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Numerical prediction of punch wear in the context of blanking process of copper alloy thin sheet

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ABSTRACT: Through the study presented here, we want to identify how the simulation of the blanking process could reduce defects of production, improve punches life and assist in the progression and control of the process. This was carried out with using software LS-DYNA. Based on the results obtained by simulation of blanking operation in two dimensions, we can predict the evolution of the gradual wear of active parts of punch according to the number of press strokes; by developing a calculation algorithm based on the Archard law of wear.

Key words: Blanking, Numerical Simulation, Finite Element Method, Punch Wear.

1 INTRODUCTION

The numerical simulation is a domain in full alteration which gradually stands out as a separate productive tool. The simulation of blanking process, subject of this paper, is a typical example of this surge in numerical calculation technology in the industry in order to reduce costs and improve the process. The implementation of a numerical modeling of blanking process seems important to control aspects of this operation. The objective of this work is to develop a finite element approach for predicting the evolution of the punch wear according to the number of press strokes. It is about implementing a numerical modeling for blanking process of copper alloy thin sheet in 2D under software LS-DYNA and correctly predicting the evolution of the geometry of the punch.

2 MODELING OF WEAR IN BLANKING

The wear of the sharp elements in a blanking tool determines the productivity of the companies and the quality of the products. The wear corresponds to the progressive loss of material of the body active surface, as a result of the relative movement of another body on this surface. For a cutting punch, this means a change of the geometry of the sharp part. The blanking tools often show abrasive wear in

the contact area. The abrasive wear occurs most generally in the tools when the surface of the sheet contains hard particles, such as carbides or oxides. When the tools wear out, there is a district of their cutting edges leading to an increase of party edges rays. The main consequences for blanking are: Increased penetration to break, appearance of shape defects and quotation variations, increased roll-over depth, increased burr, degradation of the mechanical characteristics of the sheet material and increased effort to blanking

2.1 The Archard wear model

Possession of wear laws helps to predict the behaviour and life of a system. Several equations are based on the hypothesis that conventional material property will be important in the process of wear. An example of this type is presented by Archard [1, 2]. He established an experimental equation to estimate the volume of used material in the case of a sliding contact at a constant speed and very different hardness of materials. He used a cylindrical wiper on a disk. From this, he measured different dry-rubbing materials. He studied rough wiper's wear against a rough plan, and adopted the following hypothesis: the amplitude of roughness does not vary during the process and the area of contact remains the same.

The Archard equation is: $V=K \times F \times x$

Were V = wear volume, K = coefficient of wear (mm^2/N), F = the load applied to the contact and x = sliding distance. The coefficient of wear (K) itself varies with the other tribological parameters such as temperature, environment, nature of friction body, sliding velocity, normal charge... Its value is also linked to the nature of the wear.

3 NUMERICAL SIMULATION OF BLANKING

3.1 Model for simulation

The model proposed in this section concerns the axisymmetric blanking from sheet thickness 0.254mm. It is an explicit formulation of 2D process of blanking, done on the code of finite element calculation ANSYS / LS-DYNA [4]. The explicit algorithms are the most used thanks to non-linearity encountered in the field of cutting, which might make diverge implicit algorithms [3]. The aim is to simulate in a realistic way the operation of blanking. 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 (Fig. 1).

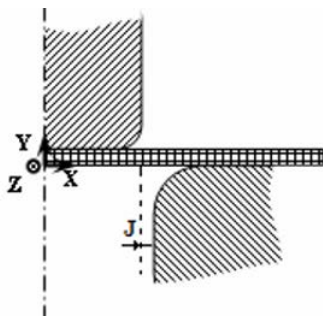


Fig. 1. Geometry of the simulation model

3.2 Getting data for the simulation

During the modeling and in order to be as close as possible to the operating conditions, we take into account the following aspects [1]:

- The punch and die are supposed rigid
- The interface elements are defined by the type of sliding contact
- The material is described by a elastoplastic behaviour law
- The process is considered as quasi-static
- The inertial effects are neglected

- The wear of tools is taken into account using the model of Archard.

