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Force, Stress prediction in drilling of AISI 1045 steel using Finite Element Modelling

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Abstract. Machining simulation is a primary research area all around the world. Many researchers are attempting to understand the underlying principles of machining. Earlier research has started with orthogonal machining then slowing is now progressing into oblique machining. Even though extensive research has been carried out in the field of machining and its allied areas, still the process of understanding the nuances of the machining processes is underway. The research is happening on the theoretical and experimental front. Numerical simulation has helped the researchers in understanding the machining processes within a quick duration and it is to a certain extent reliable. Here the authors of the work have tried to outline the procedure and the method involved in Finite element simulation of the machining processes. In the present work, commercially available software is used for numerical simulation purposes. The machining purposes considered for the research work is drilling process.

1. Introduction

Manufacturing primarily is done by additive method or material removal method. Machining process such as milling, turning, shaping, planning, grinding, drilling have been used since long time. Machining is one of the plastic deformation process that is used to realize the product. It is a highly complex process when we want to understand it at the microscopic level. Researchers have been using simulations to help them understand different processes [1-4]. Finite Element Analysis to understand the machining processes in a better manner has been used by many researchers [5-9]. In the present work, the drilling process is taken and the finite element simulation of the drilling process is achieved. The forces generated during the drilling process and the reaction force in the drill tool is determined using the commercially available software.

2. Finite element model

In this work, 3D FEM is considered. The reason for going for 3D model is that it is more realistic [5, 10], that is, oblique cutting is simulation. The work piece that is considered is assumed to be AISI

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1045 steel and in this case the tool is assumed to be rigid, hence the model developed is mechanical mode. The work piece that is modelled is shown in Figure 1. Partitions made on the work piece allow us to do fine meshing at the cutting zone. The drill tool Figure 2. that is used is twist drill bit. The tool is modelled using a 3D modelling software and the same is imported into the finite element modelling software. A dynamic explicit analysis was done. For the work piece Johnson Cook material model and Damage model was considered. These two model are important because material fracture happens due to the machining operation.

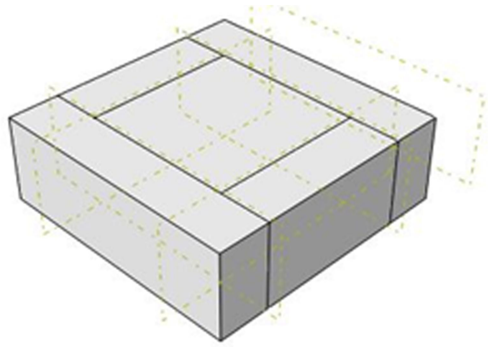

Figure 1. Work piece with partition

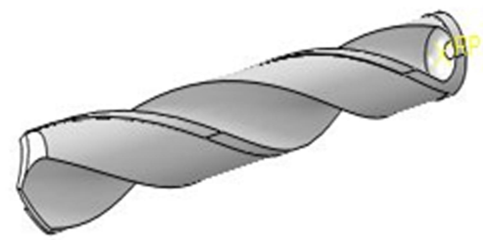

Figure 2. Twist Drill Bit

Table 1. gives the material properties that were used in the analysis and Table 2 gives the Johnson cook material and damage model values.

Table 1. Material Properties of AISI 1045 steel[11]

Parameter	Value
Young's Modulus	210 GPa
Poisson's Ratio	0.3
Specific heat	432 J/kg/◦C
Thermal Conductivity	47.7 W/m◦C
Density	7800 kg/m^3
Friction Coefficient	0.3

The Johnson-Cook material values are given in Table 2.

Table 2. Johnson-Cook material and damage properties[11]

Parameter	Value
A	553.3 MPa
B	600.8 MPa
C	0.013
n	0.0234
m	1
D_1	0.06
D_2	3.31
D_3	-1.96
D_4	0.0018
D_5	0.058

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2.1. Analysis Setup

The assembled view is shown in Figure 3. As discussed earlier the work piece was modelled separately and the tool was modelled in a 3D modelling software and imported to the simulation environment owing to the complexity of the tool. A 3D dynamic explicit analysis was run for about 0.04 second and the results are discussed in the future section.

