

NUMERICAL AND EXPERIMENTAL VALIDATION OF CHIP MORPHOLOGY

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ABSTRACT

The extensive research studies are used to divination the behavior of complex Metal cutting processes. The cutting parameters such as speed, feed and force play important role on conform chip morphology. The experimental techniques for investigation the chip morphology is expensive and time consuming. To overcome these difficulties Finite element modeling and simulation process are used as effective tool to divination the effect of cutting variables. In the present study FEA simulation process model is developed to divination the chip morphology and cutting forces in turning of Al-6061 with WC tool. Johnson cook material models are considered for visco-elastic material behavior. The obtained simulation process results are compared with experimental process results.

Keywords: FEM, Chip morphology, DOF, Johnson-Cook material model, WC

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1. INTRODUCTION

Metal cutting is most important creating process in processing industry. In Metal cutting, the procedure of eliminate the excess unwanted material is in appearance of chips through a v-shaped tool. Chip morphology plays a key role on finish obtained on workpiece machined surfaces. Hence the study on chip morphology is emphasized. Young [1] indicated the chip temperatures additionally the tool chip interface temperature using the infrared camera for cutting tools with different flank wear land values and related flank wear of a cutting tool.

Yourong et al. [2] find temperature distribution on the rake and flank side faces of two ceramic tools during turning operation using the infrared image. Wang et al. [3] used an infrared imaging system to measure the unsteady temperature passed throughout, within curled chips during dry machining of cold rolled steel. The surface roughness on machined surfaces was measured off line on machining of Inconel-600 with carbide tools. Shih [4] existed a model to analyze the orthogonal Metal cutting with unbreakable chip formation, using a Eulerian method. He verified that lack of all material properties and friction variables directly affect the correctness of the finite element simulation process. Shi et al. [5] studied the cutting with finite element method under plane strain approach. The effect of friction on thermo mechanical quantities in an Metal cutting process is presented. A friction coefficient from 0.0 to 0.6 is taken in to consideration and eventually found that general purpose finite element code ABAQUS used to simulate the Metal cutting process and far chip formation, the shear angle of initial primary shear zone, increasing in temperature and required force, depend strongly on the coefficient of friction and on the rake angle. Fang and Jawahir [6] divination three important machining variables, i.e. the cutting force ratio, chip size, and chip back-flow angle, on the basis of universal slip-line model, a maximum value principle in order to find the stresses in the plastic zone in restricted machining. Fang [7] suggest a slip-line model in favor of the tool–chip contact zone on the tool secondary rake face. Spiral chip in machining was also taken in to account. Fang [8] analyzed the forces, chip thickness, and tool–chip contact length in machining with a rake-angled tool and reveal that double-rake-angled tool increases the thrust forces in comparison with single rake angled tool. Found that tool–chip contact friction on the tool secondary zone rake face plays an role in machining than the tool–chip friction on the tool primary zone rake face. Shet and Deng [9] finish a finite element method to simulate and to analyze the orthogonal Metal cutting process under plane strain conditions, with main on the residual stress and strain fields in the finished work piece. The main target of this work is to divination the forces and chip morphology, in the chip formation region using the method of FEM in turning process. Further the obtained fem simulation process results are compared with experimental process results of forces and chip morphology measured by three-dimensional Dynamometer and Tool makers microscope.

2. NUMERICAL SIMULATION PROCESS

For accurate simulation process of Metal cutting by finite element procedure, a better perception of the material removal process in Metal cutting is first necessary. Metal cutting is a highly nonlinear and combined thermo-mechanical process. Coupling is initiate because of confine heating, temperature increases in the work piece and the excess plastic flow in the shear zone in work piece due to the cutting forces, developed friction through the tool –chip interface zone. The tool signature and its design plays important role in the dimensional perfect and surface uprightness of the final product. This complexity is to be translated into the finite element simulation process. In now a days, finite element method emerged as a tool for the analysis process of Metal cutting because it has following.

3.1. Tool and Workpiece Modeling

From the practical approach, it is show that the tool model has a great impact on the surface model of the machined work piece. Hence it is important to model the design of tool model. In the present numerical analysis process, the tool of Tungsten carbide (WC) material is selected with 8° rake angle, 3° clearance angle and 0.8 mm nose radius. Tool geometry and work dimensions are as shown in Fig 1.

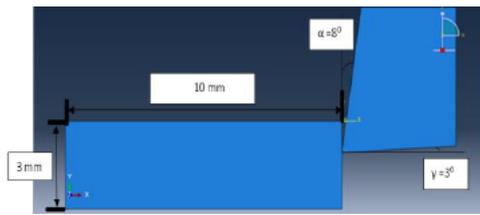


Figure 1 2D Modeling of Tool and workpiece

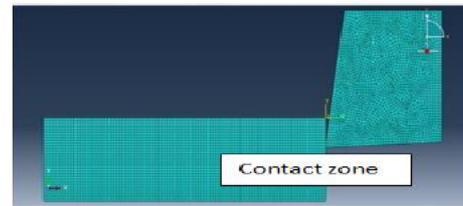


Figure 2 Mesh generation

Work piece material properties (Al-6061) are shown in Table.1. During cutting process the plastic behavior of material is transient due to localized heating, temp distribution and the friction. To study the plastic behavior of Al-6061, the Johnson cook material constitutive model is used. Johnson cook material constants used are presented in the Table 2. As shown in Fig. 1, work piece dimensions of 10mm x 3mm, and width of tool about 1mm is considered. ABAQUS as plane stress/strain thickness.

