Finite Element Simulation of Punching Process Using in Process Characterization of Mild Steel

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Abstract—Punching or piercing is among the oldest and most frequently used sheet metal forming process. Nowadays the technology on sheet metal forming has rapidly grown. This paper described a piercing process by using the finite element method in order to reduce the failure of punch for a given sheet material and thickness to be pierced. In this research paper the clearance and various shape of the punch were studied for piercing operation of 6mm thick Milled steel strip. ANSYS 14.5 software is used for analyzing effect of changing punch geometry. The Finite element method is used to predict the effect of punch geometry and clearance in punching process.

Key words: Piercing process, Clearance, Heat treatment, Punch geometry, Finite element method.

Nomenclature:
- T = thickness of sheet metal (mm)
- D = Diameter of hole or Blank (mm)
- Dp = Diameter of punch (mm)
- Dd = Diameter of die (mm)
- C = Clearance (mm)
- Fc = Cutting force (tones)
- Fs = Stripping force (tones)
- Rd = Radius of Die (mm)
- Rp = Radius of punch (mm)
- Sut = Ultimate shear strength of sheet metal (N/mm²)
- E = Modulus of elasticity
- Lp = length of punch (mm)
- COP = Center of pressure
- FEM = Finite element method

I. INTRODUCTION

Punching and blanking are similar sheet metal cutting operations that involve cutting the sheet metal along a Closed outline. If the part that is cut out is the desired product, the operation is called blanking and the product is called blank. If the remaining stock is the desired part, the operation is called punching. For piercing process, there are several mold factors that affect punch wear. The factors are: the clearance between the punch and die; the sharpness of the cutting edges; the angle of shear on the punch and die; the percentage penetration. Much work on tooling optimization has been done in the past. But the vast majority of work has been done on piercing punch geometry (various shapes flat, shear, step taper).

II. LITERATURE SURVEY

Yuan Yongfu [1] and Liu Cunping [2] conducted experimental research on simulating piercing of a Q235-A sheet and conclude that 1) the clearance was the most influential factor of the mold parameters in piercing process and it is followed by punch-die round radius. While the interaction of clearance and punch-die round radius had almost no effect. 2) The results also showed that the punch-
die round radius has little influence to the real crack propagation and ideal crack propagation showed a slow declined tendency. 

Pravitr Paramaputi [3] conducted research on step taper shaped punch in piercing of Aluminum (Al1100-o) thickness 3mm by using finite element method and conclude that the FEM simulation could be useful tool to predict the cut surface features of step taper shape punch.(STSP). The suitable taper angle of approximate 6° obtain by FEM corresponded with the experiments and using ANSYS.

Amol Totre [4] conducted research on factors affecting in blanking process and conclude that most affected factors in blanking and piercing process are Clearance, Tool wear, Sheet material and Thickness, Punch geometry, Heat treatment.

Gang Fang [5] , Pan Zeng [6] conducted research on Finite element simulation of the effect of clearance in piercing process with the help of using LS-DYNA software and conclude that the clearance between the punch and the die will affect the precision of the shape and dimensions dramatically. It can be predicted that numerical simulation can be helpful to determine process parameters, which can improve the quality of the work piece.

Dae-Cheol Ko [7], Dong-Hwan Kimb [8] conducted research on Finite element analysis for the wear of Ti–N coated punch in the piercing process on Piston pin. The material of piston pin is SCM 415H and punch material is SKH51. They conclude that In case of the coated pin with Ti–N wear rate is quite little until Ti–N coated layer is removed from the tool surface, whereas wear rate increases rapidly after the coated layer is worn out. It is known from wear test that the difference of wear coefficient between the coated layer and the base material is about 10 times.

Gang Fang [9], Pan Zeng [10] conducted research on Finite element simulation of the effect of clearance in piercing process and conclude that the clearance between the punch and the die will affect the precision of the shape and dimensions dramatically. It can be predicted that numerical simulation can be helpful to determine process parameters, which can improve the quality of the work piece.

