

Finite Elemental Analysis of Influence of Shape and Profile of Cutting Edge of Twist Drill on Drilling Process

M. J. Pawar, V. S. Jadhav

Abstract:- The aims of the investigations presented in this paper were to measure the tool load under conditions of drilling and to analyze if changes of the cutting edge shape and profile significantly influence the edge stresses. The described methods to analyze the influences of edge shape modifications will contribute to the optimization of drilling tools. Based on a specific cutting edge shape of a drill, systematic changes to the edge were made. Forces and temperatures on the cutting edge were measured as well as the heat flow into the chips and the workpiece. Using a quick-stop device, length and type of chip for the different drills under various machining parameters were observed. It could be shown that the modification of the transition from the chisel to the cutting edge influences the stress developed, heat in chip and chip formation. Machining with a rounded cutting edge shape compared to a sharp edge reduces the mechanical load but slightly increases thermal tool load. The presented experimental and FEA method show the possibility of determining influences of modified cutting edge shapes and to adapt the drill to the needs of the drilling process. The cutting force and stress developed during drilling processes has direct influence on the generation of heat, tool wear, quality of machined surface and accuracy of workpiece. Due to complex tool geometry, cutting conditions and some unknown factors theoretical cutting force and stress calculation failed to produce accurate results. To see the behavior of drill either experimental or Finite Elemental Analysis can be used. By using both the methods validation of results can be possible.

Index Terms:- Finite Elemental Analysis, Cutting edge, Chip formation

I. INTRODUCTION

The machining processes Turning, Milling and Drilling represents most frequently used cutting processes. Drilling plays an important role as it is always last step at the end of the value chain. Two types of drills can be used for drilling process, one straight fluted drill and other twist drill. Most of the drilling processes are carried out by using twist drill. Twist drill has cutting edge divided into two parts, chisel cutting edge and main cutting edge. The shape and profile of cutting edge of twist drill significantly influences stresses developed during machining.

The effect of speed is not as significant as that of feed rate and it is even negligible at low feed rates [1]. It is possible to carry out systematic computer assisted study focused on determining and describing mathematical point of view the relationship between the drill point geometrical features and

predicted performance measures as assessed by the cutting forces for twist drills [6]. FEM simulation model of orthogonal cutting process tools can be prepared. Methodology employs FEM model with more accurate properties of the materials. [8]

II. DRILLS USED FOR TEST AND TEST MATRIX

Four twist drills of material high speed steel of varying geometry are used for testing. For drilling process cutting speed and feed are the two machining parameters. For experimentation cutting speed kept constant at 800 rpm. At constant cutting speed testing is carried out at three different feeds viz 0.05mm/rev, 0.1mm/rev and 0.15mm/rev. (40m/min, 80m/min, and 120m/min). Drill used and test matrix is given in the table 1 and table 2 respectively.

Table No. I-Drills used for analysis

Parameter	A	B	C	D
Material	HSS	HSS	HSS	HSS
Diameter (mm)	12.7	12.7	12.7	12.7
Helix angle (°)	35	35	35	35
Point Angle (°)	118	118	90	90
ChiselEdge(mm)	2.5	2	2.5	2
Main and Chisel edge	Sharp	Rounded	Sharp	Rounded

Table No. II- Test Matrix

Tool ⇒ Feed (mm/rev) ↓	A	B	C	D
0.05	•	•	•	•
0.1	•	•	•	•
0.15	•	•	•	•

III. FINITE ELEMENTAL ANALYSIS OF TWIST DRILL

A. Modeling of Twist Drill

The algorithm to model a two-flute conical twist drill based on its manufacturing process is as follows,

