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# FEM Analysis of Orthogonal Cutting of Aluminium Alloy using Rigid Tool

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***Abstract* – Numerical analysis of aluminium alloy 5057 was performed using ABAQUS tool. A rectangular block was modeled as workpiece with a rigd sharp 2D tool performing orthogonal cutting in it. Tool feed was kept constant with variation in its depth of cut and rotation speed. Chip morphology of the workpiece was observed to be different with depth of cut variation.**

***Keywords- Orthogonal cutting, aluminium alloy, ABAQUS***

## I. INTRODUCTION

Manufacturing technology has been the driving force behind modern economics since the Industrial Revolution (1770). Metal shaping processes, in particular, have created machinery and structures that permeate almost every aspect of human life today. Metal cutting is a typical irreversible process, comprising large plastic deformation coupled with temperature rise at high strain rates. From a continuum mechanics point of view, suitable constitutive or governing equations that can describe this phenomenon are needed to predict chip flow, cutting forces, cutting temperature, tool wear, etc. Cutting processes are quite complex, largely due to the fact that two basic operations occur simultaneously in a close proximity with strong interaction.

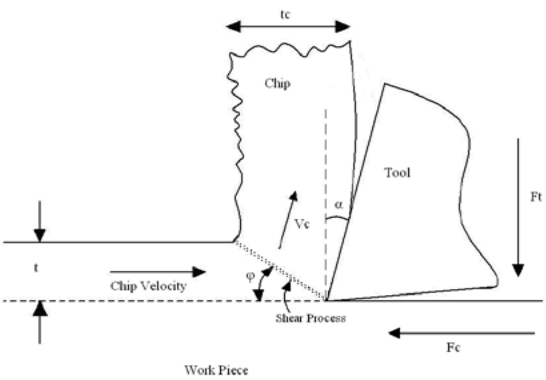


Fig 1. Orthogonal cutting

The plane-strain orthogonal metal cutting process, for which, the direction of relative movement of wedge-shaped cutting tool is perpendicular to its straight cutting edge, has been extensively studied since it provides a reasonably good modeling of the chip formation on the major cutting edge of many metal removal processes such as turning, milling, drilling, etc.

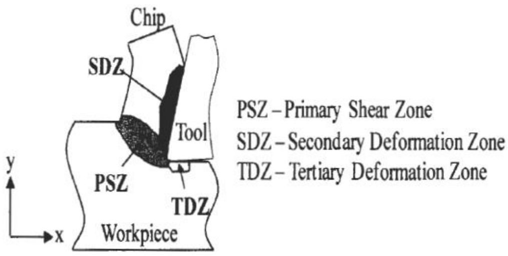


Fig. 2 Zones of deformation

## II. LITERATURE REVIEW

An overview of the literature related with and numerical and experimental analysis of metal cutting and chip formation is given. Ivester et.al. The orthogonal cutting (two dimensional) experiments using diamond coated tools were conducted with forces and tool-tip temperatures measured by dynamometer and infrared thermometer on A356 aluminium alloy that was cast and heat treated, respectively. In this paper they analyze cutting parameter effects on process behavior in diamond coated tool machining. DAOUD et al studied the thermo mechanical behaviour of machined material is described by constitutive law. This constitutive model proposed by Johnson and Cook (JC) is widely used in the modeling of machining processes. Malkote et al. works on size effect. The size effect in metal cutting is occurs in the nonlinear scaling phenomenon observed in the specific cutting energy with decrease in uncut chip thickness. Maranhao et al. in the paper focus is on to study the thermal and mechanical behaviour in machining of aluminium alloy (Al7075-0) using PCD (polycrystalline diamond ) and K10 (cemented carbide) tools and to make a comparision between the performance of both tools. Chengguang et al. had studied the influence of tool geometrical parameter in high speed cutting of aluminium alloy. Kara et al carried out the study of experimental and numerical analysis of the cutting forces and numerically obtain the cutting temperature. The deform 2D programme was used for numerical modeling and the Johnson-Cook (JC) material model was used. The numerical cutting forces for the coated and uncoated tools were compared with the experimental results.

Li analyze the orthogonal cutting tests of surface micro groove cutting tool in machining titanium alloy. Arrazola et al performed orthogonal cutting experiment on a tube of 80 mm diameter and 3 mm wall thickness of material AISI4140 steel, orthogonal cutting was carried out without lubrication, so as to measure the cutting forces during experimental tests, a kistler dynomometer device was used.

