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NUMERICAL SIMULATION OF THE SHEET METAL BLANKING PROCESS

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Summary. *The purpose of this communication is to present the main parts of a numerical tool developed to simulate the blanking process and predict the geometric and mechanical characteristics of the blanked component. A damage modelling or fracture criterion could be used to predict the crack initiation. Then a finite element separation method, denoted discrete cracking approach is adopted to describe the crack propagation. Finally, the numerical results are compared to the experimental one.*

1 INTRODUCTION

The blanking of sheet metal parts is a widely used process in industry for mass production. In many cases the adjustment and control of the technological parameters are still based on empirical rules and know-how of designers. Currently, the industrial requirements need to produce at a reduced cost smaller components made of new or unusual materials with high controlled geometry. A more scientifc approach is necessary. So a numerical finite element approach has been developed in our laboratory. The mechanical modelling is based on a full analysis of the material behaviour during blanking, from the elastic deformation to the complete rupture of the sheet. Strain rate and thermal sensitivities of the material are taken into account by means of a thermo-elasto-viscoplastic model in an adiabatic context. Considering quasi-static conditions, the modelling is formulated in a finite element framework in large strains. An implicit algorithm based on Newton-Raphson scheme is used to solve the non linear equilibrium and the constitutive equations. A uncoupled approach by fracture or damage criteria and a coupled approach by Gurson and Lemaître models are incorporated to describe the damage mechnism and predict the crack initiation. The large strain localization between die and punch corners needs an automatic remeshing procedure for the whole piece during deformation. A numerical propagation approach[1] is proposed, slightly different of the discrete cracking approach[2], in which the direction and the intensity of the fracture propagation are obtained by examination of the local damage variable in the vicinity of the crack tip. Then a new node corresponding to the updating of the crack tip position is added to the contour of the mesh and a remeshing process is applied. This method provides better results in terms of cut edge profile estimation and mesh sensitivity than the classical element elimination method.

A FEM code untitled "BLANKFORM" has been developed, is dedicated to the numerical simulation of 2D and axisymmetric blanking problems[1]. A small part of the capacity of this software is illustrated through the simulation of a axisymmetric blanking test.

2 FINITE ELEMENT SIMULATION

2.1 Blanking test description

The geometry and the initial mesh of the sheet are shown in figure 1a. Due to the axial symmetry, only one half of the problem is analysed. The punch is on the upper left side, while die and blank-holder are respectively on the lower and upper right side. Figure 1b presents a zoom in on the finite element mesh in the working area between punch and die corners.

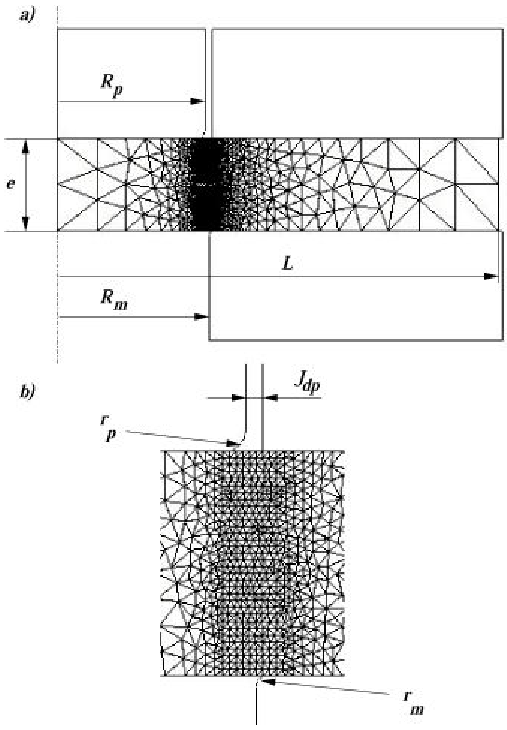

Figure 1: Modelling of an axisymmetric blanking test ; a) geometry and initial FE mesh ; b) enlargement of the shearing zone.

The main geometrical and material characteristics of the test are summarized in table 1. For the simulation, die, punch and blank-holder are considered as rigid body and only represented by their contour lines. Sliding contact conditions are assumed between the tools and the sheet. The FE initial mesh used is made up of 1342 triangular elements with 6 nodes and 6 integration points. In the shearing zone, the mesh size is kept to 0.075 mm. An automatic remeshing procedure of the whole piece is used during all the simulation.

