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Effect of Ratio Mandrel Radius to Sheet Thickness on the Spring-Back in Bending Steel and Aluminum Sheets

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Abstract— ***Forming and forging processes are among the oldest and most important of materials-related technologies. Today, industry must continuously evaluate the costs of competitive materials and the operations necessary for converting each material into finished products. Manufacturing economy with no sacrifice in quality is paramount. Therefore, "precision" forming methods, net and near-net shape processing, and modern statistical and computer-based process design and control techniques are more important than ever.***

Bending is one of the important methods for manufacturing sheet metal components that is extensively applied in automotive industry and electronic devices. Spring-Back is an unavoidable phenomenon in sheet metal forming that occurs in the end of stamping process because of releasing elastic stress that results changing the final dimensions of sheet. So, Prediction of spring-back is essential for dimensional control of parts in the end of stamping process. In this project a finite element model is presented for simulation of U-bending process and also calculating the amount of spring-back. Comparison between finite element , numeral and experimental results is done for validating the finite element method.

Index Terms— ***Aluminum, Bending, Forging, Spring-back, Steel.***

I. INTRODUCTION

In the past the designer`s experience and trial and error method were used to reduce reversibility and to enhance dimensional accuracy of the product which cause increasing the time and cost of the tests [1]. In the past decades to predict the reversibility, a simple theory based on engineering assumptions were pure bending of a simple beam, was used. Hill to describe the mechanical characteristic, presented the non-isotropic plastysyth theory [2]. Leu provided a method for calculating the reversibility and flexibility anisotropic plastic metal sheets [3]. Today, the advances in numerical simulation techniques cause to predict the reversibility correctly. Finite element method can correctly predict reversibility of metal sheets [4]. Samuel used the finite element method to study the reversibility of three alloys of aluminum and steel sheets in the bending process [5].

In this study U-bending test is done on steel and aluminum plates to investigate the spring-back. Then the problem is solved based on the theory and then the process is modeled in Ansys. Finally the results of the experiments are compared with theoretical and FEM.

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II. THEORETICAL ANALYSIS

The relationships resulted from the rules of the bending are used to calculate the amount of the spring-back. Values of curvature ($\rho = r + \frac{t}{2}$) and bend angle (θ) are known and based on the geometric relations, we have:

$$\varepsilon_f = \frac{y}{\rho} = \frac{t/2}{\rho} \qquad (1)$$

Where Y is equal to dim the neutral sheet surface of the rectangular cross section of the sheet, this amount is equal to half the thickness. On the other hand the graphs of the stress - strain behavior of the two lines we will have:

$$\varepsilon_y = \frac{\sigma_y}{E} (for \sigma < \sigma_y)$$
$$\varepsilon = \frac{\sigma - \sigma_y}{E'} + \varepsilon_y (for \sigma > \sigma_y) \qquad (2)$$

Where E is elastic modulus in the first region and E' is elastic modulus in the second region. So:

$$y_y = \rho * \varepsilon_y \qquad (3)$$

The bending moment in the elastic region is:

$$M_{el} = \int_0^{y_y} E \frac{y}{\rho} ydy \qquad (4)$$

And the bending moment plastic region is:

$$M_{pl} = \int_{y_y}^{t/2} [\sigma_y + E'(\frac{y}{\rho} - \varepsilon_y)]ydy \qquad (5)$$

The bending moment of the sum of the bending moment in the elastic region and the plastic region of the bending moment is:

$$M = \int_0^{y_y} E \frac{y}{\rho} ydy + \int_{y_y}^{t/2} [\sigma_y + E'(\frac{y}{\rho} - \varepsilon_y)]ydy \qquad (6)$$

The spring-back tension is:

$$\sigma_{sb} = \frac{Mc}{I} \qquad (7)$$

And the spring-back strain is:

$$\varepsilon_{sb} = \frac{\sigma_{sb}}{E} \quad (8)$$

The total strain is outcomes of the engineering strain and spring-back strain:

$$\varepsilon' = \varepsilon_f - \varepsilon_s \quad (9)$$

And on the geometric relations, the radius of curvature of the bending operation (ρ') can be calculated:

$$\rho' = \frac{t/2}{\varepsilon'} \quad (10)$$

And the length of the string buffer before bending and after bending are equal and the assumption of constant thickness before and after bending:

$$\rho * \theta = \rho' * \theta' \quad (11)$$

So the angle of the bending (θ') can be calculated after the spring-back.
By entering the specification sheet and mandrel used in the experimental tests and procedures, the results obtained in the Fig.1 and Fig.2 are provided.

