Effect of Rake Angles on Tool during Orthogonal Metal Cutting Process for Different Materials through Ansys

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Abstract— *the process of orthogonal metal cutting is analyzed using the Academic FEA package ANSYS/Explicit 14.5. The focus of the results presented in this paper, effect on tool by different rake angles and depth of cuts in orthogonal metal cutting process. A number of finite element simulations have been done with the ANSYS/Explicit Dynamics 14.5 to initiate the stress variations on tool during orthogonal metal cutting process. A tool rake angle varying from 20°, 25°, 30° and a friction coefficient is constant 0.4 mm and constant cutting speed 2.54 m/s with depths of cut are 0.05, 0.1, 0.15 mm has been considered in the simulations. The results of these simulations provide insight how stresses are influenced by rake angle and depth of cuts.*

Keywords: —*ANSYS, explicit dynamics, FEA, Materials, Tool life.*

I. INTRODUCTION

Two types of metal cutting used in industries orthogonal cutting and oblique cutting. In orthogonal cutting, the cutting edge of the tool is at right angles to the direction of the relative motion between the tool and the work piece. In oblique cutting, the cutting edge is inclined but not perpendicular to the direction of the relative motion between the tool and work piece. During the cutting process several forces acting on the tool. The study of effect of these forces is necessary for the qualitative analysis. The cutting parameters include the cutting speed, feed and depth of cut.

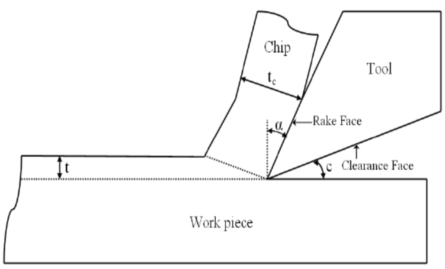

Fig. 1: The classical orthogonal cutting model

Machinability is partial by the tool variables, machine variables, cutting conditions and work material variables. These parameters may create failure of tool, poor surface finish, impulsive increase in forces, increase in temperature and stresses. The tool life and tool wear also depends on these parameters. For the optimum machining, these parameters should be in proper consideration like nature of cut to be made, feed, depth of cut, speed.

II LITERATURE REVIEW

F. W Taylor (1907) [1] showed that an optimum or economic cutting speed exists which could maximize material removal rate. Manufacturing industries have long depended on the skill and experience of shop-floor machine-tool operators for optimal selection of cutting conditions and cutting tools. Considerable efforts are still in progress on the use of hand book based conservative cutting conditions and cutting tool selection at the process planning level. The most adverse effect of such a not-very scientific practice is decreased productivity due to sub-optimal use of machining capability.

Jossel (1865) [2] forces were obtained in lathe cutting and drilling by measuring the torque required to turn the machine while cutting, care being taken to subtract the torque required to overcome the friction of the machine. The effects of uncut chip thickness, speed and rake angle were studied. References to "cutting fluids" are also found in his work (linseed oil, quicklime and nitric acid to name a few), although no explanation of their benefit was attempted.

Tresca (1878) [3] time was the first to correctly model the process ahead of the tool as one of shear, although he may be criticized for his viewpoint that the chip formation took place by fracturing of the metal on successive shear planes rather than by plasticdeformation. This is understandable though since the plastic deformation of metals in operations other than cutting was only beginning to be investigated at the time.

Atul P. Kulkarni et al. [4], experimentally investigated the effects of machining parameters on the surface finish, cutting force, tool wear, chip thickness and tool life. The AISI 304 austenitic stainless steel used as a workpiece and AlTiCrN coated insert produced by High Power Pulsed Magnetron Sputtering (HPPMS) used for dry turning. The experiment was carried out at different cutting speed and feed with constant depth of cut. The results show that the surface roughness value increases with increase in feed and low at the high cutting speed. The flank wear was prominently affected by cutting speed and feed.

Dr. Merchant's (1944) [5] presented a simplified 2-D model of the conventional oblique machining process called the orthogonal machining process which considers only two axes at a time which is also one of the widely used research model as it involves less complicated computations, easier to analyze and moreover is found to be in good agreement when extended to a 3-D model. Merchant's orthogonal machining model is of two types 1) orthogonal plate turning at moderate and high speeds (OPT), 2) orthogonal tube turning at moderate speeds (OTT)

II. Simulation Parameters

The purpose of this section is to discuss the modeling options in the Academic FEA software ANSYS/Explicit 14.5. A schematic diagram of the model problem in 2D is given below.

