PARAMETRIC VARIATION STRESS ANALYSIS OF KEYWAY BROACH TOOL

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ABSTRACT

Broaching is machining process for removal of layer of material of desired width and depth usually in one stroke by bar type cutter with series of cutting edges.Broaching enables remove the whole material in one stroke only by the gradually rising teeth of cutter called broach. Due to the process geometry broaching tool is the most critical parameter of broaching process.Therefore optimal design of tools is needed prediction of stress with respect to various parameter of tool in order to improve the productivity of the process.In this paper ,a methodology is presented for prediction of stress with respect to variation in variables .The method has also been implemented on computer code. Matlab code was written in an m-file which helped us to determining the stress with respect to force, height,thickness,face angle,gullet radius and land.

Keyword :Broaching, Optimization,Tooling

I INTRODUCTION

The concept of broaching can be traced back to the early 1850s, with the first applications used for cutting keyways in pulleys and gears. The term broaching is derived from an ancient Roman word braccus which meant an object having projecting teeth. Broaching is machining process for removal of a layer of material of desired width and depth usually in one stroke by a slender rod or bar type cutter with series of cutting edges. Broaching enables remove the whole material in one stroke only by the gradually rising teeth of the cutter called broach.In broaching there is a pilot hole through which broach is pulled or pushed.Machining by broaching is used for making holes of various forms and sizes,internal and external slots or grooves,teeth of splines and gears.

Broaching is commonly used for machining time internal or external complex profile that are difficult to generate other machining processes such as milling and turning. Originally broaching was developed for non circulars internal profiles and keyways.

The process is very simple and decreases the need for talented machine operator while providing high production rate and quality because of the straight non circular motion, very high quality surface finish can be obtained. In addition, roughing and finishing operation can be completed in one pass reducing total cycle time. Main disadvantage of broaching is the in flexibility of the process in terms of process parameter. In broaching, all machining conditions, except the speed are defined by the tool geometry, and thus, once a tool is designed it is impossible to change any process parameters such as depth of cut or chip thickness. This makes tool design the most important aspect of the broaching process. For improve productivity and part quality with reduced process cost, broach tools must be designed properly and for that effect of stress on broach tooth is very important factor.

Optimization of machining processes has been the topic of many studies for a long time, starting with pioneering works of F.W. Taylor is the great historical figure in the field of metal cutting. Taylor’s most important practical contribution was his invention, with White, of high speed steel cutting tools. Taylor’s most important research contribution was his famous tool life equation after his recognition of the importance of tool temperatures in tool life..

U Kokturk et.al presented a methodology for optimal design of broaching tools by respecting the geometric and physical constraints. The models and algorithm developed implemented in computer program for practical use. Result indicate that proposed procedure may yield to much shorter tool length than the once designed intuitively. Budak &and Ozturk presented a model for simulation of the broaching process which can be used for improved tool design.

In this paper an approach of stress analysis for parametric variation of broach tool for keyway operation is presented for broach tool design on the previously developed process and structural model. Following work is carried out for enhancing production rate and down reduction time .The paper is organized as follows.Pre implementation study and analysis is done. Based on the above analysis the design of broach tool geometry with the constraints are explained in second section..Use of Graphical user interface (GUI) for parametric variation of broach tool geometry to prediction of stress analysis is presented in section three. The computer implementation is presented in section four. The paper is concluded by the overview of the parametric variation stress analysis and the future work.

II PARAMETERIC VARIATION OF BROACHING TOOL OPTIMIZATION

A. Broaching variable

There are several important variables such as height, width ,land ,thickness ,rake angle ,gullet radius that must be considered in the parametric variation of stress analysis of broach tooth profile. They strongly affect the process mechanics and machined part quality.

These variables are interrelated and the governing equations are implicit and non linear, thus they cannot be optimized in a straight forward manner. In this section the important variable considered in broach tool will be briefly reviewed