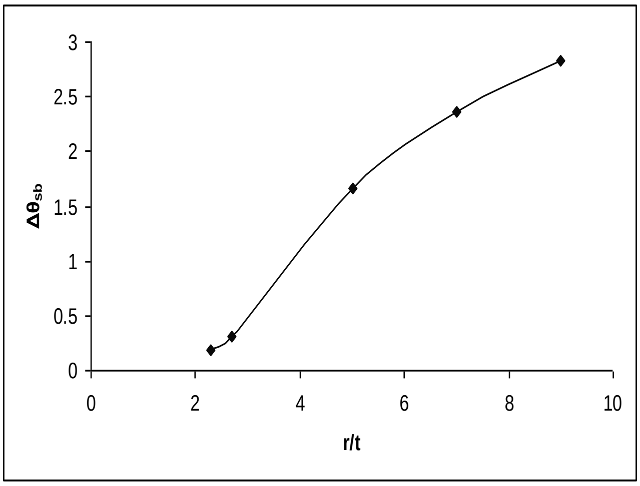

Fig.1: The results of spring-back analysis based on theory for steel sheets of experimental tests

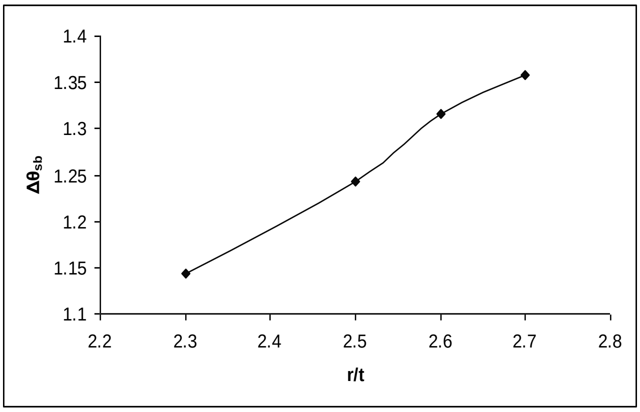

Fig.2: The results of spring-back analysis based on theory for aluminum sheets of experimental tests

III. FEM MODELING IN ANSYS

In geometric modeling, mandrel is modeled as a quadrant, the plate is modeled as a rectangular and the matrix is modeled as another rectangular that in the upper corner near the pines fillet. It is shown in Fig.3.

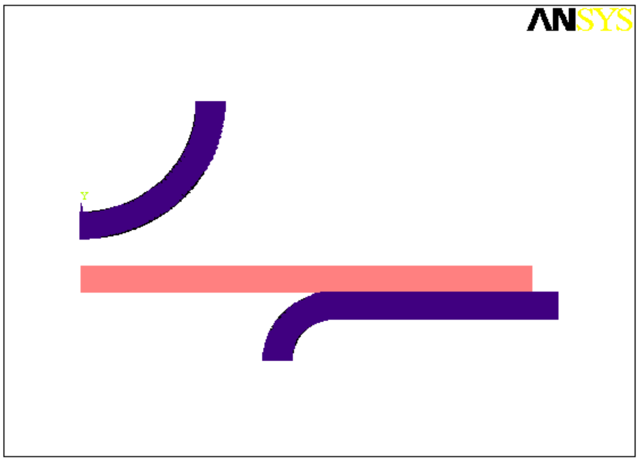

Fig.3: Geometric model of mandrel, sheet, and matrix

In this analysis the element shell 163 is selected. Selected material properties for the mandrel, matrix and plate are presented in Table (1).

Table 1: The properties of selected materials

Modulus of elasticity (Pa)	**Density** (kg/m^3)	**Material Type**	
200×10^9	7850	Rigid	Mandrel
200×10^9	7850	Rigid	Matrix
200×10^9	7850	Bilinear Isotropic	Steel sheet
69×10^9	4000	Bilinear Isotropic	Aluminum Sheet

IV. RESULTS AND DISCUSSION

The horizontal axis of the Fig.4 and Fig.5 indicates the mandrel radius to thickness ratio, and the vertical axis indicates the ratio of the spring-back. In this diagram, the spring-back ratio is the ratio of the final bend angle to initial bend angle. In all cases the initial bend angle equal to 90 degrees is considered.

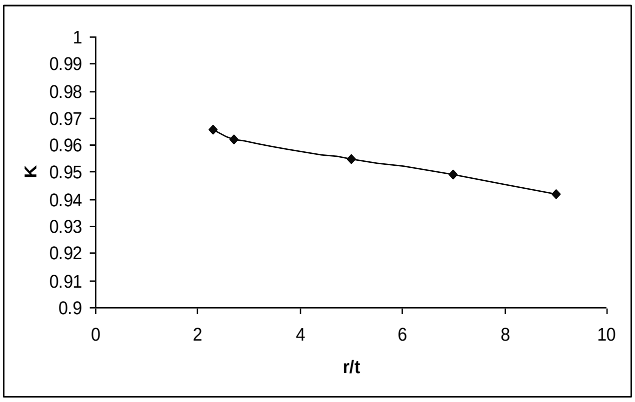

Fig.4: The effect of mandrel radius to thickness ratio on the spring-back ratio of steel sheet