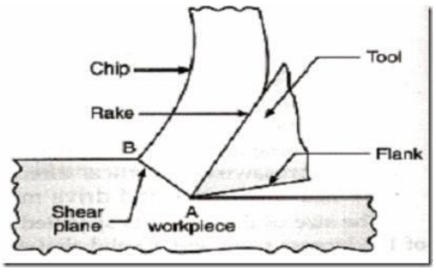

Fig. 2: Schematic diagram of orthogonal metal cutting process

The material used is AISI 4340 steel with a Young's Modulus (E) of 207 GPa and density (ρ) of 7800 kg/m^3.The chip layer has a height of 50 µm, 100 µm and 150 µm for the various depth of cuts. The rest of **the** work piece has a length of 2540 µm and a height of 889 µm. The tool in this study is of a parallelogram shape and has a base length of 407 µm and a height of 762 µm. The tool material properties are taken as E =207 GPa and ρ = 7800 kg/m^3. The boundary conditions for the chip-work piece-tool system are given as follows. The upper boundary of the tool moves incrementally towards the left with a constant speed of 2.54 m/s (152.4 m/min) while it is restrained vertically. The left end and right end of the work piece are restrained in the cutting direction but not vertically. Since the bottom boundary of the work piece is expected to undergo very little deformation during cutting, it is assigned zero displacements in both directions. A contact pair between the chip and tool face is defined (as shown in Fig 2.) in ANSYS/Explicit 14.5 to take care of the chip sliding on the tool face during the machining.

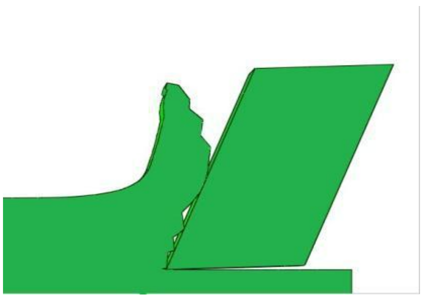

Fig. 3: Position of tool and work piece

III 3D MODELING

The tool material is considered is AISI 4340 steel molded with CATIA V5.

In this project the model dimensions is following. The chip layer has height of 50 µm. 100 µm and 150 µm for the various depths of cuts. The rest of the work piece has a length of 2540 µm and a height of 889 µm. The tool in this study is of a parallelogram shape and has a base length of 407 µm and a height of 762 µm. The tool material properties are taken as E =207 GPa and ρ = 7800 kg/m3. The tool material properties are taken as E =207 GPa and ρ = 7800 kg/m3. Three different rack angles 20°, 25° and 30° are used and nose radius is 0.2mm.

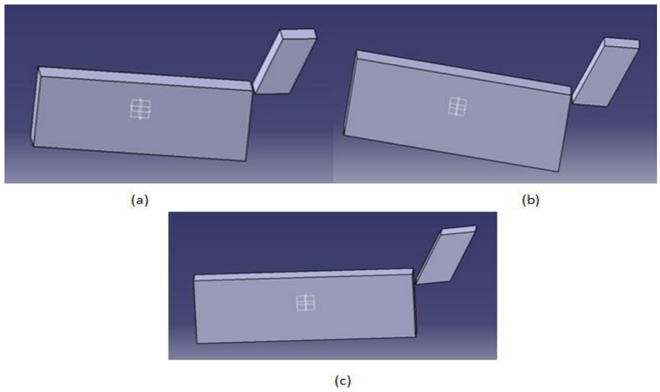

Fig. 4: (a) 20° rack angle, (b) 25° rack angle. (c) 30° rack angle

VARIATION IN MACJINING PARAMETERS

Table 1: Variation in Machining Parameters

Rake angle (α)	Depth of cut(t),(mm)	Cutting speed(v), (m/s)	Coeff. of friction(µ)
20°	0.05,0.1,0.15	2.54	0.4
25°	0.05,0.1,0.15	2.54	0.4
30°	0.05,0.1,0.15	2.54	0.4

IV FEA MODELING

Explicit dynamics simulation performed for analysis of orthogonal machining process in ANSYS 14.5. Material properties have been provided in ANSYS engineering data. Two models in orthogonal machining geometry one is tool and second is work piece. The material property of both geometries is given as follows.

Tool material is AISI 4340 steel, M2 steel and Tungsten steel

Table 2: Tool material properties

Material	Density	Elastic modulus	Poisson's Ratio
AISI 4340	7800 kg/m3	207 GPa	0.3

Meshing of orthogonal machining model

Meshing is an important thing in finite element analysis. We have use 0.9 mm element size and we got 4494 nodes and 3474 element.