1. Obtain the manufacturing and geometric dimensions of drill

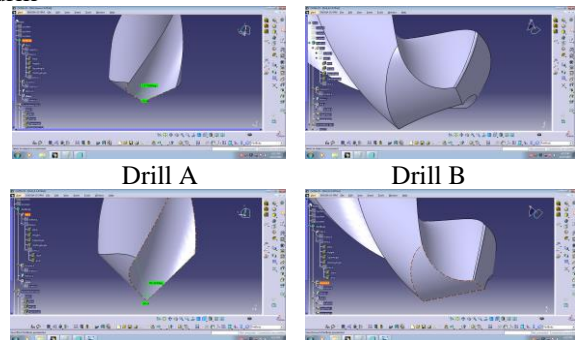


Fig.1- CAD model of drill

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* Correspondence Author (s)

M. J. Pawar, Mechanical Engineering Department, Govt. Collage of Engg., Karad(MS), India,

Prof. V. S. Jadhav, Mechanical Engineering Department, Govt. Collage of Engg., Karad(MS), India,

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2. Draw the cross section of the flute
3. Create the solid flute by helical extrusion
4. Form the cutting edge of twist drill
5. Prepare the shank
6. Prepare the cutting edge

B. Analysis of Twist Drill

1. Mechanical Load

The prepared CAD model imported in analysis software and meshing is done. Fine meshing is applied to the cutting edge of drill model. The torque and thrust force are calculated from empirical formula and applied as shown in fig.3.

2. Thermal Load

For thermal analysis of drill, the temperature at the cutting edge and shank end of twist has to be specified as boundary conditions. The thermal load is applied on the drill bit in form of temperature at cutting edge calculated from empirical formula [9]. At the shank end atmospheric temperature is applied.

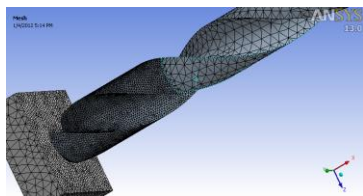


Fig.2- Meshing for drill and workpiece

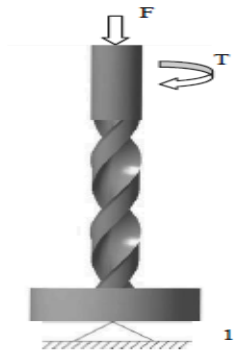
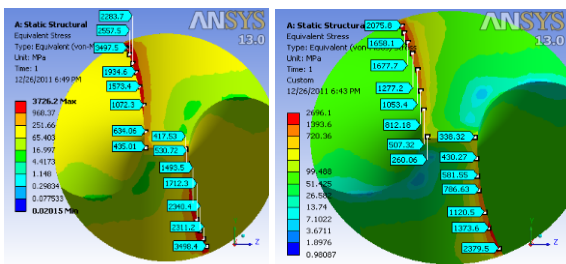


Fig.3- Model with boundary conditions



a. Drill A at 0.15mm/rev b. Drill A at 0.1mm/rev
Fig.4- Stress distribution

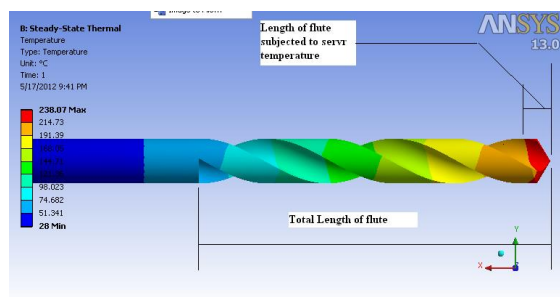


Fig.5- Temperature Distribution along the length of drill

C. Solution

1. Mechanical Load

The model is solved to determine Vom Mises equivalent stress. The solution is obtained in the form of stress distribution (fig.4).

2. Thermal Load

For thermal analysis temperature distribution is the most predominant parameter to determine. In ANSYS the temperature distribution considered as output quantity. Solver solves the problem for given operating conditions and set of boundary temperature. Output is in form of temperature distribution in the material of drill bit (fig.5).

IV. EXPERIMENTAL ANALYSIS OF TWIST DRILL

Another method for analysis is experimental analysis. The FEA gives us the exaggerated results than actual but the experimental analysis gives us actual results.

