Fem Based Analysis Of Chip Tool Interactions To Study The Stress Distribution On The Rake Face

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ABSTRACT

Introduction of green concepts in machining operations is being envisaged by introducing different echo friendly cooling systems in the modern machine shops. The role of cutting fluids usage in metal cutting is predominant as it influences the surface quality and production cost. The current work mainly focuses on the study of chip tool interactions viz. contact pressure, temperature and chip flow pattern on the rake surface in plain turning operation for different cutting parameters without any cooling medium and analyze the influence of high pressure air jet as the cooling medium on the chip tool interactions like contact pressure reducing the tool wear, cutting temperatures thereby increasing tool life.

KEYWORDS: *Modelling; Machining; Compressor; Air Jets; Nozzle;*

I. INTRODUCTION

The use of high speed air jet as a coolant in machining is a challenging scenario in environmental friendly machining. Despite the extensive literature, air jet cooling in machining is an area of ongoing research. Until now, the jet cooling technique has been studied only from a thermal point of view. The new aspect investigated in this work is the chip bending ability of the jet. The idea of chip-bending and its beneficial effects in cooling the cutting area is not related to maximizing the heat transfer, but to avoid the temperature increase. The heat generation in the chip-tool interface is due to the contribution of deformation in the shear zone and to the frictional contact between the chip and the rake face of the cutting tool. The importance of the frictional contact is proportional to the friction coefficient and to the pressure of the chip on the rake face. The traditional way of reducing this contribution is using a cutting fluid (flooding) or, more recently, injecting a coolant in the chip-tool interface. The new approach with high speed air jet shows the temperature reduction is strongly dependant on the position of the nozzle. By directing the jet onto the top face of the chip it is possible to reduce the pressure on the rake face, responsible of temperature increase in the chip-tool interface. The pressure on the top face of the chip generates a stress on the bottom face of the chip close to the constraint and in the chip-tool interface. The global stress is due to air jet pressure and cutting pressure on the rake face. When the air jet is directed on the top face of the chip (overhead position) the global stress is less than the cutting stress in dry machining.A fully thermo-mechanical model has been developed with DEFORM-3D and a mechanical only model with DEFORM-2D, in order to investigate the chip bending. From an analytical point of view the chip can be modeled as a structural cantilevered beam with uniform load. The results from finite element modeling show the displacement of the chip is mainly due to the chip-breaker. The displacement due to the air jet bending moment is minimized by the stiffness close to the constraint point, but the mechanical effect of the air jet has a significant impact on the energy in the tool.

II. DRY CUTTING MODE

A. Objective

Analysis of effect of the cutting parameters like cutting speed, feed rate and depth of cut on cutting force components which influence the contact pressure, temperature and chip flow pattern on the rake surface during turning operation

B. Equipment

Lathe machine, Lathe Tool Dynamometer, Amplifier, Cutting tool, PC, Job piece.

C. Experimental Setup

Figure 1 shows the schematic of the experimental setup for carrying out the experiment. Work piece is mounted in the chuck of the lathe headstock. The tool dynamometer is mounted on the carriage at the place of tool holder[6].The tool holder is mounted on the dynamometer as shown in Figure 2. Output of the dynamometer is amplified by charge amplifier (Kistler 5070A) and data are collected in the PC by using data acquisition system[7]. This setup is used to find the cutting forces for different speeds feeds and depth of cuts. The results are carefully tabulated and are used for the analysis of the cutting tool ,stress distribution on the rake face of the tool by the forces that are taken from the dynamometer

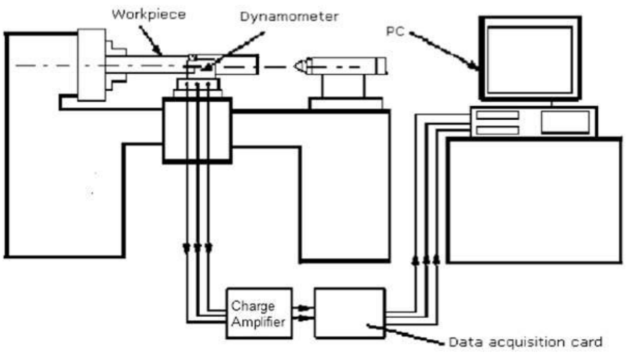


Fig 1: Schematic diagram of the experimental setup.