## III. METHODOLOGY

A finite element model of rectangular 2D block (workpiece) was created along with a rigid sharp nose tool. Rigid tool was allowed to move in one direction with a fixed bootom of rectangular workpiece. Tool was considered as rigid while workpiece was allocated material property using Johnson cook material model. Fig.3. shows the proper methodology followed in the study.

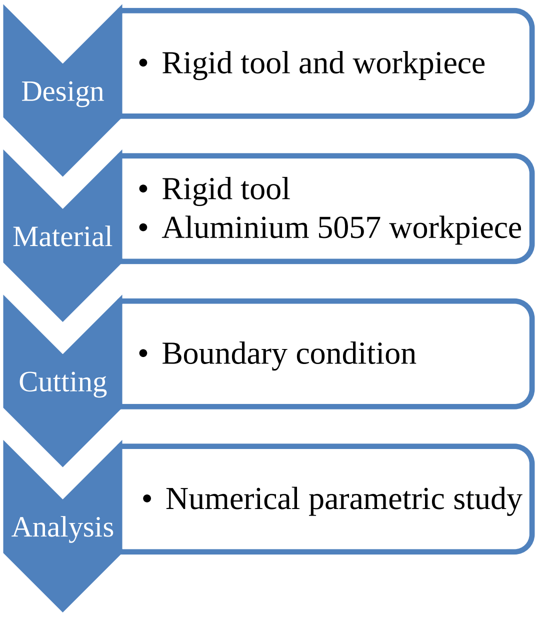


Fig.3. Methodology

The tool is modeled with given geometry and workpiece was also modeled with approximate given size. Workpiece was assigned material property and assembly was performed so that both the parts namely tool and workpiece can be assigned in a single space while reference point was set in the tool geometry which was further used for assigning different properties.

In this abaqus model of a metallic aluminium was created while tool was constructed with geometry shown in the above figure. Tool was modeled as a rigid body therefore assigning material property to the tool was not required and it was observed that Johnson crook damage criterion was provided for the aluminium profile workpiece. Workpiece was basically being formed in three layers with the facilitation of proper removal of the chip as the upper layer contact can be broken.

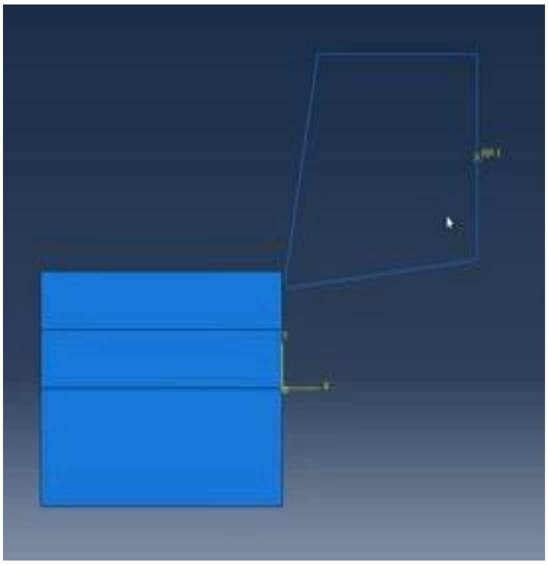

Fig. 4. ABAQUS model

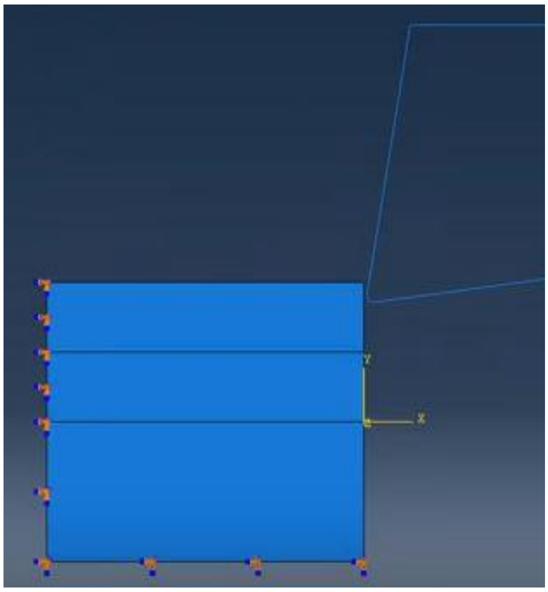

Fig. 5 Boundary conditions

## IV. RESULTS AND DISCUSSION

Analytical model created in ABAQUS was analysed by incorporating proper material model and boundary conditions and the results obtained were discussed in below conditions.