The mechanical properties of the sheet [5] are summarized in the following table.

Table1. Mechanical properties of sheet metal

Size	Value
Young modulus (E)	99500 MPa
Poisson ratio (ν)	0.31
Yield strength (σ)	199 MPa

The geometric parameters of the sheet and tools used in the simulation are represented in this table.

Table2. Geometric characteristics of tools and sheet metal

Size	Value
Sheet thickness	0.254mm
Sheet width	15mm
Diameter edge of punch	0.05mm
Diameter edge of die	0.05mm
Clearance punch - matrix	20 μm
Angle end of the punch	0°
Punch diameter	3.7mm

3.3 Mesh definition

One of the most important steps for simulation by the finite element method is the meshing phase.

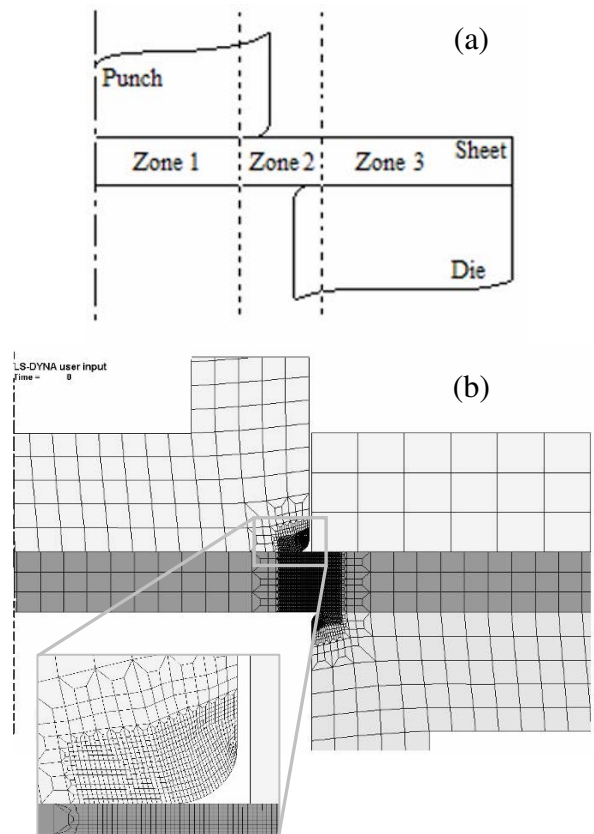


Fig. 2. (a and b) Decomposition of the mesh into three zones.

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 blanking, the material undergoes great rate of strain located in a small strip. A correct numerical description of mechanical phenomena occurring in this area requires the choice of small size elements. In order to set the mesh size, we can separate the sheet into three distinct areas (fig. 2). Zones 1 and 3 may be meshed grossly because the deformations are limited to it. The size of the mesh is of the order of 0.09mm. While the meshing of the zone 2 must be clearly refined, it is of the order of 0.003mm. For the choice of the element type, an initial meshing, consisted of elements quadrangles axisymmetric in 4 knots, was used.

3.4 Boundary conditions

Regarding the boundary conditions, the die and the blank-holder are blocked in rotation and translation. For the punch, only the vertical translation is allowed.

4 IMPLEMENTATION OF THE WEAR CRITERION

4.1 Sliding distance

The method that is used is the determination of wear with the Archard law. First, this is realized with the sliding distance (x) calculation of each node, this calculation is realized between two increments of time from the results of node displacement which come from the simulation. The second step is the determination of the normal effort in each node in the contact between the punch and sheet metal. The calculation of node sliding between two increments is done in the following way (fig.3.):

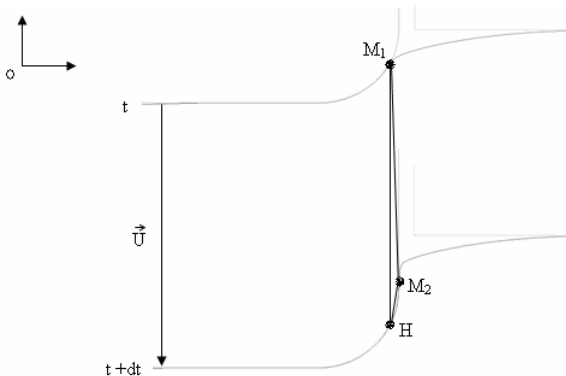


Fig. 3. Sliding between two increments

At the moment (t): the node M_1 is considered belong to the sheet metal and to the punch.