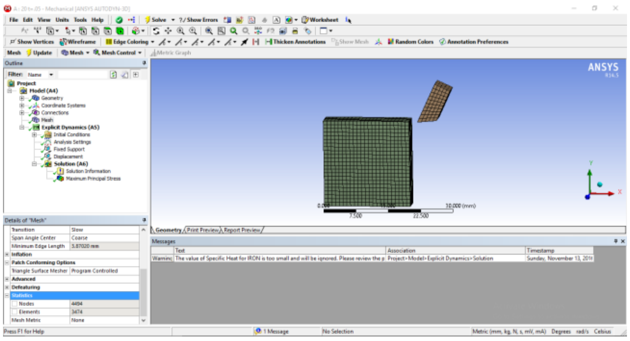

Fig.5:4 meshing of orthogonal machining model

Boundary conditions for orthogonal machining model
Initial conditions for tool
V= -2540m/s

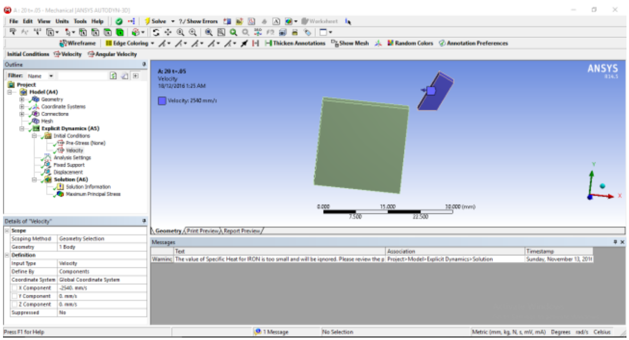

Fig.6: Velocity for orthogonal machining model (tool)

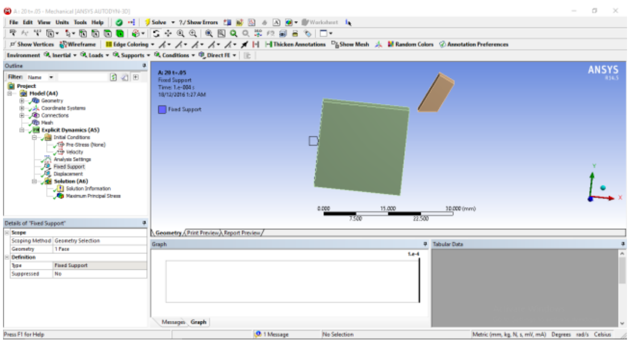

Fig.7: Fixed support for orthogonal machining model (work piece)

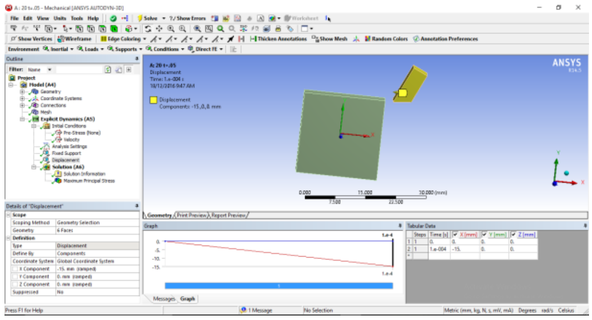

Fig.8: displacement for orthogonal machining model (tool)

V RESULT AND ANALYTICAL DISCUSSION

In this project three different material of steel in orthogonal machining process analysis. Different rack Angles and depth of cuts modeled for FEA work 20°, 25°and 30° rack angles and 0.05, 0.1 and 0.15 depths of cuts.

Reference results of AISI 4340 steel are

Table 3: Reference results of AISI 4340 steel

Rack angle	Depth of cut (t) mm	Cutting speed (v) m/s	Coefficient of friction (µ)	Stress (MPa)
20°	0.05	2.54	0.4	1421
20°	0.1	2.54	0.4	1381
20°	0.15	2.54	0.4	1376
25°	0.05	2.54	0.4	1416
25°	0.1	2.54	0.4	1416
25°	0.15	2.54	0.4	1341
30°	0.05	2.54	0.4	1715
30°	0.1	2.54	0.4	1387
30°	0.15	2.54	0.4	1416

Dynamic analysis results from ANSYS 14.5 of AISI 4340 steel

Table 4: Dynamic analysis results from ANSYS 14.5 of AISI 4340 steel

Rack angle	Depth of cut (t) mm	Cutting speed (v) m/s	Coefficient of friction (µ)	Stress (MPa)
20°	0.05	2.54	0.4	1426
20°	0.1	2.54	0.4	1356
20°	0.15	2.54	0.4	1320
25°	0.05	2.54	0.4	1462
25°	0.1	2.54	0.4	1403
25°	0.15	2.54	0.4	1374
30°	0.05	2.54	0.4	1800
30°	0.1	2.54	0.4	1268
30°	0.15	2.54	0.4	1470

