Formability Analysis of Aluminum Based Alloy By Using Finite Element Method

V.P. Srinivasan[1], S. Balamurugan[2]
[1, 2] Assistant Professor
[1, 2] Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India. Pin: 641008

Abstract- *The formability analysis of an aluminum-based alloy 8011 sheet is carried in this work. Erichsen test is carried out and they are simulated by the axisymmetric finite element method. The effects of sheet thickness and frictional condition between the punch and sheet on formability is predicted and compared with the experimental results of the Erichsen test. The rate independent elasto plastic material is chosen as the material model. By considering the contact problem and applying the nonlinear finite element method, the dome height and stress and strain values for aluminum sheet are computed and compared with the experimental results. The results show that increasing sheet thickness the formability is increased. Also lubricant has shows significant effect on the formability.*

Keywords- Aluminum alloy 8011; Erichsen test; Erichsen index; Finite element method; elasto plastic model.

I. INTRODUCTION

Formability is the ability of the sheet metal to be stamped or formed without developing any failures, thus formability is not easily quantified as it depends on several interacting factors. All of such factors (material flow properties, ductility, die geometry, lubrication, sheet thickness etc.,)

Instabilities or defects limit useful shape changes during sheet metal forming. Puckering, wrinkling and tearing are some of common instabilities that can develop during sheet forming. Sheet tearing is the most common and important instability that can be observed under stretching conditions and usually takes place in regions that have thinned locally, i.e. in localized necks. It has been observed majority of industrial failures occur by splitting near to plane strain conditions.

The localized necking has been studied and characterized both by experimental and theoretical methods. Hill has predicted conditions for localized necking under conditions of negative minor strains under a biaxial state of stress. Marciniak and kuczynski have introduced an approach to predict localized necking under biaxial stretching conditions. Wagoner's research group has used finite element methods for the time to predict limit strains under biaxial stretching conditions. In their approach a more realistic finite defect was assumed to be present in the sheet.

In the present investigation the commercial finite element code ansys-lsdyna is used to model a Erichsen cupping test. Therefore in the present investigation a 3D simulation is performed to assess the effects of friction, thickness and geometry of die set on sheet formability in a hemispherical punch-stretching process.. A rate independent elastic plastic material that obeys vonmises plasticity is chosen as the material model. For isotropic hardening and associative flow rule will be considered

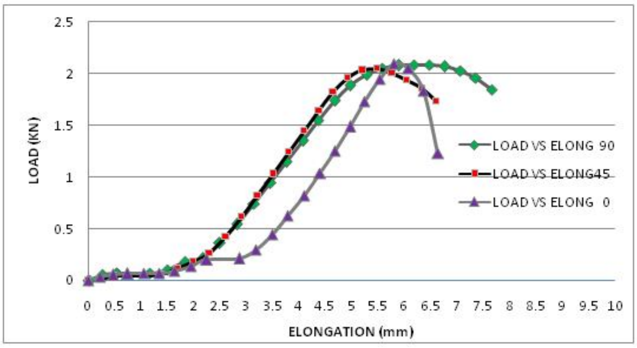

Fig. 1. Relationship between tensile load and elongation in uniaxial tension tests.

TABLE 1
TENSILE PROPERTIES OF MATERIAL

Tensile strength(Mpa)	114
Elongation (%)	4.91
Youngs modulus(Gpa)	69
Poisson's ratio	0.3
Yield strength(Mpa)	92
Tangent modulus(Gpa)	67

TABLE 2
R- VALUE MEASURED AT ROLLING, TRANSVERSE AND 45 DEGREES ORIENTATIONS

R0	R45	R90	Mean value
1.012	1.0004	1.0041	1.0062

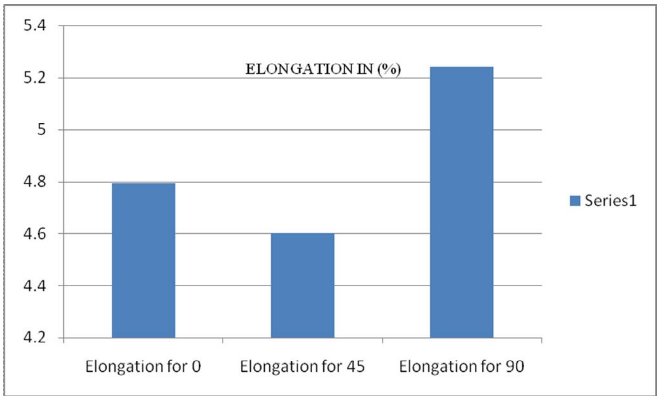

Fig. 2. Elongation level in rolling, transverse and 45^0.

