Design and Analysis of Reaming Tool by Finite Element Modeling and Simulation

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Abstract The reamers are rotary cutting tools extensively used in enlarging the previously drilled holes. Precision reamers find application in finishing operations and are very expensive. So, it is extremely important to design the reamer tool with utmost care taking into account all the factors involved so as to avoid any quality issue at later stage. The actual testing of tool may cost a lot which can be minimized by modeling and simulation of designed tool. So, this paper deals with the design of reamer tool using the design formulas and the second is the modeling of reamer through ANSYS 19.2 and then comparing the stress and strain developed by both the processes. It is a cost-effective method and by analyzing the different forces and stress developed it becomes easy to optimize the model which in turn increases the efficiency of the process.

Keywords Reamers · Finishing operations · Modeling · Simulation · Stress · ANSYS

1 Introduction

Economical design of machine tool has always been a challenge to design engineers. Industrial modernization has enabled us to produce more economical and better design with the help of advanced tools and techniques [1]. Reaming is a machining process used for enlarging and finishing the already drilled holes to very fine tolerance and is suitable for batch type of production [2], 3. A complete description about the special-purpose tools can be found in international manual [4]. For common machining applications, the average surface roughness is found to be in the range of 0.8–3.2 mm. Reamers with high accuracy can produce even better results which may close to 0.4 mm [6]. Figure 1 shows a typical reaming operation [5].

Much work pertaining to reaming tool modeling has been done [7–11]. Yang et al. worked on optimization and design of reamer tool for directional reaming of

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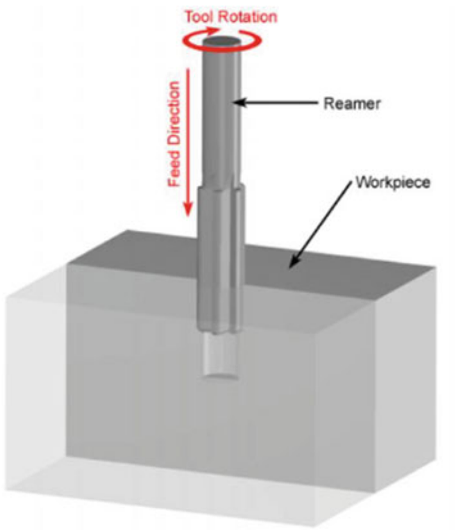

Fig. 1 A typical reaming operation

polycrystalline diamond compact which enhanced the performance of the reaming process [12]. Povolny et al. studied the reamer tool system performance under various types of load through FEM. They confirmed the system design with defined rigidity [13]. Reis et al. analyzed the technical and economic aspects of two manufacturing systems in drilling of compacted graphite iron (CGI) workpieces. This resulted in 40% reduction in machining time and 57% reduction in total cost [14]. The stress analysis of barrel reamer was evaluated through FEM by Baksa et al. They provided useful insights into boundary conditions required for performing numerical simulation of a barrel reamer [15]. Reaming improves the accuracy of a round hole enough to allow interchangeability. Reamers hold size consistently and can be applied to the metal-machining process with a minimum amount of skill. Reaming is a finishing operation and is not intended to remove a large amount of material. The speed of reaming is generally considered to be two-thirds of the speed used for drilling the same material. Reamers are most easily damaged than drills when subjected to chatter. Since rotating cutting tools are less likely to chatter when the cutting speed is reduced, reamers generally produce better results at lower cutting speeds. Reaming feeds are much higher than drilling feeds because there are more teeth in the reamer. Feeds vary from 0.0015 to 0.005 mm per flute per revolution, depending upon the size of the reamer. Reamer feeds that are too low can cause burnishing, glazing, or chatter. High feeds tend to reduce the accuracy of the hole and the quality of the finish.

2 Design for Tapered Shank Straight Fluted Machine Reamer

Outside Diameter (D): Hole resulting from reaming is bigger (overcut) than the reamer size. Consequently, reamer should be made smaller than the maximum permissible size of the reamed hole. The reduction in size (overcut) is usually 15% of the tolerance for the hole. The manufacturing tolerance for the reamer is confined to 35% of the tolerance for the hole.

Back Taper (t): Reamers are tapered down toward shank to provide axial clearance on teeth. The back taper ranges from 0.05 to 0.08 mm for hand reamers, and 0.04–0.06 mm for rigidly held machine reamers on diameter for the entire flute length. Back taper can be higher 0.06–0.08 mm if a floating holder is used for reamer.

Back Taper Flute End (D1): D1 = Minimum diameter of reamer − back taper *t*.

Lead (l): The length l of the lead chamfer depends upon the reaming allowance as well as the lead angle.

$$l = [(2.6 \text{ to } 2.8) \times A \times \cot \Phi]/2 + (1 \text{ to } 3 \text{ mm})]$$

where

- A Radial machining allowance (mm).
- Φ Lead angle number of teeth (T): This depends upon the workpiece material.