2.2. Meshing

The meshing of the work piece was done using C3D8R: An 8-node linear brick, reduced integration, hourglass control. The element chosen for the tool is inconsequential since the tool is modelled rigid. The meshed model is shown in Figure 4. It can be observed the model has a fine mesh at the cutting zone and course mesh outside the cutting zone

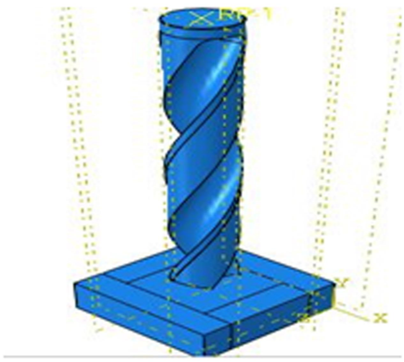

Figure 3. Specimen

Table 3. Cutting Conditions.

Cutting Speed	7000 rpm
Feed	10 mm/s

2.3. Interaction

The contact between the tool and the work piece is important. The analysis is setup in such a manner that the surface of the tool is contacting the entire cutting zone. The tool acts as the master surface and the work piece acts as the slave surface meaning that the work piece is the one which is effected becase of the interaction between the tool and the work piece. Simple coulomb friction is considered between the tool and work piece. The co-efficient of friction is considered to be 0.1.

2.4. Boundary condition

The boundary conditions are similar to the cutting process. The base of the work piece is arrested for all degrees of freedom. Apart from the base of the model the sides of the work piece is also arrested to mimic the drilling process. The tool is free to rotate about the z axis and the tool is free to translate about the y axis. All other degree of freedom is arrested. The cutting condition that is used for the simulation is provided in the Table 3. The boundary conditions are shown in Figure 5.

3. Results

The chips forming during the drilling process is shown in Figure 6 along with the stress plot. The Figure also show the drilled hole. It can be observed that the circumference of the hole is not circular. Proper geometry can be achieved if the mesh is refined at the cutting zone. The force generated during the drilling process is shown in Figure 7. The model can predict the residual stresses that are induced and the variation of it along different direction. This will help us to determine the nature and effect of such residual stresses in the components[12]

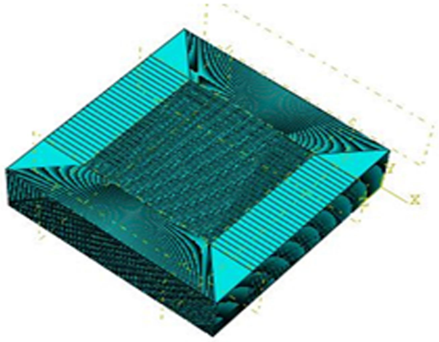

Figure 4. Chip formation.

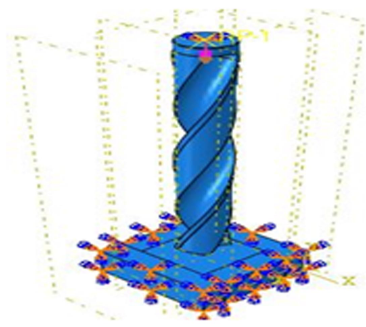

Figure 5. Boundary Conditions

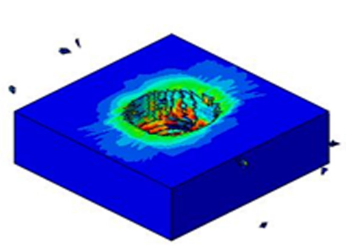

Figure 6. Chip formation and drilled hole showing Von- Mises stress plot

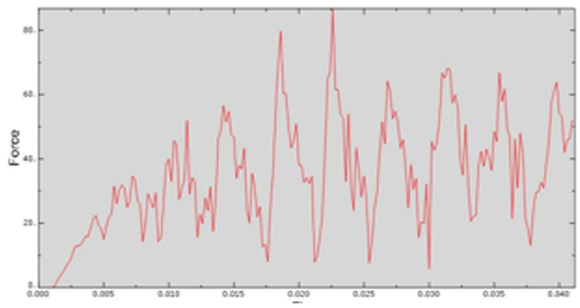

Figure 7. Force Versus Time

4. Conclusions

A 3D model to predict the cutting force during the drilling process was developed. The chip formation process was observed and the different stress plots were obtained using the simulation. Using the model the variation of force for different cutting conditions can be achieved without having to perform costly experiments. The residual stresses that get induced due to the machining process that can be studied along with the other parameters [13]. The future work involves the modelling of a coupled thermos mechanical model, which can be used to predict the temperature developed during the cutting process. In future, a model to understand the cutting process in composite materials[14] can be developed with slight alteration in the analysis set up and material modelling.

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