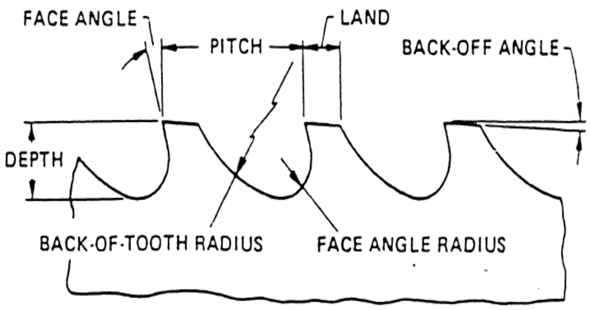


Fig. 1 broach tool geometry

Figure 1 show general broaching tool geometry .There are different variables that should be considered in the optimization of broach tools. That forces us to understand the variables and the relations between them very well. The general tool geometry variables such as land, gullet radius, rake angle and the back off angle are the parameters that create the tool geometry. In this paper, these parameters are selected according to the common values that are used in industry.These variables are important for the cutting performance of the tools. Pitch length is the main tool geometry variable which is going to be analyzed in detail. Pitch is the distance between two successive teeth, and it determines the number of teeth in the cut at a time. Smaller pitch would reduce the tool length at the cost of increased total broaching force .Tooth depth should be 0.25 to 0.5 of pitch and width of land is 25 to 30 % of its pitch . Another important variable is the gullet space between the teeth, which depend on the tooth height and land, radius and depth Gullet volume is the other important value determined by the pitch. The profile of the tooth geometry is one of the most important variables. The profile means the shape the tooth creates while it passes through the work piece. The profile is selected according to the part geometry to be cut. The stress are directly related to the chip geometry to be cut.. Each tooth is approximated by the general tooth geometry in order to use the general stress equations. The profile of the tooth gives us the profile parameters such as tooth height (*H*), tooth width (*B*) and angle of side face (*Ψ*). Tooth height, tooth width and other general tooth geometry parameters such as the angle of the side face, rake angle, land length are necessary to find stress values.

The optimization of broaching process is complicated due to several reasons.First of all of these parameter are interrelated thus the modification of one would affect others strongly. For example, if the pitch is decreased, the number of simultaneously cutting teeth may increase resulting in higher cutting force and power.This in turn may require lower rise to be used. Combination of these may result in shorter or longer broach.

B. Tooth stress

Constraints due to structural deformations and stresses are important part of broaching process modeling and optimization. In this section , parametric variation for tooth stress and part geometry will be presented.

Many tooth geometries can be obtained by varying the parameters shown in Figure 2-1. It will later be shown that even complex tooth profiles can be represented by this model for stress analysis. Broaching forces can be quite high due to large width of cuts which may be required by a given profile. High forces may cause tooth breakage, thus tooth stresses must be considered during tool design. Tooth stress analysis can be performed using the Matlab R2008a.Broach tooth profiles can have variety of complex shapes which makes the stress analysis time consuming as analysis of each profile needs to be performed separately. In order to simplify and generalize the modeling, generalized tooth geometry has been used in Matlab.

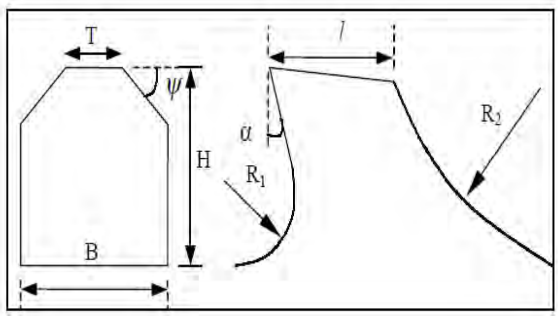


Fig. 2 General tooth profile

Following equation has been determined by curve fitting for stress in the tooth as a function of different tooth geometry parameters.

Where dimensions are in (mm),Ψ in Degrees, and σ is in (MPa), The general form is shown in 2.2

$$\sigma_t = F(1.3H^{0.374}B^{-1.09}T^{0.072}\psi^{0.088}R_1^{-0.082}l^{-0.356})$$

A test matrix is formed in order to determine the effect of each parameter of the tooth stress. The maximum stress on a broaching tooth may be one of the constraints as it may cause tooth breakage. In general broching teeth have complex geometry and it is not possible to model the stresses analytically. Matlab analysis can be used to determine the stresses however considering the verity of parametric variations. Matlab is used for stress analysis of each case.

Test No.	H (mm)	B (mm)	T (mm)	ψ (°)	R_1 (mm)	*l* (mm)
1	4	4	2.8	15	2	4
2	4	4	2.8	15	2	4.5
3	4	4	2.8	15	2	5
4	4	2	1.5	25	1	4
5	4	2	1.5	25	1.5	4
6	4	2	1.5	25	2	4
7	4	2	1.5	25	2.5	4
8	4	4	2	15	2	4
9	4	4	2	25	2	4
10	4	4	2	35	2	4
11	4	4	2.8	15	2	4
12	3	4	2.8	15	2	4
13	5	4	2.8	15	2	4
14	6	4	2.8	15	2	4
15	3	1.3	1	45	2	4
16	3	2.5	1	45	2	4
17	3	3.5	1	45	2	4

Table 1 Tooth Stress test matrix

III COMPUTER IMPLEMENTATION

The main purpose of the procedure is to obtain prediction of stress at various parameters of broach tool.Flowchart of keyway broach teeth stress analysis is as follow.