Table 1 Thermo mechanical Properties of the Work piece and Tool Material.

Properties	Young's modulus (G Pa)	Density (kg/m ³)	Poisson Ratio	Conductivity (W/m K)	Specific heat (J/kg K)
Al-6061 (Work Material)	85	2700	0.29	173	885
WC (Tool Material)	540	12000	0.22	40	203

Table 2 Material constitutive model (Johnson Cook constants for model) Al-6061

A MPa	B MPa	n	C	m	Rake angle °	Clearance angle °
369	684	0.73	0.0083	1.7	8	3

3.2. Meshing of Work and Tool Geometry

To mesh model this behavior CPE4RT element is considered. This element is 4-noded, bilinear in displacement and temperature, hybrid with constant pressure. It is most reliable for thermo coupled mechanical application of Metal cutting system. The Johnson–Cook plasticity model to relate the stress, rate of strain and heat with temperature is the key requirement for a successful simulation process. Below shows the general equation of this model. The simulation process used material constitutive model (Johnson cook) depicts the stress as a function of strain, rate of strain and heat with temperature and it is commonly embedded into FEM simulation process software(ABAQUS).In this material model, strain hardening ,thermal softening are considered. Where σ is equivalent stress, ϵ is equivalent plastic strain, T is temperature of material, T_m is the melting temperature, ϵ_o is the strain rate, T_r is the reference temperature, A, B, m and n are the four coefficients' needed to be included.

$$\left(A + B(\epsilon^n) \right) \left[\left(1 + C \ln \frac{\dot{\epsilon}}{\epsilon_o} \right) \left(1 - \left(\frac{T - T_o}{T_{fix} - T_o} \right)^m \right) \right] \quad (1)$$

The constants in the equation (1) for Al-6061 are taken from standard experiments. During simulation process, it is accept that work piece allowed shows only plastic response. In this simulation process model, surface-to-surface contact is created to define the chip tool as well as work tool piece interfaces. Fig 2 shows the meshed model with contacts. At this zone numerical methods become dominant, as in the various outputs and attribute of the Metal

cutting processes such as cutting forces, chip shape, etc. can be divination by using FEM without doing any experiment.

In this experiments carried out on 2.2KW Kirloskar center lathe with variable speed drive, the following conditions are explicitly followed for the FE simulation process. Maintain at constant speeds of 600rpm, 800rpm and 1000 rpm, nose radius of the tool and assumed room temperature 30°C.Neglected tool wear and consider dry machining for simulation and experimental.

This Finite element Metal cutting model is developed with three stages: Pre-processing, Solving, and Post processing. In preprocessing stage, model has been defined with geometrically suitable boundary conditions and material properties. With meshing it is submitted to solver to solve all the field variables at the nodes, elements and outputs are carried to the post processing stage such as sorting, printing and plotting selected results as shown in Fig.3. Table 3 shows the test cases for which simulation process have been performed.

Table 3 Experimental & Simulation process Test cases

Parameter	Test.1	Test.2	Test.3	Test.4	Test.5	Test.6	Test.7	Test.8	Test.9
Spindle speed in rpm	600	800	1000	600	800	1000	600	800	1000
Depth of cut (DOF) in mm	0.2	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.6

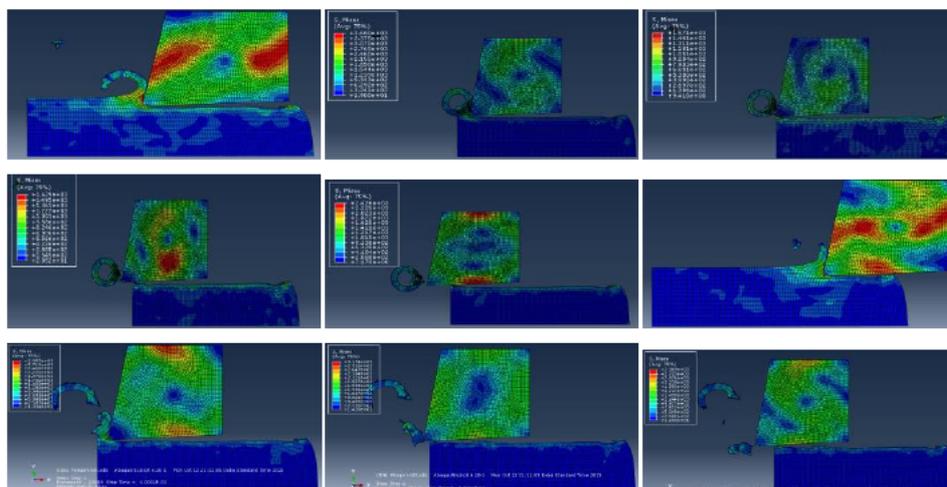


Figure 3 Chip formation in different parameters simulation process tests in Al-6061 machining