A. Mechanical Load

In drilling process thrust force and torque are significant parameter than cross feed and longitudinal feed force. Mechanical load is measured in terms of thrust force and torque.

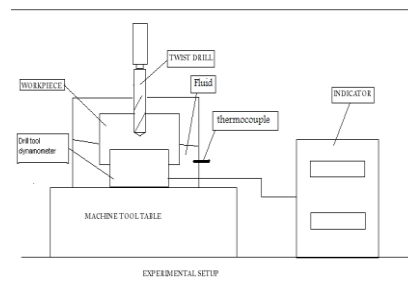


Fig.6- Experimental Setup



Photo 1- Experimental Setup for Mechanical Load

Table III- Thrust force

Thrust force (N)				
Drill	A	B	C	D
Feed (mm/rev)				
0.05	636	573	595	506
0.1	861	820	829	806
0.15	1359	1245	1305	1229

The thrust force on cutting edge measured with drill tool dynamometer is shown in table III. The stress on cutting edge can be calculated from the area of cutting edge on which the thrust force is exerted. The stress for all drills is shown in table IV.

Table 4-Stress on cutting edge

Stress (MPa)				
Drill →	A	B	C	D
Feed (mm/rev) ↓				
0.05	636	229	540	202
0.1	861	328	753	322
0.15	1359	498	1186	491

B. Thermal Load

While drilling heat is developed due to cutting and friction between work and tool material. The total amount of energy supplied for drilling process is converted into heat energy. Heat is developed in drill material, workpiece material and chip. For better performance minimum heat should be developed in the drill material and workpiece material. In other words maximum heat should be carried out by chip. Hence thermal load can be measured by measuring heat carried away by chip. For measurement of thermal load calorimeter and temperature sensor are used. During machining chips are restricted to drop in coolant in the calorimeter. The calorimeter is insulated from surrounding to minimize loss of heat of chip to environment. For better performance minimum heat should be developed in drill and workpiece or in other words maximum heat should be carried by chip. The heat carried by chip is liberated to coolant. The heat in chip calculated by formula,



Photo 2- Experimental Setup for Thermal Load

$$\Delta Q = C_{chip} \cdot m_{chip} \cdot \Delta T_{chip} = C_{coolant} \cdot m_{coolant} \cdot \Delta T_{coolant}$$

Instead of calculating heat in chip it is convenient to calculate heat rejected by chip to coolant. Specific heat and mass of coolant remains constant. Now equation can be modified as,

$$\Delta Q = K \cdot \Delta T_{coolant}$$

Where,

$$K = 5.7 * 1 = 5.7 \text{ kJ/K}$$

The heat carried away by chip is same as that of heat absorbed by coolant and directly proportional to increase in temperature of coolant. Hence the increase in temperature of coolant is indicator of heat carried away by chip.

C. Chip Formation

Material removal rate of drilling process is much more compared with any other machining process. The flutes of

twist drill are so designed that all the chips should flow out of hole through the flutes. The formation of chip is depends on the shape and profile of cutting edge of twist drill. For effective drilling and smooth contact area the chip formed should be continuous so that it can easily flow out of hole without disturbing drilling process. When chips form in the discrete form it creates irregularities on the surface of work piece. Whereas if chips are discontinuous more or less it get blocked in the hole and it has to force out of hole. Formation of chip was visually inspected during experimentation for decided test matrix. The drilling is intermediately stopped with help of quick stopping device and contact area was observed. From experimentation following observations was recorded.

1. For tool B length of chip formed was observed of continuous and maximum length at all the machining parameters.
2. For tool C length of chip formed was observed of minimum length at all the machining parameters.
3. The length of chip increases form tool C, tool D, tool A and tool B. For point angle 90° the chip formed was of discrete type and for point angle 118° the chip formed was of continuous type.
4. Chip formed at feed rate 0.05mm/rev is continuous and of maximum length and as feed rate increases the chips formed become discrete.