ANSYS results of AISI 4340 steel

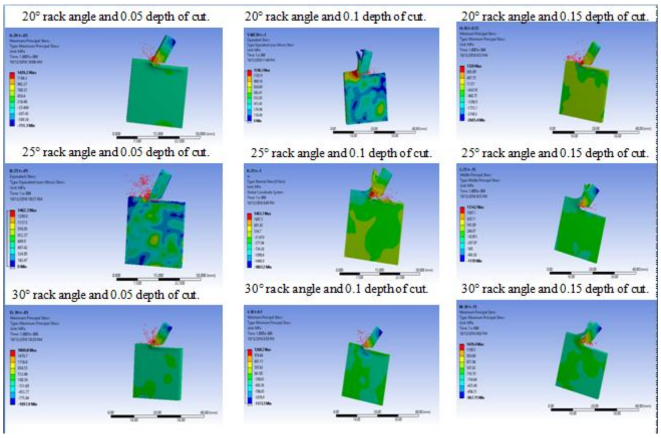

Fig. 9: ANSYS results of AISI 4340 steel

The von-Misses stress distributions in Fig 10 help us to observe the plastic flow behavior. Upon close observation it can be seen that the stress contours are parallel to the tool chip ahead of the tool tip and aligned slightly towards the left in a forward direction. The peak contour is seen to connect the tool tip and the turning point on the chip's free boundary, forming the ``shear" angle (Shet and Deng) [1].

Analytically solution for 20° rack angle and 0.05 depth of cut

Given data

Force, F = 205 N

Stress

$$\sigma = \frac{F}{AB * w}$$

Where

W= ρ * L*b*t

W= 7800*0.762*0.5*0.407

W= 1.209 Kg

To find area

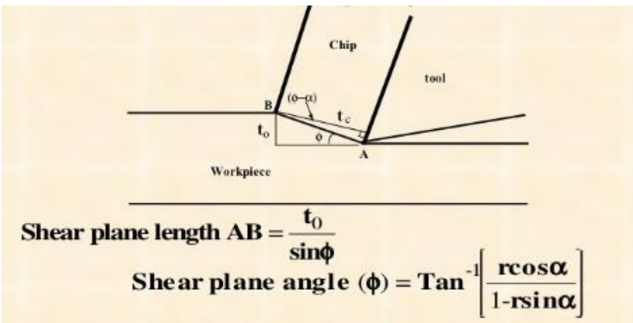

Fig. 10: Shear plane angle

Then AB = 0.1196

Stress

σ= 1417.73 N/mm²

Graphically representation of results

Variation of cutting force with varying rake angles and depth of cut

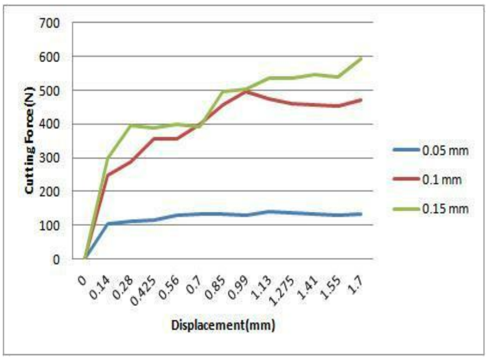

Fig. 11: Stresses at 20° rake angle

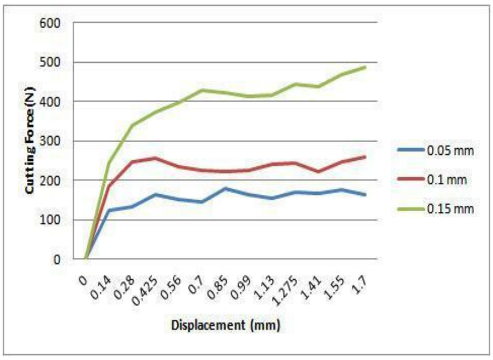

Fig. 12: Stresses at 25° rake angle

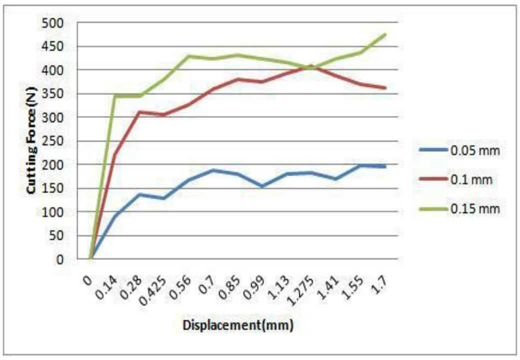

Fig. 12: Stresses at 30° rake angle

Following figure shows the variation of horizontal cutting forces with the tool tip displacement for varying rake angles and depth of cut. For each value of depth of cut, the cutting force is seen to increase with increase tool tip displacement. For each rake angle, the cutting force for a particular depth of cut is seen to decrease with tool tip displacement.

VI. CONCLUSION

Finite element simulations of the machining of AISI 4340 steel have been successfully carried out using the commercial FEA software explicit dynamics 14.5.Chip separation was properly simulated under dry friction condition. Steady-state finite element solutions for the cutting forces and von-Misses stress have been presented. This study shows that the simulation can be extended to parameters like rake angle and depth of cut and for various materials so as to optimize the machining process for that particular material.

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