Step 1: Read variables from Graphical User Interface (GUI)

Step 2: Input values for Force, Height, Breadth, Thickness,faceangle,Land,Gullet radius between the given range

Step 3: Calculate stress

Step 4: Subplot Graph

Step 5: Repeat step no. 2 for other parameter

Step 6: Display graph

The procedure are being implemented in computer program.Matlab code was written in an M-file which helped us in determining the stress with respect to various parameters of broach tool such as force, height, width,thickness,gullet radius face angle and land.The F-file which show us actual graphs of particular parameters shown in figure 3

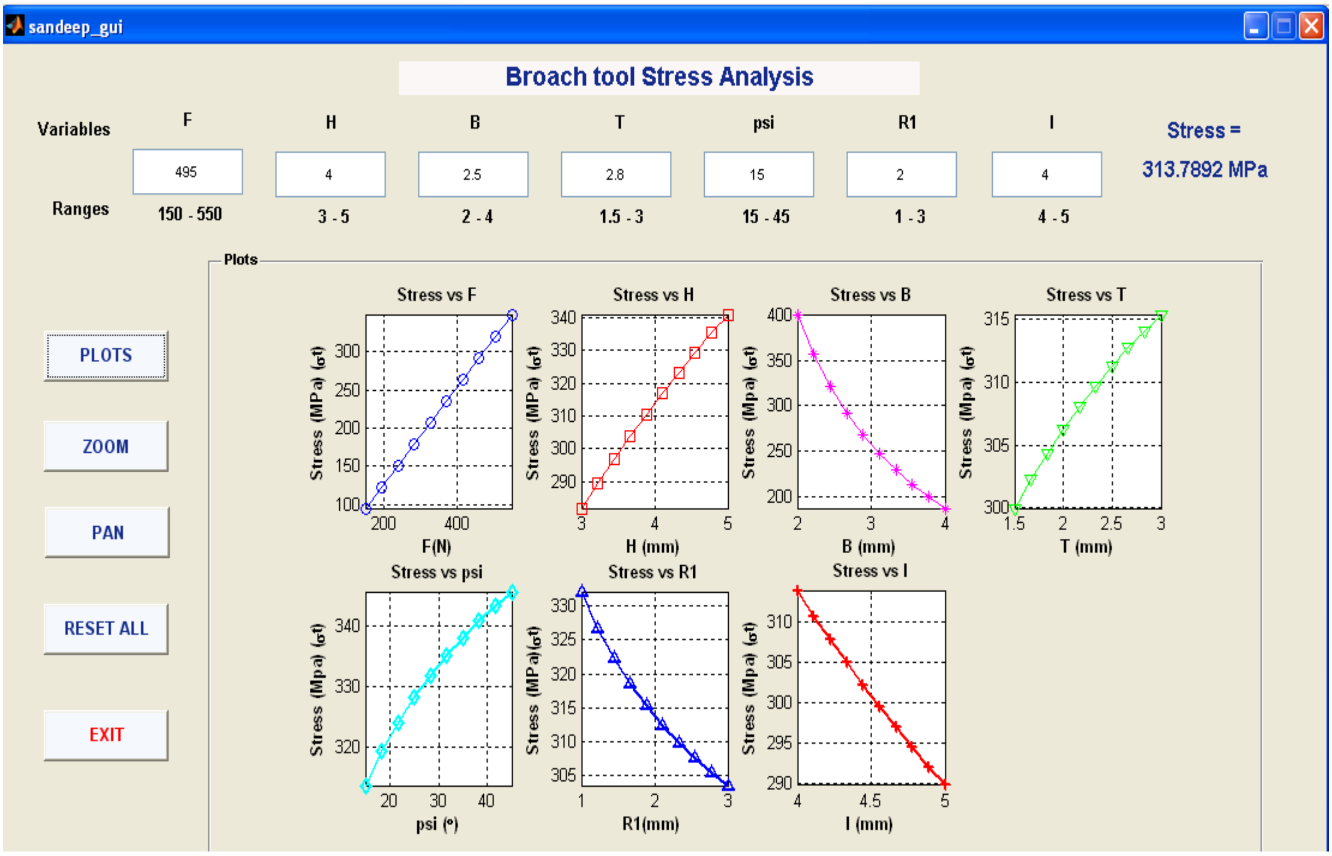


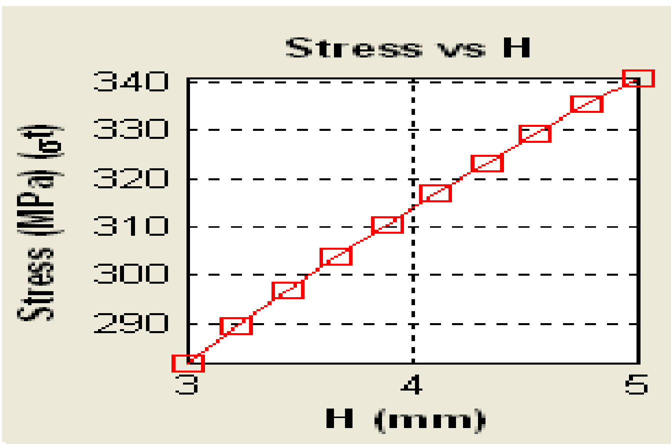
Fig .3 GUI OF Broach tool stress analysis

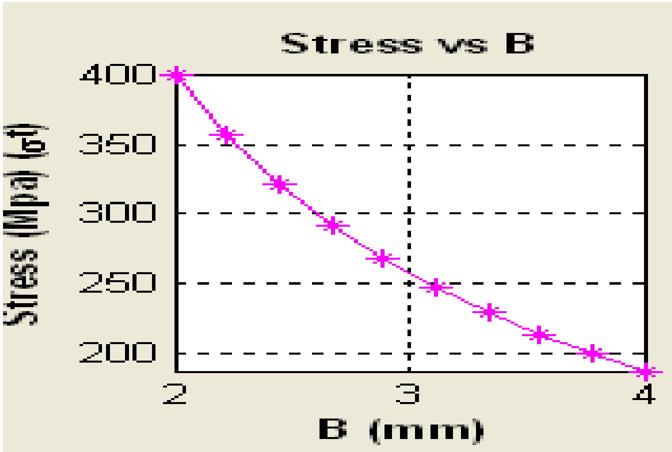
IV APPLICATION

A. *Tooth Width and Tooth Height*

Height and width of a tooth determine its general structure with land length .Tooth stress is directly related with the tooth width and tooth height parameters. The increase in the tooth height increases the stress while an increase in the tooth width affects the stress in opposite way. Wider tooth means a longer cutting edge which as a result means increased chip width.So, the force applied on the tooth increases with the increasing width of the tooth. However, if decreasing rate of the stress is higher than the increasing rate of force with increasing tooth width the stress may decrease instead of increasing. A proper ratio between the change of height and width values also gives the same result

As per given table 1 test matrix for stress analysis in the height of tooth range lies in between the 3mm to 5mm. Hence the effect of stress on the height will be predicted by the graphical user interface graph shown in the figure. In such type of case value of stress is 313 MPa on the time height is selected 3.8 mm., also when variation happens it shows that at a 3mm the stress will be 280 MPa by the same way at a condition 5 mm stress value will be 340 MPa. It shows that the graph of stress is increases as the range of height will be increased.