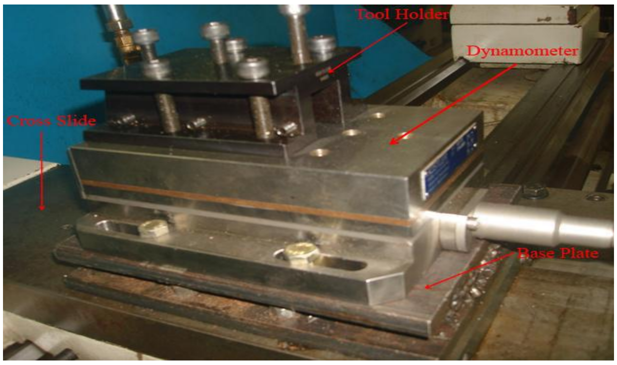


Fig 2: Eexperimental setup for finding the cutting forces

D. Observations of Cutting forces

Initial diameter of the bar = 25mm
Bar material = MS(Mild steel)
Cutting tool material = HSS(High speed steel)[2]

TABLE 1: OBSERVATIONS OF CUTTING FORCES WITH OUT COOLANT

Speed (rpm)	Feed (mm/rev.)	Depth of Cut (mm)	Cutting Force (N)
550	0.1	0.1	23.88
440	0.1	0.1	17.73835
330	0.1	0.1	13.9618
220	0.1	0.1	22.2015
118	0.1	0.1	14.57215
118	0.2	0.1	20.82825
220	0.2	0.1	21.293
330	0.2	0.1	19.0354
440	0.2	0.1	30.9735
550	0.2	0.1	16.86095
550	0.3	0.1	67.5965

440	**0.3**	**0.1**	**44.5175**
330	**0.3**	**0.1**	**36.3159**
220	**0.3**	**0.1**	**23.68925**
118	**0.3**	**0.1**	**62.866**
118	**0.4**	**0.1**	**46.0434**
220	**0.4**	**0.1**	**44.632**
330	**0.4**	**0.1**	**24.719**
440	**0.4**	**0.1**	**28.8391**

III. MATERIAL PROPERTIES

Material	:	High Speed Steel
Young's modulus	:	190-210Gpa
Poisson's ratio	:	0.27
Density	:	7800 kg/m3
Work piece	:	Mild steel

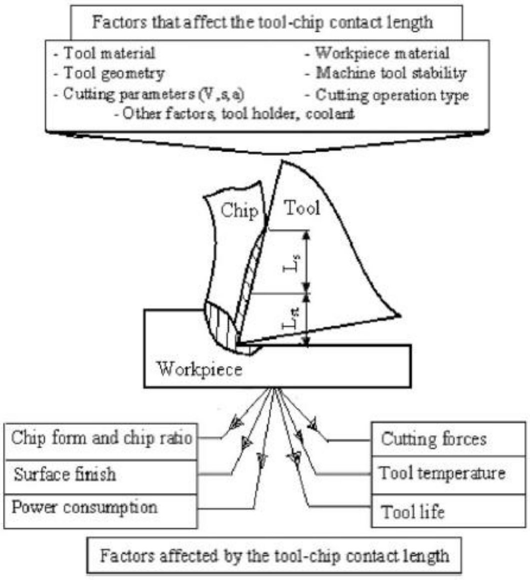


Fig 3: Chip Tool contact length

IV. ESTIMATION OF THE CHIP TOOL CONTACT LENGTH

A number of theoretical and experimental estimators have been proposed for the contact length in the orthogonal cutting process Based on the experiments conducted on different types of steel using a tool with an unrestricted rake face, a relationship between the chip–tool contact length, chip thickness, the chip compression ratio and the friction coefficient has been developed. It suggests that the length of the sticking region is approximately equal to the deformed chip thickness hc, and in accordance with Tay's assumption[3]
Total chip–tool contact length Lc as shown in the Figure 3 is given as [4]