V. RESULTS AND DISCUSSION

The objective of this work is to optimize the geometry of twist drill. The result reveals that geometry of twist drill has influence on drilling process.

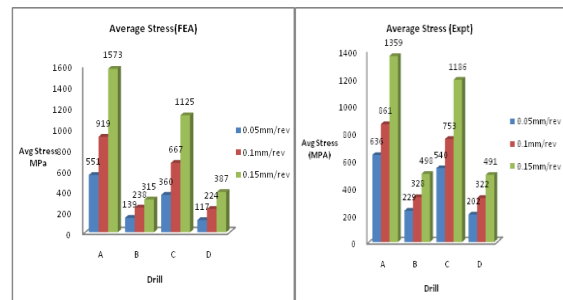


Fig.7- Comparison of FEA and Expt. results

Form the above results it is observed that there is effect of shape and profile of cutting edge of twist drill on stress developed, heat in chip and chip formation.

A. Mechanical Load

For feed 0.05mm/rev experimental stress developed for drill B was 36% of the stress developed for drill A and stress developed for drill D was 37.4% of the stress developed for drill C. For feed 0.1mm/rev experimental stress developed for drill B was 38.09% of the stress developed for drill A and stress developed for drill D was 42.7% of the stress developed for drill C. For feed 0.15mm/rev experimental stress developed for drill B was 36.6% of the stress developed for drill A and stress developed for drill D was 41.3% of the stress developed for drill C. Similarly for feed 0.05mm/rev FE stress developed for drill B was 25.2% of the stress developed for drill A and stress developed for drill D was 45.2% of the stress developed for drill C. For feed 0.1mm/rev FE stress developed for drill.



B was 25.8% of the stress developed for drill A and stress developed for drill D was 38.5% of the stress developed for drill C. For feed 0.15mm/rev experimental stress developed for drill B was 20% of the stress developed for drill A and stress developed for drill D was 34.4% of the stress developed for drill C. (fig.7)

B. Thermal Load

Fig.8 shows heat carried away by chip for different geometry of drill. At feed 0.05mm/rev for drill A heat in chip was 0.741kJ. It decreased to 0.513kJ for drill B. For drill C heat in chip was 1.026kJ. It decreased to 0.798kJ for drill D. At feed 0.1mm/rev for drill A heat in chip was 0.912kJ. It decreased to 0.57kJ for drill B. For drill C heat in chip was 1.14kJ. It decreased to 0.969kJ for drill D. At feed 0.15mm/rev for drill A heat in chip was 1.026kJ. It decreased to 0.741kJ for drill B. For drill C heat in chip was 1.311kJ. It decreased to 1.083kJ for drill D. (fig.8) It is observed that for feed 0.05mm/rev, for drill B heat in chip was decreased by 30% than heat in chip for drill A and for drill D heat in chip was decreased by 22% than heat in chip for drill C. For feed 0.1mm/rev, for drill B heat in chip was decreased by 37% than heat in chip for drill A and for drill D heat in chip was decreased by 15% than heat in chip for drill C. For feed 0.15mm/rev, for drill B heat in chip was decreased by 27% than heat in chip for drill A and for drill D heat in chip was decreased by 17% than heat in chip for drill C.