II. EXPERIMENTAL AND ANALYTICAL PROCEDURES

2.1. Material

The material used in this study is a commercial aluminum based alloy 8011 sheet with a thickness of 1mm, 1.5mm, 2mm.

Uniaxial tension test were carried out in the direction of 0^0,45^0,90^0, to the rolling direction. The gauge length and width of the specimens were 50mm and 12.5mm respectively. The relationship between the tensile force and the elongation are shown in figure.1, note that the elongation in the 90^0 is quite small in comparison with that direction of 0^0 as well as 45^0.

R-value measured by using following formulae,
R=$\ln(W_o/W_{f)}/\ln(L_oW_o/L_fW_{f)}$
Mean value(**R**) =1/4(**R_0**+**R_{45}**+**R_{90}**)

2.2. Sheet Forming Test

The Erichsen test using a hemispherical punch with a diameter of 20mm to measure the formability of 8011aluminum sheets of 1mm, 1.5mm, 2mm thickness, respectively. Square specimens of 85×85mm were cut from the sheets. The specimens were stretched until either a macroscopic localization or a sudden reduction in force was observed. In this set-up the depth of the punch was measured as the Erichsen index (IE) to identify sheet formability. The schematic diagram of die set used in this test is shown in fig3.

Three kinds of lubrication consisting of; (1) dry (μ=0.3), (2) lubrication by grease (μ=0.21) were used in the test. Regarding the standard, we applied a minimum amount of blank holder force of 10KN on the specimen. The set of experiments were carried out considering the process parameters presented in Table 3.

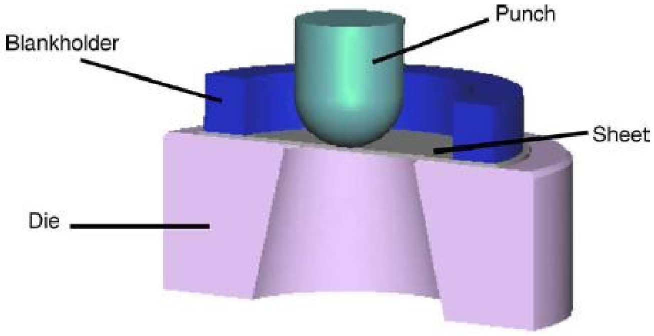

Fig. 3. Erichsen test: problem layout.

TABLE 3
ERICHSEN TEST PROCESS PARAMETERS

Cross section of the sheet	85×85mm
Initial thickness of the sheet	1mm,1.5mm,2mm
Punch diameter	20mm
Blank holder inner diameter	33mm
Blank holder force	10KN
Die inner diameter	27mm
Radius of curvature at the die shoulder	0.75mm

3) Finite Element Method

Finite element analysis is a simulation technique which evaluates the behavior of components, equipments and structures for various loading conditions including applied forces, pressures and temperatures. Finite element analysis is a computerized method for predicting how a real object will react to forces, heat, vibration, etc.

The commercial finite element code ansys-lsdyna is used to model an Erichsen cupping test. Therefore in the present investigation a 3D simulation is performed to assess the effects of friction, thickness and geometry of die set. A rate independent elasto plastic material that obeys vonmises plasticity is chosen as the material model. For isotropic hardening and associative flow rule will be considered.

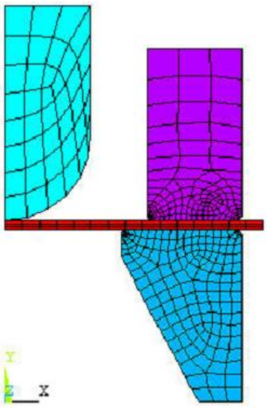

Fig. 4. Erichsen Cup Test Finite Element Mesh Model

All parts of the experiment setup were meshed using a 2D solid162 element, which has 4node and each node has a six degrees of freedom. The generated mesh is shown in figure4.

III. RESULTS AND DISCUSSION

The contour of vonmises stress and strain of the aluminum sheet(thick1mm) using grease as the lubricant between punch and sheet are shown in fig. 6a,6b respectively. As the contour show,the stress is monotonically raised from the die rim to the pole and accordingly the strain is increased towards the pole.Figure.6c exhibits the experimentally stretched specimen.As can be seen,the failure has occurred in the vicnity of the pole.The punch displacement was measured as the 8.55mm.The erichsen index was measured as the 8.46mm.It is observed that a good correlation exist between the experiment and fem results. The predicted strain and stress contour also indicates that the minimum of thickness and the maximum of stress have occurred in this region.

In fig.8 the time versus punch displacement curve is presented. It shows punch displacement for each time interval.