Lc = 2hc
Thickness of the chip = 1.5mm
Width of the chip = 4mm
Contact Length = 2*1.5 =3mm
Area of the chip contacting the tool =3*4= 12mm^2
Pressure acting on the contact area =Force/Area
P1 =23.88/12 =1.99 N/mm^2
Similarly for the remaining forces
P2 =1.419 N/mm^2
P3 =1.163 N/mm^2
P4 =1.85012 N/mm^2
P5 =1.214 N/mm^2

V. ANLAYSIS OF CUTTING TOOL WITH OUT COOLENT

A. *For the Speed (N) =550 rpm, Feed=0.1mm/rev, Depth of cut=0.1mm*

1) Meshing

Finite element method is purely based on the dividing the cutting tool in to finite number of elements .Here the edge length that is taken for division of elements is 5mm.The mesh division is as shown in the Figure 4

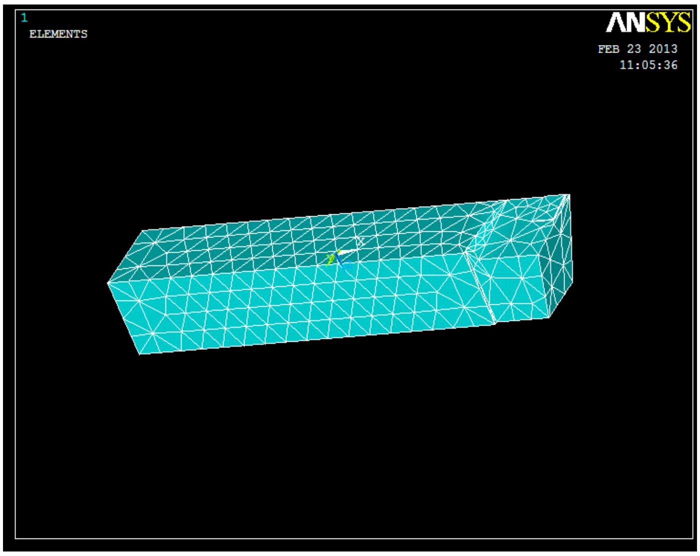
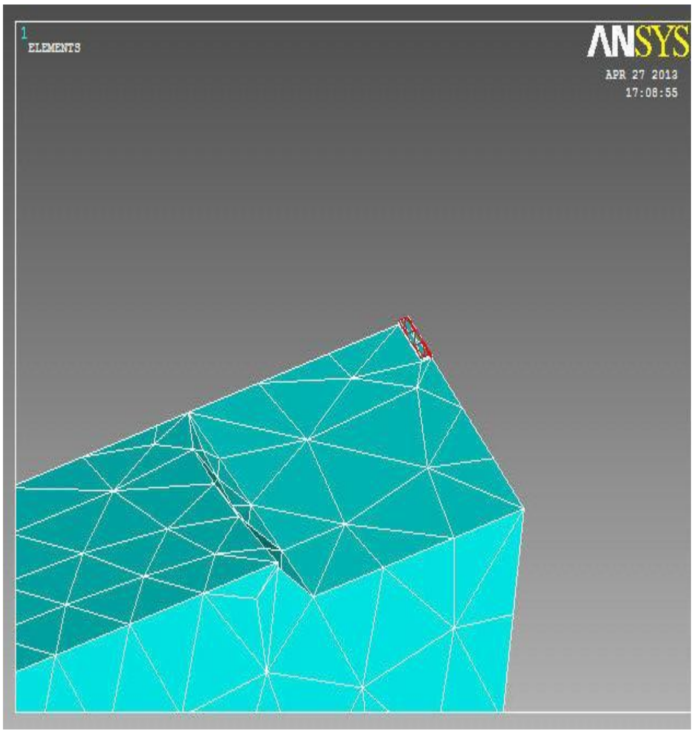


Fig 4 Meshing of cutting tool

2) **Area Selection For Applying The Load**



For applying the load that is pressure first choose the area that the chip is in contact with the tool .Then apply the load on that area as in the Figure 5

