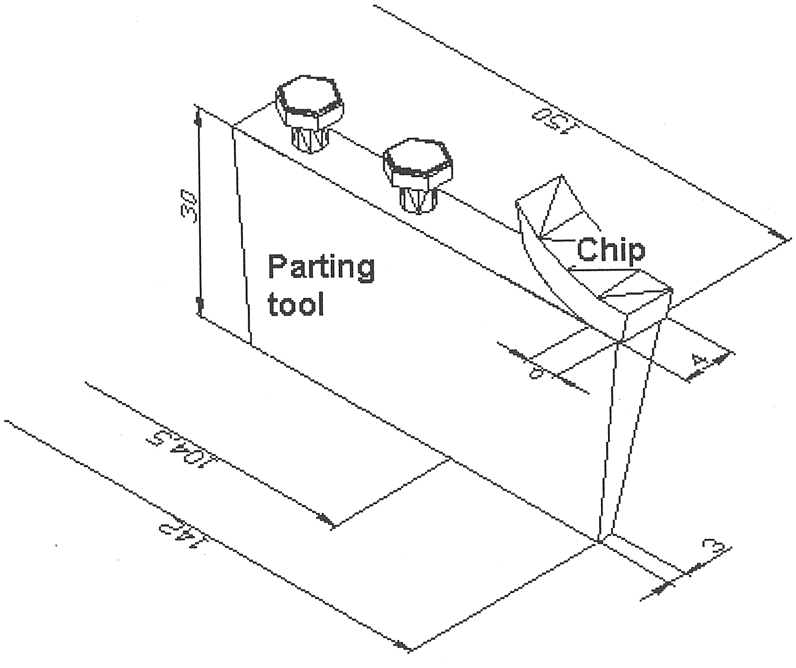


Figure 1. Geometry of the studied parting tool.

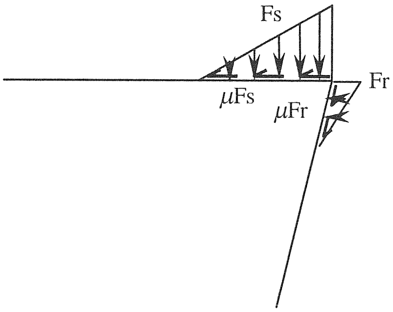


Figure 2. Normal and tangential forces exerted on the tool

2. METHOD

The computer code generated by Taşgetiren and Topçu [13] for two dimensional stress analyses is used in this study for modeling of the problem. The code models both thermally and mechanically created stresses. The entire problem is one of the plane stress problem subjected to bending and axial loading [12].

The stress and strain can be related by elastic properties. In matrix notation,

$$\{\sigma\} = [D]\{\varepsilon\} \tag{1}$$

Where $\{\sigma\}$ is the stress vector, $[D]$ is the elasticity matrix and $\{\varepsilon\}$ is the strain vector. These are in the following form,

$$\{\sigma\} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}, \quad [D] = \frac{E}{1-\upsilon^2}\begin{bmatrix} 1 & \upsilon & 0 \\ \upsilon & 1 & 0 \\ 0 & 0 & \frac{1-\upsilon}{2} \end{bmatrix}, \quad \{\varepsilon\} = \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} \tag{2}$$

On the other hand, the strain and displacements are related by a geometric interpolation matrix [B].

B is obtained from element properties such as type of element, number of nodes per element, type of interpolation functions and coordinates of each nodes.

Mathematically;

$$\{\varepsilon\} = [B]\{q\} \tag{3}$$

The four node quadratic elements are used in the present analyses. The element rigidity matrix is,

$$[k]_e = t_{or}\int_{-1}^{1}\int_{-1}^{1}[B]^T[D][B]\det J dr ds \tag{4}$$

Because the thickness of the tool is varying, the thickness at the midpoint of every element (t_{or}) is used in the model. After the calculation of elements rigidity matrix, general rigidity matrix is assembled and the general finite element equation is constructed as,

$$[K]\{Q\}=\{F\} \tag{5}$$

This equation is solved after the application of boundary conditions. After extracting the element nodal displacements, the stresses are calculated by,

$$\{\sigma\}= [D]\,[B]\,\{q\} \tag{6}$$

The estimation is done by the consideration of von Misses yield criterion in the present analyses. The equivalent stresses are calculated by,

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2} \tag{7}$$

2.1 Finite Element Model

The mesh generated for the plane stress problem has 550 four node quadratic element and a total of 601 node (Fig. 3). As given in the fig 1., a 104 mm part of the tool is considered as constrained in the y direction. Three bolts each applying a 500 N force are considered on the upper surface. The tool can be used for parting materials having diameters up to a 90 mm. The chip has a 3 mm contacting distance on the tool.

The relation between cutting and axial forces is given as Fs=3-10 Fr in the literature [3]. Fs=5 Fr is accepted in this study. Three friction coefficients are considered for the determination of effect of frictional forces on the stress distributions.

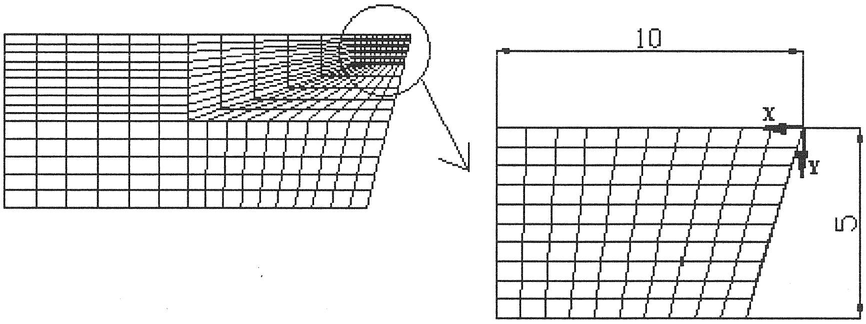
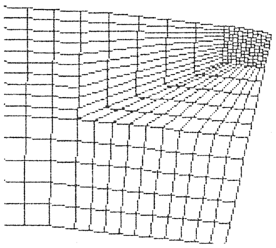


Figure 3. The finite element model of the parting tool. The largest element has a length of 1 mm and a width of 0.5 mm.