At the moment (t+dt): geometric point M_1 becomes:
- M_2 , which belongs to the sheet metal.
- and the H point, which belongs to the punch.

On the other hand, (\bar{U}) represents punch penetration between the two increments of time (t) and (t+dt).

The hypothesis put forward in this context is to consider the distance between the two points (H) and (M_2) as the sliding distance with a given length of metal faced to a punch node. Thus, for all the nodes in contact between the sheet metal and the punch, we have the following data (fig.3):

$$\overrightarrow{OM_1} = \begin{bmatrix} X_1 \\ Y_1 \end{bmatrix} \quad \overrightarrow{OM_2} = \begin{bmatrix} X_2 \\ Y_2 \end{bmatrix} \quad \bar{U} = \begin{bmatrix} 0 \\ Y \end{bmatrix} \quad \text{with } \overrightarrow{M_1H} = \bar{U}$$

And: (X_1, Y_1, X_2, Y_2 and Y) Known data.

$$\text{Hence: } \begin{cases} \overrightarrow{OH} = \overrightarrow{OM_1} + \overrightarrow{M_1H} = \overrightarrow{OM_1} + \bar{U} \\ \text{So: } \overrightarrow{OH} = \begin{bmatrix} X_1 \\ Y_1 + Y \end{bmatrix} \end{cases}$$

$$\text{Finally: } \overrightarrow{HM_2} = \begin{bmatrix} X_2 - X_1 \\ Y_2 - (Y_1 + Y) \end{bmatrix}$$

So the sliding distance (x) is given by:

$$x = \|\overrightarrow{HM_2}\| = \sqrt{(X_2 - X_1)^2 + (Y_2 - (Y_1 + Y))^2}$$

4.2 Normal effort

The determination of the normal effort in each node in the contact between the punch and the sheet was geometrically studied, as well as the sliding distance. Thus, we proceeded in the following manner (fig.4):

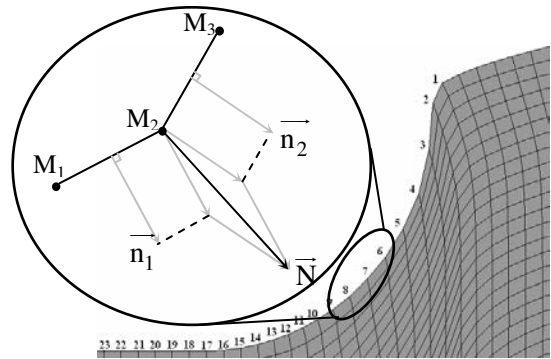


Fig. 4. Normal effort at the nodes

In figure 4 (M_1M_2) and (M_2M_3) represent elements between two successive nodes. (\bar{n}_1) and (\bar{n}_2) are

two normal unit vectors of (M_1M_2) and (M_2M_3) .

$$\overrightarrow{M_1M_2} = \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}; \overrightarrow{M_2M_3} = \begin{pmatrix} x_2 \\ y_2 \end{pmatrix}$$

$$\text{So: } \overrightarrow{M_1M_2} \cdot \vec{n}_1 = 0 \Rightarrow \begin{pmatrix} x_1 \\ y_1 \end{pmatrix} \cdot \begin{pmatrix} n_{1x} \\ n_{1y} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\text{Hence: } \begin{cases} x_1 \cdot n_{1x} + y_1 \cdot n_{1y} = 0 \\ \|\vec{n}_1\| = \sqrt{n_{1x}^2 + n_{1y}^2} = 1 \end{cases} \Rightarrow \vec{n}_1 = \begin{pmatrix} n_{1x} \\ n_{1y} \end{pmatrix}$$