Parameter	Size (in mm)
Punch radius, R_p	4.0
Die radius, R_m	4.125
Punch cutting edge radius, r_p	0.225
Die cutting edge radius, r_m	0.15
Sheet thickness, e	2.5
Punch-blankholder clearance, J_{dp}	0.2
Length, L	12.0
XES steel properties	Value
Young's modulus, E	210000 MPa
Poisson's ratio, ν	0.29
Initial yield stress, σ_y	150 MPa
Material constant, k	448 MPa
Strain hardening, n	0.406

Table 1 : Geometrical and mechanical characteristics of the blanking test

The considered material is an XES steel. The mechanical properties are given in table 1. Considering the punch speed for the experiments (5 mm/min), the thermal and viscous effects are neglected. The material behaviour is elasto-plastic and the effective stress σ_0 obeys the following non-linear strain-hardening law :

$$\sigma_0 = \sigma_y + k\,(\varepsilon_{eq}^{p})^n \tag{2}$$

The critical damage value D_C of the material related to fracture criterion has been identified by an inverse method which consists in comparing the measurement of the cut edge profile and the numerical prediction of this one. Here a value of 1.36 has been obtained for D_C.

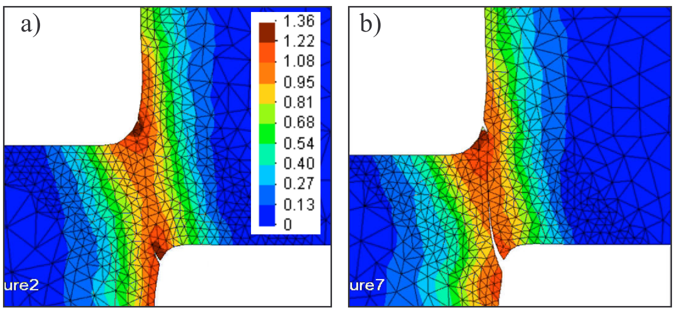

Figure 2: Distributions of the damage variable D ; a) initiation of a first crack ; b) initiation of a second crack

2.2 Numerical results

Figure 2a illustrates the evolution of the damage field during the crack propagation with discrete cracking approach. It can be seen (figure 2a) that at a punch penetration of 76% a first crack is initiating near the die corner, then a second crack is appearing on the punch side (figure 2b). Finally, the two cracks are propagating quickly to one another in a realistic way. As shown in figure 3, the experimental load-displacement punch curve and the numerical one are identical up to a displacement of 0.5 mm. The crack initiation is correctly predicted at 2 mm of punch penetration. The overvaluation of the punch load before the crack initiation can be reduced by using a coupled approach of the constitutive equations which takes into account the decreasing of the mechanical properties due to the damage during the plastic deformation.

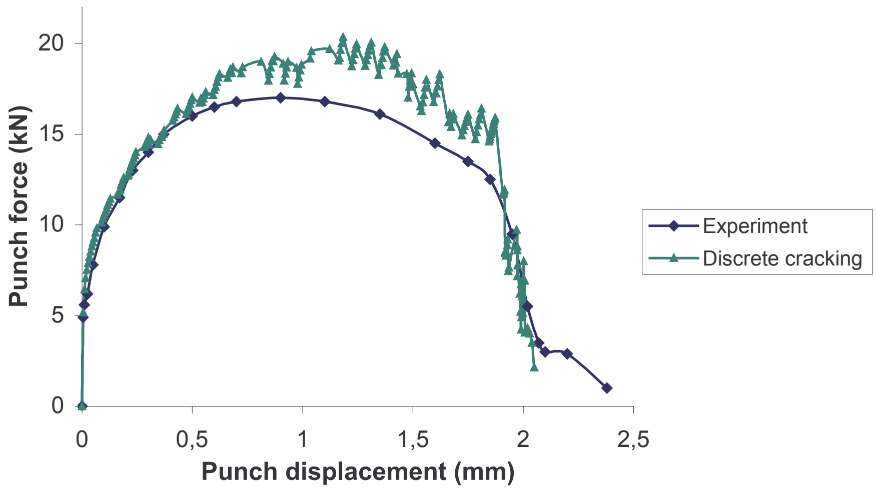

Figure 3: Comparison between the experimental and numerical load-displacement punch curves

4 CONCLUSION

A finite element software has been developed in order to help blanking operators to adjust and control the technological parameters of the process and obtain a final part with the desired geometrical and mechanical characteristics. That scientific approach allows manufacturers to reduce their experimental and development costs.

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