3. RESULTS AND DISCUSSION

The deformed geometry of the tool under the given loading are given in Fig. 4. The vertical and horizontal displacements show that this type of geometry can not be considered as a fixed end beam. They must be calculated according to short beam theory [5]. The displacements at the very end of the tool are 0.213, 0.195 and 0.186 mm for μ=0, 0.25 and 0.5 respectively.



μ=0

x=-0.066, y=0.213

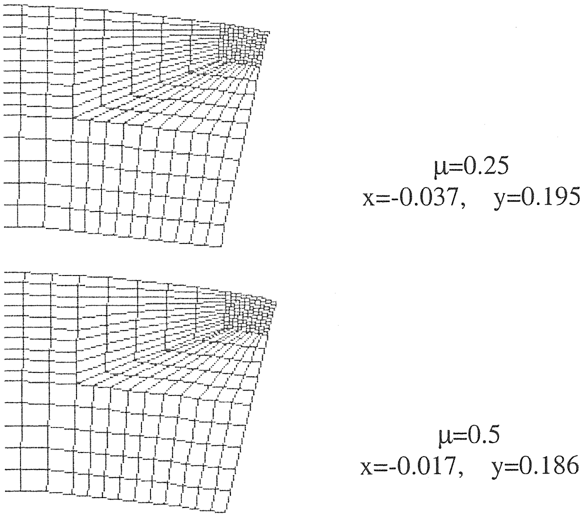
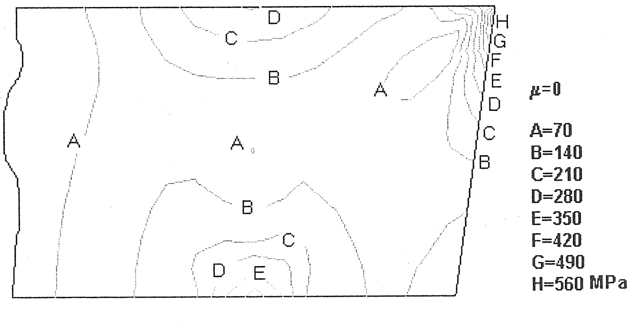


Figure 4. Deformed geometry of the tool. Displacements are multiplied by 20.

Possible failure zones are investigated by equivalent stress distributions (Fig. 5). The greatest stress values are obtained at the front surface and near the tip of the tool. However the maximum value decreases with increasing friction coefficient, the location of the greatest stress point becomes closer to the upper surface.



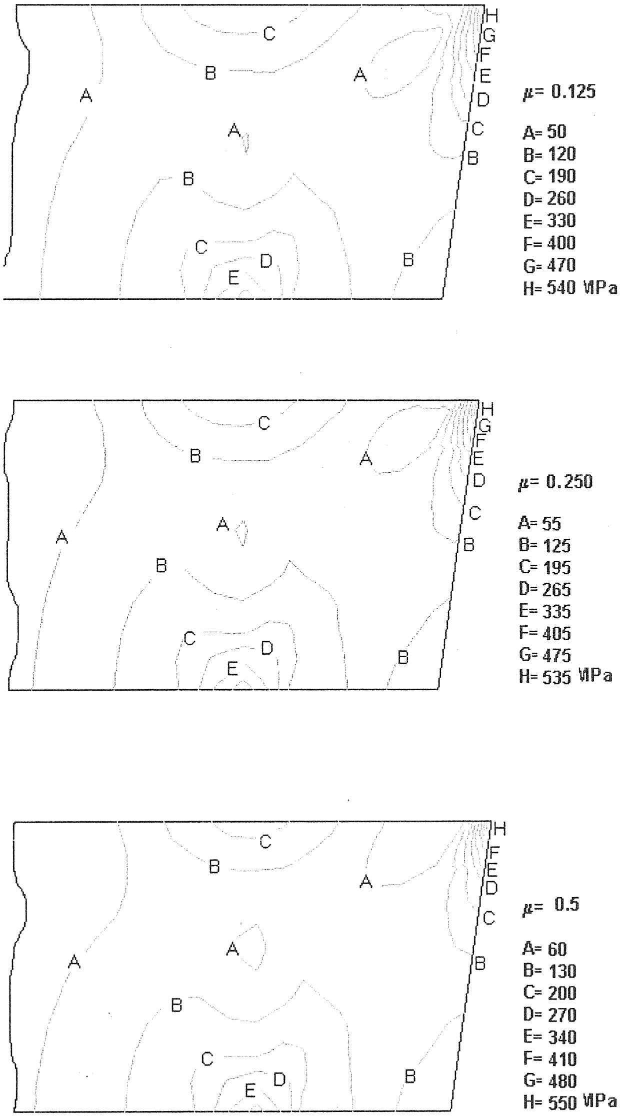


Figure 5. Von Misses equivalent isostress contours for different friction coefficients.

The stress at the tip is also increases. This suggest that the deterioration begin at the front surface and frontal wear is the most important failure type for this tool. Increasing friction constant also increases the wear debris. The stress distribution becomes more linear with increasing friction constant.

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