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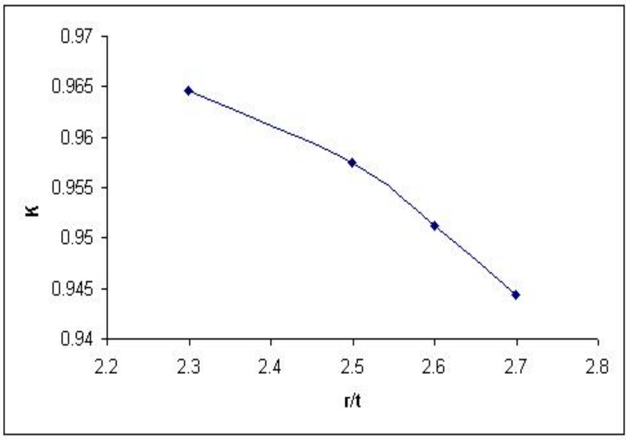

Fig.5: The effect of mandrel radius to thickness ratio on the spring-back ratio of aluminum sheet

The horizontal axis of the Fig.6 and Fig.7 indicates the mandrel radius to thickness ratio, and the vertical axis indicates the spring-back angle.

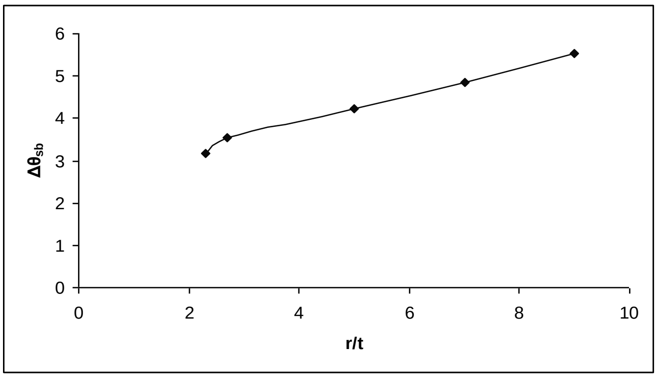

Fig.6: The effect of mandrel radius to thickness ratio on the spring-back angle of steel sheet

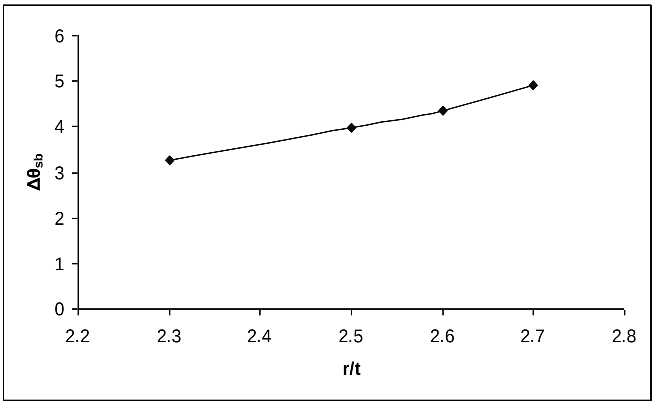

Fig.7: The effect of mandrel radius to thickness ratio on the spring-back angle of aluminum sheet

The Fig.4 and Fig.5 are observed with the increase of $\frac{r}{t}$, the spring-back ratio k is reduced. The Fig.6 and Fig.7 are observed with the increase of $\frac{r}{t}$, the spring-back angle k is increased.

In Fig.8 the overall similarity of the curves obtained from finite element analysis theory and with the results of the experiments can be found in the Handbook represents a general method of analysis is correct.

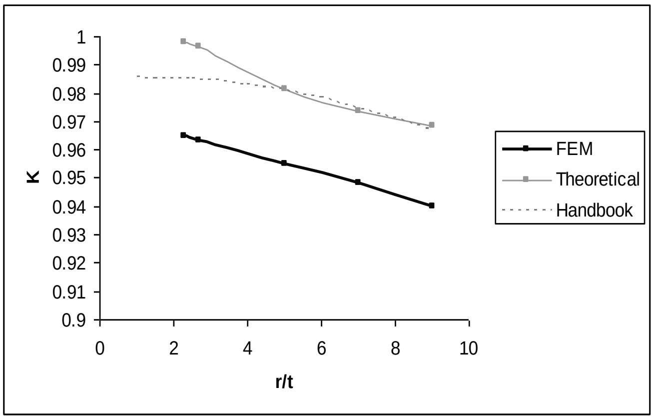

Fig.8: Comparing the results of theoretical analysis and finite element method for the Handbook of radius to thickness ratio of the spring-back of steel.

V. CONCLUSION

In addition, this study tested experimentally, using finite element analysis theory and methods to study the phenomenon of the spring-back Anlsys software to assist in bending sheet aluminum and steel were investigated. Was observed compared with the mandrel radius to thickness ratio of the return spring is inversely correlated with the angle of the spring-back and versely correlated with the spring-back ratio.

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