$$\text{And: } \overrightarrow{M_2M_3} \cdot \vec{n}_2 = 0 \Rightarrow \begin{pmatrix} x_2 \\ y_2 \end{pmatrix} \cdot \begin{pmatrix} n_{2x} \\ n_{2y} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\text{Hence: } \begin{cases} x_2 \cdot n_{2x} + y_2 \cdot n_{2y} = 0 \\ \|\vec{n}_2\| = \sqrt{n_{2x}^2 + n_{2y}^2} = 1 \end{cases} \Rightarrow \vec{n}_2 = \begin{pmatrix} n_{2x} \\ n_{2y} \end{pmatrix}$$

$$\text{Finally: } \vec{N} = \vec{n}_1 + \vec{n}_2 \quad \vec{N} = \begin{pmatrix} N_x = n_{1x} + n_{2x} \\ N_y = n_{1y} + n_{2y} \end{pmatrix}$$

$$\vec{n} \text{ Unit vector of } \vec{N}; \text{ so: } \vec{n} = \frac{\vec{N}}{\|\vec{N}\|} = \begin{pmatrix} n_1 \\ n_2 \end{pmatrix}$$

$$F \text{ is the force measured to each node as: } \vec{F} = \begin{pmatrix} F_x \\ F_y \end{pmatrix}$$

So, the efforts at each point are calculated by using the following equation: $F_n = \vec{F} \cdot \vec{n}$

4.3 Remark

The next work aim an experimental study to identify the coefficient (K), and integrated by following an incremental form of the Archard law, to establish a relationship giving the volume of punch wear at all increments of penetration.

5 RESULTS AND CONCLUSIONS

Preliminary results show the mesh distortion in the band shear and a loss of contact after a few depths of penetration. Figure 5 shows the distribution of Von Mises equivalent stress for two different penetrations, we can see there is a loss of contact between the punch and sheet metal, for a penetration of 0.217mm, representing about 85% of thickness of the sheet metal.

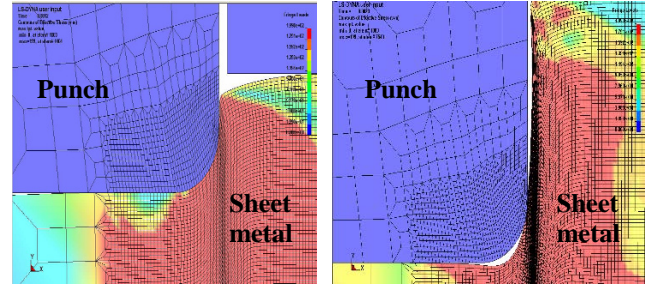


Fig. 5. Distribution of Von Mises equivalent stress.
(a) 0.07mm penetration and (b) 0.217mm penetration

The calculation of nodes sliding between two increments shows that the rate of displacement of nodes in the shear zone is more important than other nodes (Fig. 6).

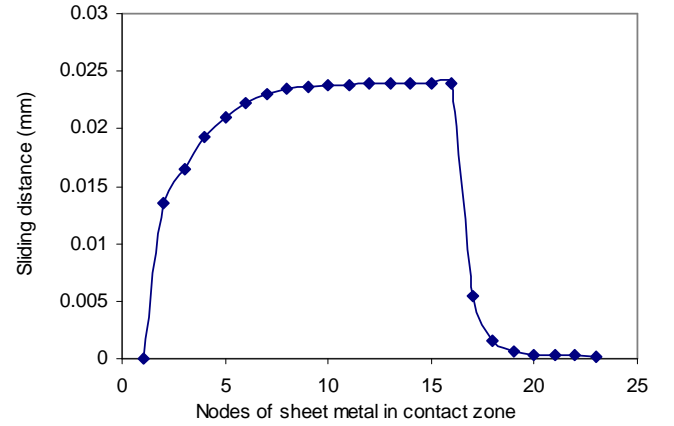


Fig. 6. Sliding distance of nodes in the contact

Currently we are working on improving the contact to get closer to the behaviour during blanking. In another, we plan experience to evaluate the empirical parameter (K) for materials used.

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