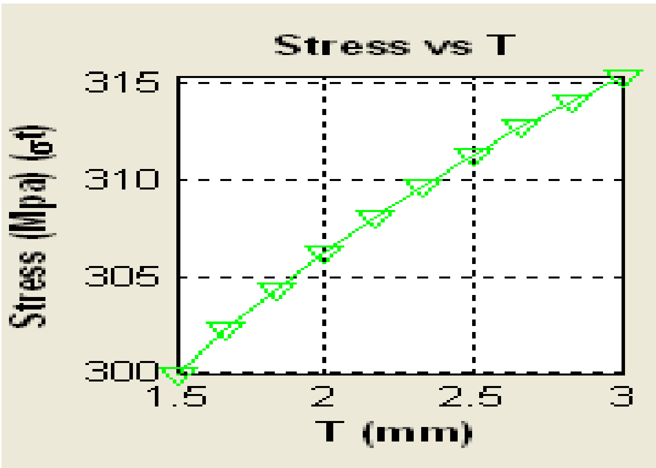
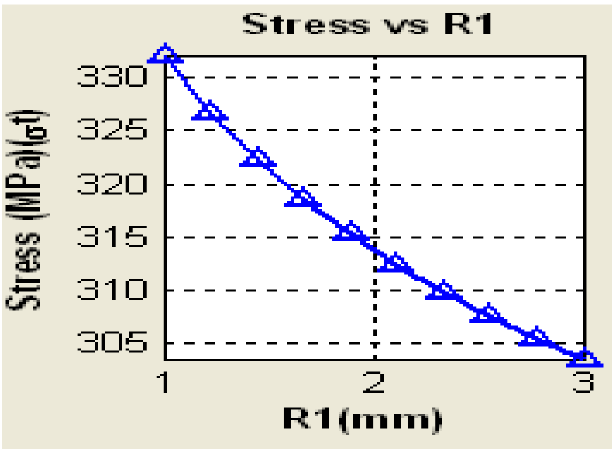
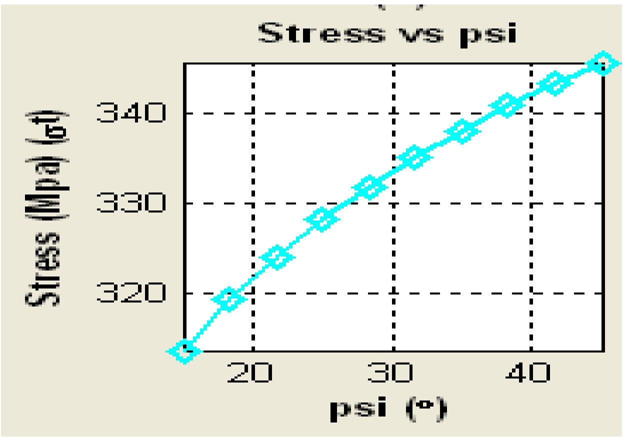
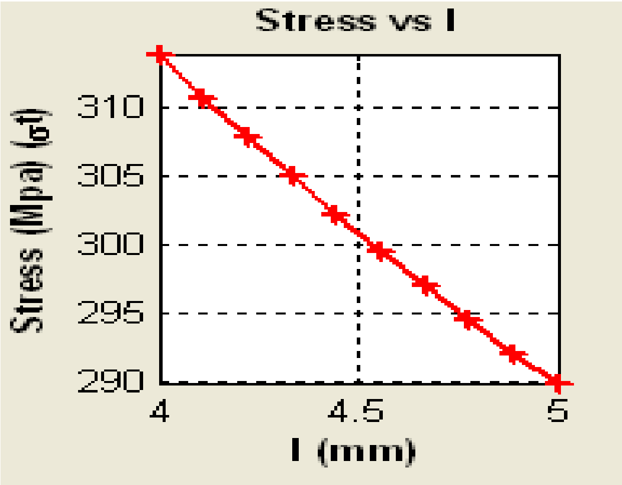


Fig. 4.Parametric variation of stress analysis







B. *Stress V/S* ***T****hickness*

The given range of tooth thickness in test matrix is in between 1.5 mm to 3 mm. the effect of change in thickness on stress is as the increase in value of thickness it shows graph of stress also increases from 300 Mpa upto the 315 Mpa

C. *stress v/s Face Angle*

The face angle or hook angle is equivalent to the rake angle. The prediction of face angle is selected to suit the machinability of work material. Figure gives the effects of stress on various points on f rake angle. As the rake angle increases the stress will be increases it shows that at 17 degree rake angle the value of stress is 300 MPa.

D. *Stress V/S Land*

At time of 4.5 mm land the stress will be shown 305MPa. As the value of land increases its effects on stress will be in decreasing rate. for detail prediction values for different land values it will be find out by following graph.

E. Stress V/S Gullet Radius

For Prediction of effect stress on the different values of gullet radius is shown in the above figure. The increase in the tooth gullet radius decreases the stress.

V CONCLUSION

Broaching is common machining process. The quality and the productivity in this process heavily depends on the tooth profile, which define the cutting condition. This procedure can be used in prediction of stress analysis of broaching tool. The results indicates that the effects of various parameters of tooth profile such as H, B, T, Ψ, R, L on stress.The procedure proposed here is may yield to obtain stress prediction.On a whole it is concluded that Graphical user interface is an developing process through the prediction of stress it should be introduced to optimization of broach tool design to bring reducing production time in design of tool .

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