Flutes: The type of flute depends upon the diameter *D* of hole and number of teeth T. The cylindrical land f ranges from Ø 0.1 for Ø 6 mm reamer to Ø 0.50 for Ø 50 reamer. Length of primary clearance ranges f_1 from 0.5 to 1.8 for same reamer sizes.

Flute length (L_f): It depends upon the diameter *D* of the hole.

$$L_\mathrm{f} = 5D$$

Morse Taper (MT): It depends upon the diameter *D* of the reamer. Depending upon the Morse taper, the angle of taper of shank is calculated.

Shank Length (L): It depends upon Morse taper MT of the reamer.

Diameter of neck (d): It depends upon the diameter *D* of the reamer.

Overall Length of reamer (Lo): It depends upon the length of flute L_f, diameter of neck *d*, and the shank length *L*.

$$Lo = L_f + d + L$$

3 Methodology

3.1 Geometry of Tooth

The geometry of tooth was first designed as shown in Figs. 2 and 3, in AUTO-CAD software and was then transferred to ANSYS. By doing so, it was easy to find out the key points.

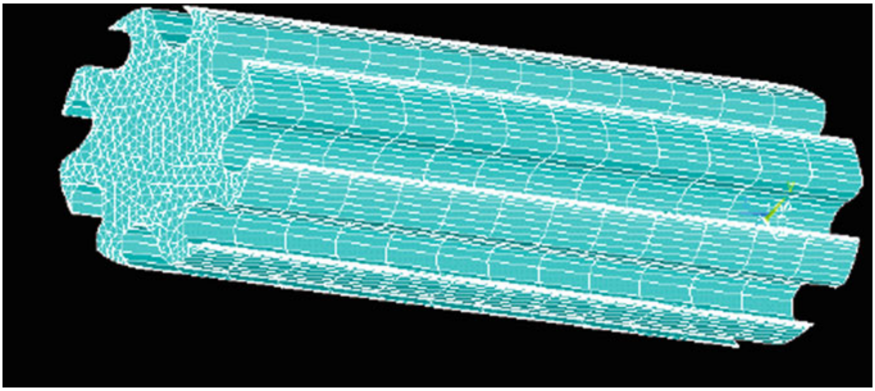

Fig. 2 Meshed volume of the complete profile of reamer cutter

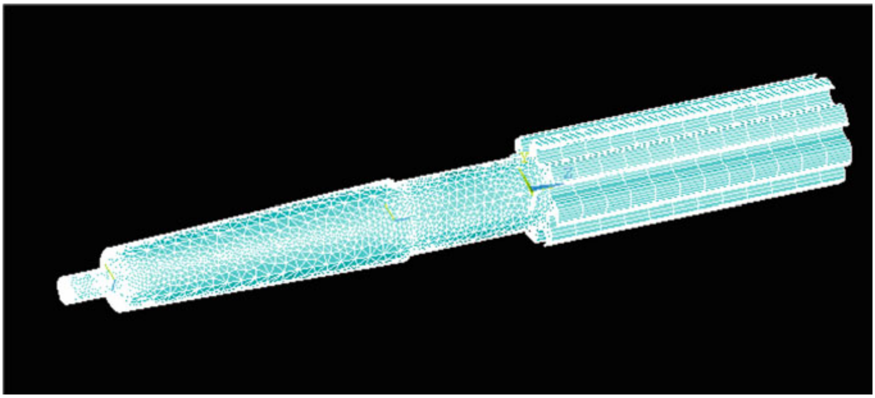

Fig. 3 Reamer profile after meshing

4 Analysis

4.1 Calculation

The maximum load which the reamer can undertake varies between 50 and 200 N. So the forces are taken in intervals of 25 N. Hence, the stress and strain have to be evaluated for 50, 75, 100, 125, 150, 175, 200 N. The stress and strain values for above loads are evaluated both through the design formulas and then through the ANSYS. Then, the values obtained from these methods are compared and if the values obtained through these values are almost comparable then there is no need for further optimization. FE Mesh is generated using Tetrahedral Solid Element with an element size of 3 mm. The model has 185,642 nodes and 94,652 elements. The reason for selecting tetrahedral element is that because they fit very well arbitrary-shaped geometries with their simple computations.