From above result of von-mises stresses inside the deformed chip it is found that the maximum stress value occure in shear plane along chip tool interface. The value of maximum stress in the shear plane are greater than yield stress value of aluminium alloy Al 5057. Therefore the deformation of the chip takes placed at tool chip interface as this phenomenon was disscussed in chip formation mechanism.

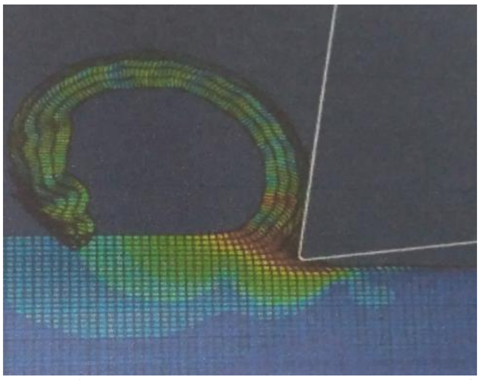

Fig 6 Chip formation at 273 rpm speed and 0.08 rev/min feed

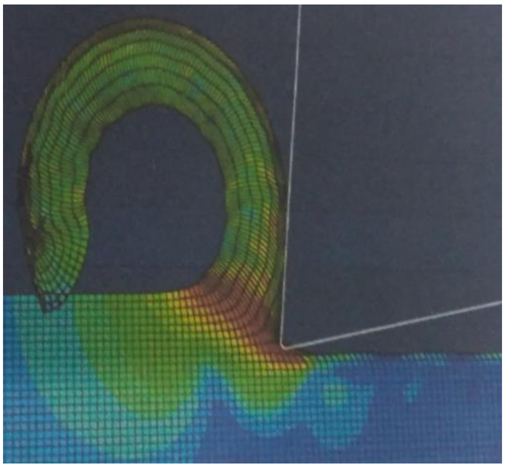

Fig 7 Chip formation at 273 rpm speed and 0.12 rev/min feed

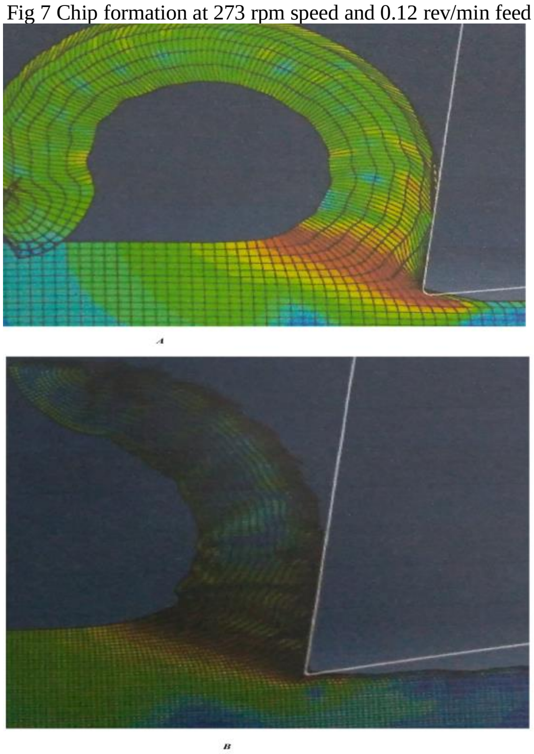

Fig.7 Comparison between material at different feed rate

It is found that the serrated chips i.e. saw-tooth appearance are formed. At low feed height these saw tooth appearance in chip but as the feed is increased, saw tooth appearance in the chip is also increased this is because of the cutting forces and alternating high shear strain followed by low shear strain.

Chip thickness in the simulation were measured using the chip elements which were coming out while the run of the simulations and this chip thickness was compared to that of experimental results obtained from the research paper.

## V. CONCLUSION

- The numerical modeling of 2D plain strain orthogonal cutting is succesfully carried out using finite element method. In numerical simulations of orthogonal cutting of aluminium alloy Al5057 it is found that the maximum stresses occur at the chip tool interface in shear plane. And the value if maximum stresses are increases with increases in the feed rate of tool with respect to the work piece.
- Chip thickness in experiment and numerical simulations are compared and it is found that the chip thickness is not exactly same. There are some errors may be due to limitations on working conditions, machine conditions, limitations on tool or operator.

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