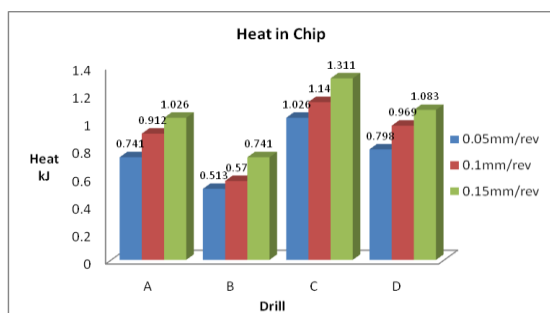


Fig.8- Heat carried away by chip

It decreased to 0.57kJ for drill B. For drill C heat in chip was 1.14kJ. It decreased to 0.969kJ for drill D. At feed 0.15mm/rev for drill A heat in chip was 1.026kJ. It decreased to 0.741kJ for drill B. For drill C heat in chip was 1.311kJ. It decreased to 1.083kJ for drill D. (fig.8) It is observed that for feed 0.05mm/rev, for drill B heat in chip was decreased by 30% than heat in chip for drill A and for drill D heat in chip was decreased by 22% than heat in chip for drill C. For feed 0.1mm/rev, for drill B heat in chip was decreased by 37% than heat in chip for drill A and for drill D heat in chip was decreased by 15% than heat in chip for drill C. For feed 0.15mm/rev, for drill B heat in chip was decreased by 27% than heat in chip for drill A and for drill D heat in chip was decreased by 17% than heat in chip for drill C.

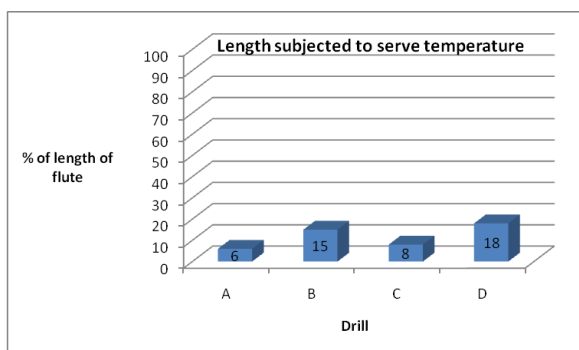


Fig.9- Length of flute subjected to serve temperature

Fig.9 shows the % of length of flute subjected to serve temperature conditions. For drill A, 6% of the length of flute is subjected to serve temperature. For drill B, Drill C and Drill D the value is 15%, 08% and 18% respectively.

C. Chip Formation

For tool B length of chip formed was observed of maximum length at all the machining parameters. For tool C length of chip formed was observed of minimum length at all the machining parameters. The length of chip increases form tool

C, tool D, tool A and tool B. For point angle 90° the chip formed was of discrete type and for point angle 118° the chip formed was of continuous type. Chip formed at feed rate 0.05mm/rev is continuous and of maximum length and as feed rate increases the chips formed become discrete.

VI. CONCLUSIONS

Shape and profile of the cutting edge of twist drill was changed and four test drills were prepared for test. The tests were carried out at three feeds for determination of stress developed.

1. Stress developed on cutting edge by finite element method for drill A, drill B, drill C and drill D was 919MPa, 238MPa, 667MPa and 257MPa respectively. Stress developed on cutting edge by experimental method for drill A, drill B, drill C and drill D was 861MPa, 328MPa, 753MPa, and 322MPa respectively. Stress developed for drill D gives minimum value; hence drill D is preferred over other three drills for better stress distribution.
2. Heat carried away by chip for drill A, drill B, drill C and drill D was 0.912kJ, 0.57kJ, 1.14kJ and 0.969kJ respectively. Heat carried away by drill C gives maximum value; hence drill C is preferred over other three drills for maximum heat carried away by chip.
3. Length of chip for drill B was observed of maximum length and continuous than other three drills, hence preferred over other three drills.
4. Heat carried away by chip for drill D was observe slightly less than drill C but more than drill A and drill B. Also Stress developed for drill D was less than other three drills. Overall performance of drill D was better than other three drills.
5. A numerical result shows better temperature distribution for drill A than rest of the drills.

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M. J. Pawar, PG Scholar, Mechanical Engineering Department, Govt. Collage of Engg, Karad, Maharashtra, INDIA, LMISTE.

Prof. V. S. Jadhav, M.E. Mech (Design), Faculty and PG coordinator, Mechanical Engineering Department, Govt. Collage of Engg, Karad, Maharashtra, INDIA. LMISTE, LMISTD.