Fig 5: Area selection for applying the load of cutting tool

3) VonMises Stress

After load is applied by giving the material properties and constraints on the selected area, deformation and stresses are developed .The required Von misses stresses are show in the Figure 6

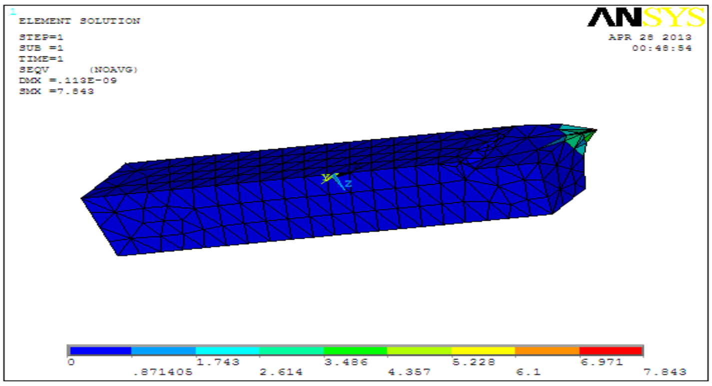


Fig6 VonMisses Stresses of cutting tool

Maximum deflection is $0.151e^{-09}$ mm.
Maximum Stress is 3.21 N/mm^2.
Now for another different set of speed, feed and depth of cut Von misses stresses are taken by using ansys and are shown in the below Figure 7.

B. *For the Speed (N) =440 rpm, Feed=0.1mm/rev, Depth of cut=0.1mm ,pressure=1.419 N/mm^2*

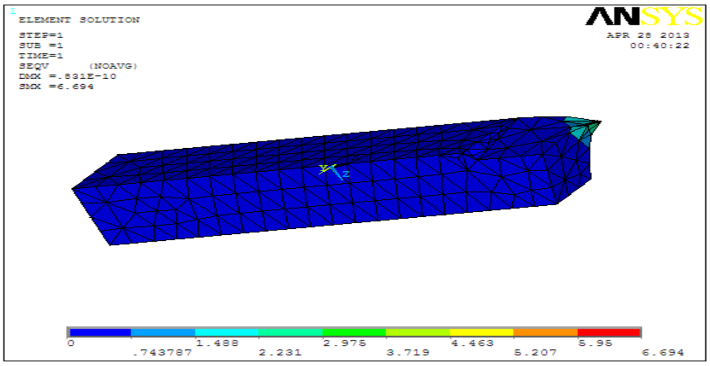


Fig 7: Von misses stresses for cutting tool

Maximum Stress 2.289N/mm^2

C. *For the Speed (N) =440 rpm, Feed=0.1mm/rev, Depth of cut=0.1mm*

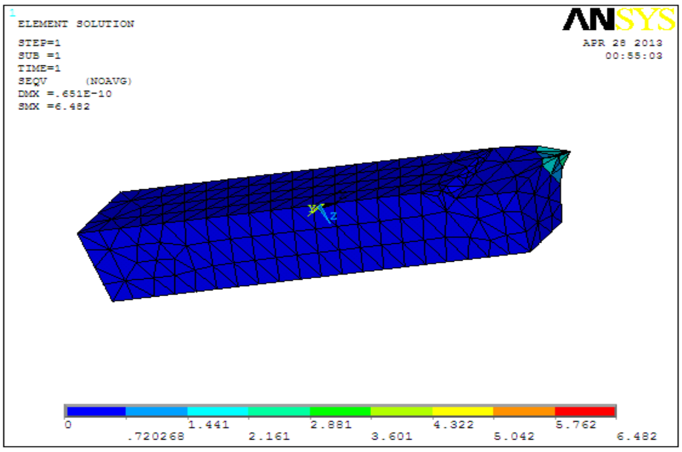


Fig 8: Von misses stresses for cutting tool

Maximum stress is 1.876N/mm^2

A graph is drawn between the pressures Vs Stress. The stresses which are taken from the applied pressures on the cutting tool, Stress varies linearly with the pressure as shown in the Figure 9