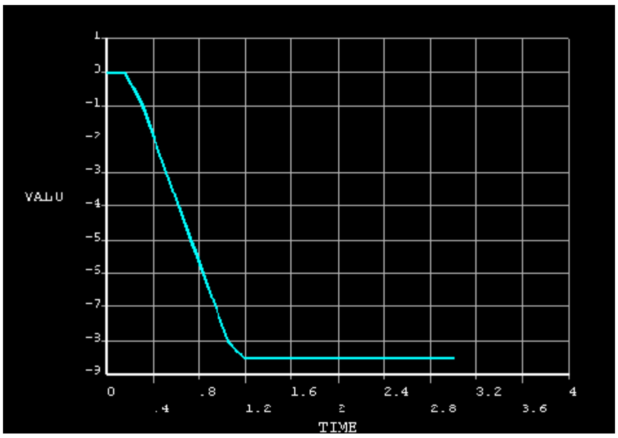

Fig.8.Time punch displacement curve for dry condition

To consider the effect of friction on the formability of the aluminium sheet, the nylon lubricant was also applied. Compared with the results presented for the nylon lubricant the stress and strain has slightly changed by changing the lubricant from grease to nylon.

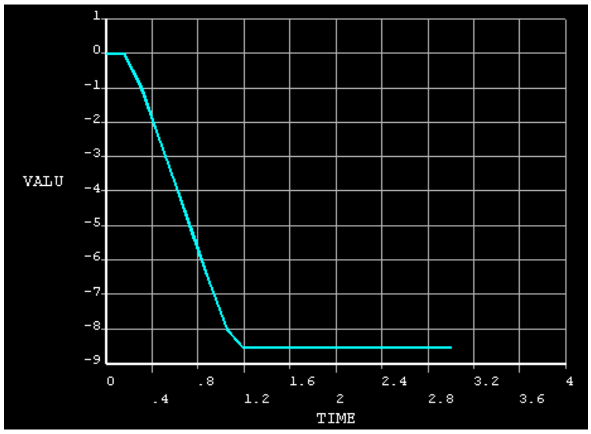

Fig.9.Time punch displacement curve for dry condition

In fig.9. the time versus punch displacement curve is presented for nylon lubricant. It shows that punch displacement for each time interval.

To further investigate the effect of friction, the erichsen test was conducted without any lubrication(dry condition). Figure5a,5b exhibits the predicted contours of the vonmises stress and strain of the sheet respectively.

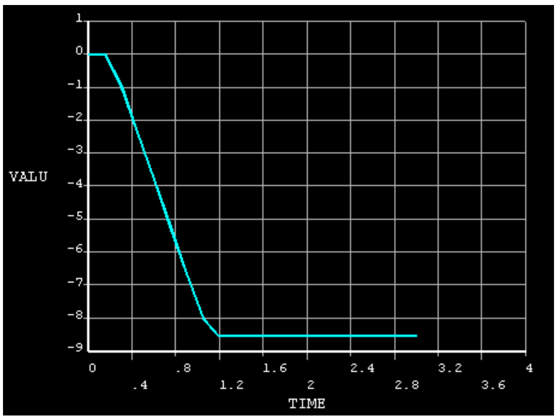

Fig.10.Time punch displacement curve for dry condition

As the contour show,the stress is monotonically raised from the die rim to the pole and accordingly the strain is increased towards the pole.Figure.5c exhibits the experimentally stretched specimen.As can be seen,the failurehas occurred in the vicnity of the pole.The punch displacement was measured as the 8.55mmThe erichsen index was measured as the 8.41mm.It is observed that a good correlation exist between the experiment and fem results.

In fig.10 the time versus punch displacement curve for dry condition is presented. It shows punch displacement for each time interval.

The contour of vonmises stress and strain of the aluminum sheet(thick2mm) using grease as the lubricant between punch and sheet are shown in fig. 12a,12b respectively.
As the contour show,the maximum stress present in the pole and accordingly the strain is increased towards the pole.Figure.12c exhibits the experimentally stretched specimen.As can be seen,the failure has occurred in the vicnity of the pole.

The punch displacement was measured as the 12.6mm.The erichsen index was measured as the 12.34mm.It is observed that a good correlation exist between the experiment and fem results. The predicted strain and stress contour also indicates that the minimum of thickness and the maximum of stress have occurred in this region. As the contour shows the formability is increased with increasing sheet thickness.

IV. CONCLUSIONS

In this study, the formabilityof aluminum based alloy 8011 sheet in fundamental forming process has been analyzed by the axisymmetric elastic-plastic finite element method. Calculations have been carried out for the Erichsen test, and the results have been compared with a experimental observations.

From the above analysis, the following conclusions can be drawn:

1. The strain distribution and limit dome height show excellent agreement with experimental data.
2. The formability is increased with increasing sheet thickness.
3. The lubricants used in this work showed a significant effect on formability.

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