4. EXPERIMENTAL PROCEDURE

Raw material cut tests are bring out on Al-6061 specimen of 100 mm length,30 mm diameter is turned by using tungsten carbide tool without coating the lathe used is Kirloskar Turnmaster-35. All Geared conventional lathe. The tool insert used in the process is THN SNMG 08. The range of speed up to 1000 rpm can be used on the Machine. The work pieces are machined previous to the experiments by removing 0.3 mm thick of the top surface in order to remove any surface defect, present clean surfaces and avoid vibrating behavior during machining. For each test, sample chips were collected and their thicknesses and chip width are measured by Tool makers’ Microscope. Cutting forces are measured using Kristlor Dynamometer. Dynamic

behavior was also picked up and displayed by the same instrument. The chip of thickness, width and cutting forces obtained from the experiments are compared with the numerical simulation process results.

5. RESULTS AND DISCUSSIONS

The experimental process results are presented in Table 4 for comparisons with ABAQUS simulation process results. From the experimental process results, chips are found to be continuous, because of high depth of cut, high cutting speed. Table 4 shows that percentage difference between FEA and chip width is found in the range of 1 to 35%, thickness 0 to 9% for experimental process result validation. The simulation process results and Experimental process results are pictorially presented in the Fig 5, correspond to the tests 1 to 9 respectively. Tests have been manually taken at 5 dissimilar places to obtain the averaging of all the instantaneous values of chip width and thickness. Chip burr is neglected. Further simulation process assume chip width is to be constant which is equal to 1mm. In this simulation process it represents plane stress/strain thickness. Same method has been complete for remaining eight cases are indicated in Table 4. Further the study was carried on the effect of cutting force on chip morphology in both FEM simulation process and experimentation. The amplitude of resultant forces observed in both simulation process and experimentation are pictorially presented in the Fig.5. The amplitude of wave form in both experiments and simulation process show a similar trend. In simulation process, resultant cutting forces differ by 12% with experimental values. In the test 8 at DOC = 0.6mm, V = 800 rpm the magnitude of cutting force is high in both simulation process and experiment and this may be a causation for breakage of chip. It is observed that the amplitude was sudden fall and which may have led for breakage of chip to yield discontinuous chip. While measuring amplitude through experiments (600 rpm, 0.2mm DOC) the force experienced by the workpiece is an average amplitude, but on the simulation process it is possible to measure the force component instantaneously as shown in Fig.5. The ALE simulation process approach presented in this work with adaptive meshing definitely divination good results for chip morphology. All above results it is stated that, numerical simulation process software is reliable tool to divination chip morphology.

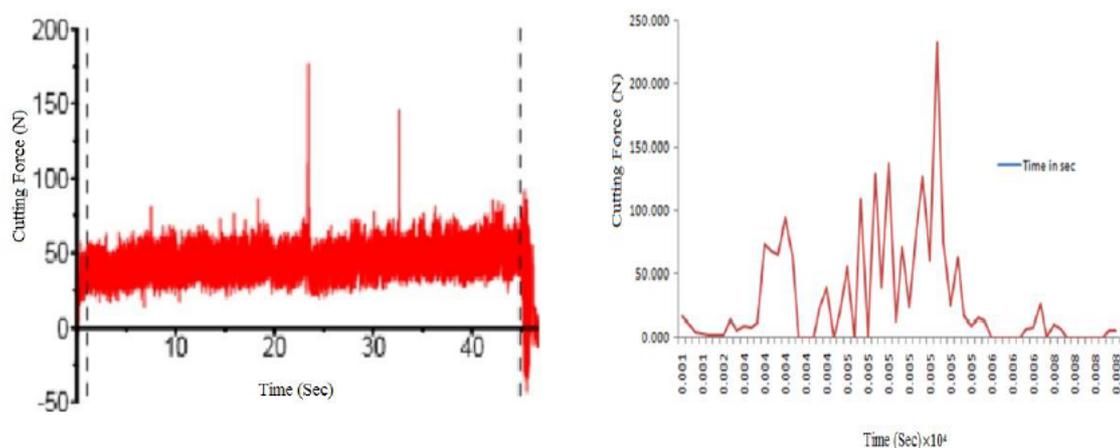


Figure 5 Amplitude of force in Experimental and simulation process at 600 rpm, 0.2 DOC

The cutting force affected by friction developed during chip flow the magnitude of cutting force is gradually increased with increasing speed at constant depth of cut. The magnitude of cutting force is gradually increased with increasing depth of cut at constant speed. The magnitude of average cutting forces at higher depth of cut are two times higher than at lower depth of cut. The test no 8 results displayed discontinuous chip in both experimental and simulation process. Also the amplitude of cutting force observed a sudden rise and fall because of discontinuous chip. The amplitude of average force developed during cutting the work piece is almost same in both experimental method and simulation process method. The behavior of cutting force both in experimental and simulation process are same. The considered Johnson cook model parameters proved to be appropriate in divinationing chip morphology.

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