M mabogo [11] conducted research on Numerical simulation of piercing using FEA with Smoothed Particle Hydrodynamic (SPH) method. The SPH method as implemented in the commercial code LS-DYNA has been used to solve the problem of piercing a hole in a stamped shock absorber seat of TM 380 steel. Results produced by SPH method for three different punches: flat, concave, and shear, for TM380 steel and HR190 steel as shown in tables.

Table 1: Maximums of Misses stress, plastic strain for TM380 steel

<table>
<thead>
<tr>
<th>Punch shape</th>
<th>Max. misses stress</th>
<th>Max. plastic strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>668 MPa</td>
<td>0.399</td>
</tr>
<tr>
<td>Concave</td>
<td>569 MPa</td>
<td>0.399</td>
</tr>
<tr>
<td>shear</td>
<td>663 MPa</td>
<td>0.382</td>
</tr>
</tbody>
</table>

Table 2: Maximums of Misses stress, plastic strain for HR190 steel

<table>
<thead>
<tr>
<th>Punch shape</th>
<th>Max. misses stress</th>
<th>Max. plastic strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>589 MPa</td>
<td>0.390</td>
</tr>
<tr>
<td>Concave</td>
<td>556 MPa</td>
<td>0.405</td>
</tr>
<tr>
<td>shear</td>
<td>583 MPa</td>
<td>0.397</td>
</tr>
</tbody>
</table>

III. FINITE ELEMENT METHOD

A. Model for Simulation:
In present paper the model concerns the axisymmetric piercing. It is an explicit formulation of 2D process of piercing, done on the code of finite element calculation ANSYS. The explicit algorithms are the most used thanks to non-linearity encountered in the field of cutting, which might make diverge implicit algorithms. The aim is to simulate in a realistic way the operation of piercing. The operation studied in this paper is performed with a cylindrical punch. Given that the cut pieces are fairly simple geometries, the shapes are symmetrical revolution around an axis, loading and boundary conditions are also of revolution around this axis, it is possible to deal with the problem by adopting a hypothesis of axisymmetric.

B. Date for Simulation:
During the modeling and in order to be as close as possible to the operating conditions, we take into account the following aspects conducted a study on the finite element analysis of the piercing process in the automatic simulation of multi-stage forging processes. 1) The punch and die are supposed rigid; 2) The interface elements are defined by the type of sliding contact; 3) The material is described by an elastoplastic behavior law; 4) The process is considered as quasi-static; 5) The inertial effects are neglected.
C. Mesh Definition:
One of the most important steps for simulation by the finite element method is the meshing phase. The sensitivity of the numerical mesh is well known in calculating. In large deformations, this sensitivity is even more important because of the large loads applied. In piercing, the material undergoes great strain located in a small strip. A correct numerical description of mechanical phenomena occurring in this area requires the choice of small size elements.

D. Ductile Fracture Criterion:
Very many experimental studies have been conducted to establish ductile fracture criteria in order to calculate the formability limits of different materials. Among the various fracture criteria proposed, as shown in fig.3 it has been found that the criterion suggested by cockroft and latham predicts the most reasonable fracture strain in metal forming operations. This criterion states that fracture takes place when the following relation is satisfied:

$$c = \int_0^\varepsilon \left( \frac{\sigma^*}{\sigma} \right) d\varepsilon$$

Where $\sigma^*$ is the maximum principal tensile stress, $\varepsilon$ is the fracture strain, and $c$ is the material constant. The effective stress and effective strain are represented by $\bar{\sigma}$ and $\bar{\varepsilon}$ respectively.

IV. CONCLUSION
From review of above literature we can conclude the following points:
- For piercing process following are the important parameters such as Clearance, Tool wear, Sheet material and Thickness, Punch geometry, Heat treatment.
- The geometry, material of the punch and heat treatment plays vital role in failure of punch.
- Tonnage capacity of the press is important parameter for piercing and other sheet metal forming operations.
- Finite element method is very use full tool to determine failure of punch and die in piercing and other sheet metal forming operations.
- The objective for my PG dissertation is Compare failure of various shape of the punch by experimentation and Finite Element simulation.

REFERENCES