4.2 Calculation of Stress and Strain Values Through Design Formulas

Since mild steel is taken as the material, therefore Young's modulus (Y) for mild steel is 2×10^5 and the Poisson's ratio (υ) is 0.3. From the table, the change in diameter (ΔD) for Ø 30 hole is 3.96 mm.

$$\text{Poisson's ratio} = \text{Change in lateral dimension/Change in longitudinal dimension}$$

$$\Rightarrow 0.3 = (\Delta D/D)/(\Delta L/L)$$

$$\Rightarrow 0.3 = (3.96/30)/(\Delta L/L)$$

$$\Rightarrow (\Delta L/L) = [(3.96)/(30 \times 0.3)]$$

$$\Rightarrow (\Delta L/L) = 0.44$$

$$\text{Strain} = (\Delta L/L) = 0.44$$

The maximum strain calculated is 0.44

$$\text{Young's modulus} = \text{Stress/Strain}$$

$$\Rightarrow 2 \times 10^5 = \text{Stress}/0.44$$

$$\Rightarrow \text{Stress} = 2 \times 10^5 \times 0.44$$

$$\Rightarrow \text{Stress} = 88,000\ \text{N/mm}$$

The maximum stress calculated is 88, 000 N/mm

Hence for Ø 30 hole the maximum stress for all values of load 50, 75, 100, 125, 150, 175 and 200 N should be within 88,000 N/mm^2 and strain should be within 0.44 for all value's of load.

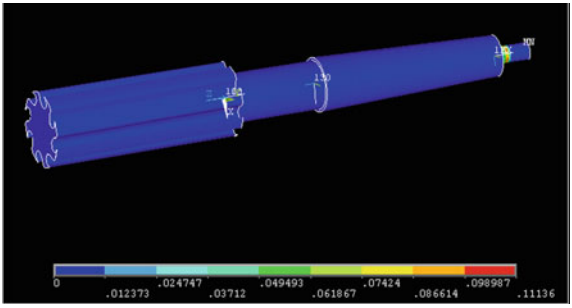

Fig. 4 Von Mises stress nodal (50 N)

4.3 Calculation of Stress and Strain Values from ANSYS 19.2

Figures 4, 5, and 6 show simulation done for stress, strain, and displacement nodal for 50 N load.

Von Miss stress nodal (Table 1).

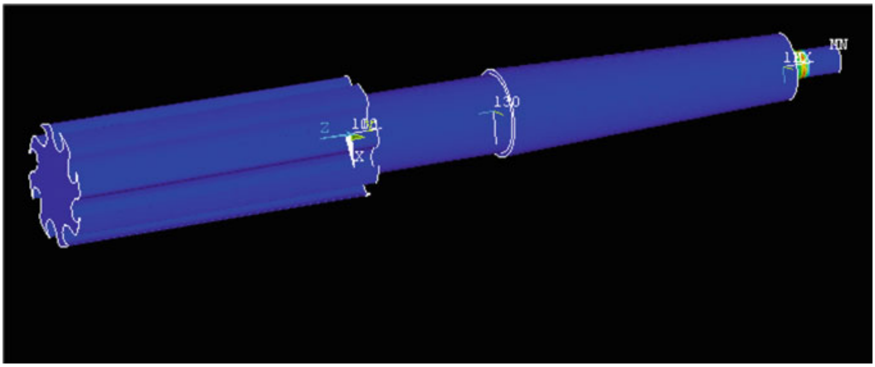

Fig. 5 Von Mises strain nodal (50 N)

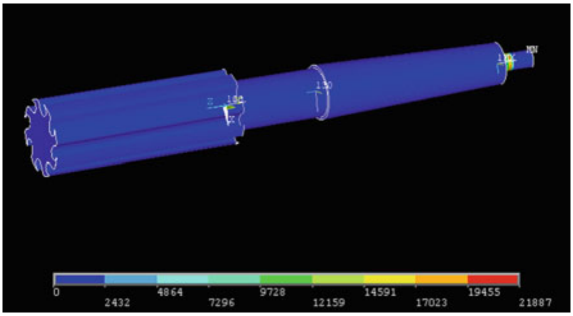

Fig. 6 Displacement vector nodal (50 N)

Table 1 Tabulation of stress and strain for the specified value of force

The results can be tabulated as shown below load/force (F)	Max. stress (N/mm^2)	Max. strain ($\Delta L/L$)	Displacement sum
50	21,887	0.11136	4.360
75	32,830	0.16704	6.541
100	43,774	0.22272	8.721
125	54,717	0.278401	10.901
150	65,661	0.334081	13.081
175	76,604	0.389761	15.261
200	87,546	0.445441	17.442

5 Conclusion

The study of optimization of a reaming tool in the form of machine reamer, using mild steel as the material, was undertaken with a view to analyze the stress and strain on the reaming tool during the operation. From the designing, it was found that maximum value of stress acting on reamer tool could be 88,000 N/mm^2 and maximum strain could be 0.44. On comparing these values with the one obtained from ANSYS for the same reamer was found well within the limits. The present study provides very effective way to get better results for economical design of reaming tool without undergoing costly actual testing however more accurate results can be obtained from dynamic analysis of reaming tool as well as its topographic optimization.

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