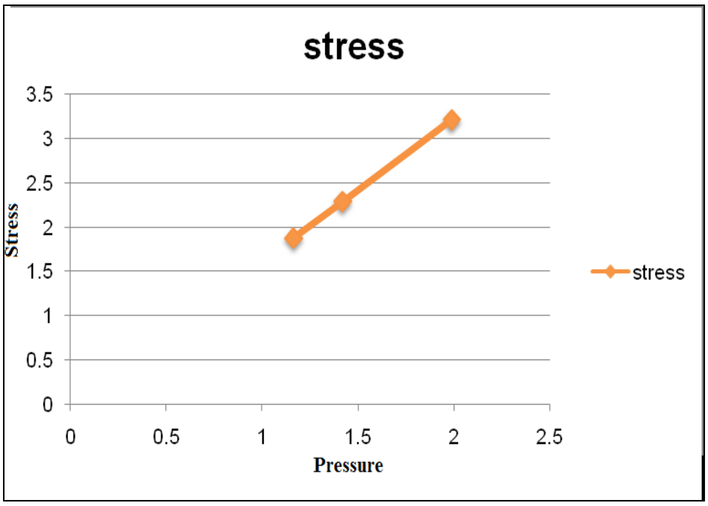


Fig 9: Pressure Vs. Stress Graph

D. TOOL LIFE

Taylor Tool Life Equation [1]

$VT^n=C$

Where v = cutting speed, m/min;
T = tool life, min;
n and C are parameters that depend on feed, depth of cut ,work material, and tooling material but mostly on material (work and tool).

TABLE 2: TYPICAL VALUES OF N AND C

Tool material	n	C
High Speed Steel		
Non Steel Work	0.125	120
Steel Work	0.125	70
Cemented carbide		
Non Steel Work	0.25	900
Steel Work	0.25	500
Ceramic		
Steel Work	0.6	3000

E. TOOL LIFE CALCULATIONS[5]

Cutting velocity=πDN/1000 (m/min)
D=Spindle diameter (mm)

1) Sample calculation

V1=πx25x550/1000
= 43.19 m/min
Similarly
V2= 34.55 m/min
V3=25.19 m/min
V4=17.29 m/min

2) Tool Life

$VT^n=C$
T1= (70/43.19)(1/0.125)
= 49.32 min
Similarly

T2= 283.92 min
T3= 2838.2 min
T4= 72.85x103 min

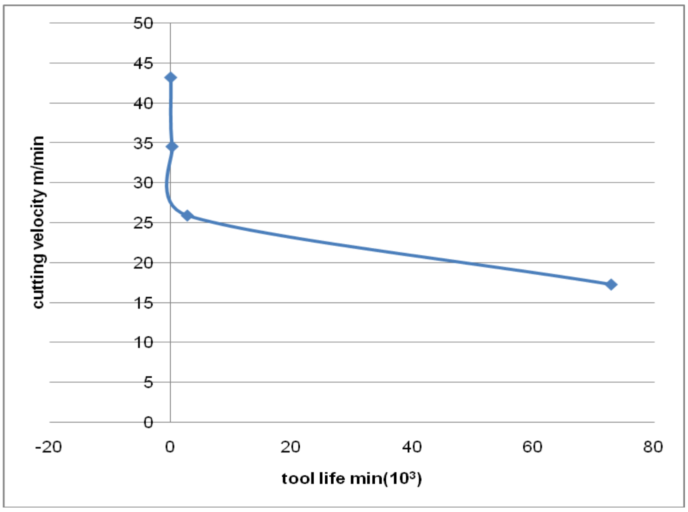


Fig 9: Graph between Cutting speed Vs Tool Life

A graph is drawn between the cutting speed Vs Tool life which varies parabolic shape .As the cutting speed increases tool life decreases as cutting speed decreases tool life increases and tool life slightly decreases at low cutting speeds which is as shown in the Figure 9

CONCLUSION

Modeling and analysis of cutting tool which is used in the turning operation without cutting fluid ie in dry cutting mode is done by the collecting the data of cutting forces that are acting on the rake face by the use dynamometer .By the modeling and analysis stresses are determined ,to study the wear pattern and a system is developed to reduce the tool wear

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