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Design of Flexible Tool for the Evaluation of Springback

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Abstract- Springback is the elastic recovery of a material when it is loaded into the plastic region and then unloaded. Springback is an implicit phenomenon in V-bending operation. This work presents the results of a systematic study of springback using different methods and considering different materials and angles. An adjustable V-bending die had been fabricated carefully to be capable of affording a wide range of angles (45~100 degrees approx.). The springback measuring algorithm has been programmed and uploaded into the Electronic Measuring Device (EMD) that is consisted of a circuit based on the Arduino platform. The results indicated a good agreement between the different methods especially the EMD which has better accuracy than ANSYS concerning the prediction of Springback.

Keywords- *Springback, V-bending Operation, Electronic Measuring Device (EMD), ANSYS*

I. INTRODUCTION

Several approaches had been made that are more basic than the preceding method were proposed to control the amount of springback and compensate for it. Some of these approaches iteratively adjust the die shape using a closed loop while the other needs to be handled in order to be adjusted. M.S. Buang, et.al. , 2015 [1], studied die and punch radii influence on the springback resulting from V-bending operation of stainless steel sheet metal. Trzepiecinski and Lemu, 2017 [2], explored the prediction of springback by numerical simulation and how it is affected by computational parameters. W. Fracz and F. Stachowicz, 2008 [3], investigated the springback occurrence in sheet metal V-air bending by means of numerical and experimental study. J. Slota, et.al. , 2017 [4], expressed a study on springback estimation of stretching process using finite element analysis FEA for DP/600 steel sheet. A. Behrouzi, et.al. , 2009 [5], stated an analytical approach for springback compensation regarding the process of channel forming. Sachin Kashid and Shailendra Kumar, 2012 [6], expressed the applications of artificial neural network ANN to predict the springback during sheet metal work. Muhamad S. Khan, et.al. , 2014 [7], proposed an Intelligent-Process Model IPM, originated on the data mining conception, for the purpose of forecasting sheet metal springback in the framework of forming. Young-Ho Seo, et.al. , 2014 [8], proposed a flexible die design and springback compensation based on adapted displacement-adjustment method. M. R. Abusrea, et.al. , 2015 [9], revealed a study on springback in multi-point discrete V-bending die. The usage of Multi-Point Discrete Dies (MPDD) for the purpose of Sheet metal forming is a forming scheme in which the die and punch are discretized by means of pins arrays leading to the flexibility of manufacturing and the capability to create more than one product with the usage of the same die. Se Yun Hwang, et.al. , 2010 [10], expressed a study on the compensation of springback by means of an adjustable tool for multi-point forming of shipbuilding thick plates. V. Paunoiu, et.al., 2009 [11], conducted a study on the compensation of a springback in a reconfigurable multipoint forming. Multi-point forming (MPF) is a flexible manufacturing technology that promises the fabrication of a variety of sheet metal parts geometry with low costs when compared to traditional, monolithic dies.

II. TOOLING DESIGN

In order to identify the traits of the Die and whether it can tolerate specific applying loads or not, an analysis based on a design criterion is carried out so as to characterize the as-built suggested die design that is shown in figure (1).

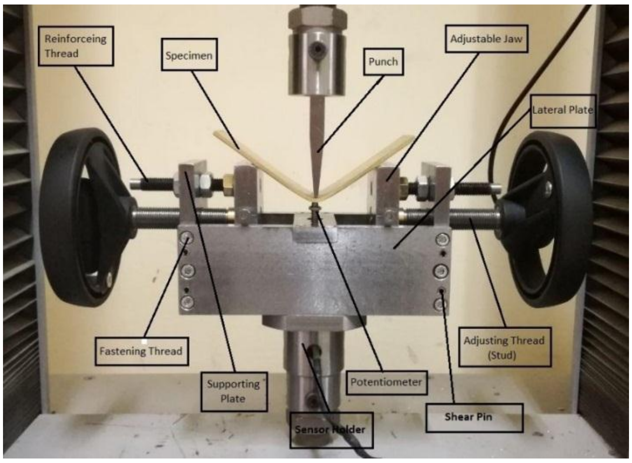

Figure 1. A detailed figure illustrates the components of the suggested design of punch and die.

The **"reinforcing stud"** threads at the diameter of the root (d_{root}) might shear owing to the axial-load (W). Supposing that the load is distributed uniformly over the contact threads, we will have:

Reinforcing stud shear stress,

$$\tau_{stud} = \frac{W}{\pi \cdot n \cdot d_{root} \cdot t} \quad (1)$$

Where;

n = Engaged threads number.

t= Thread thickness or width.

The direct stress resulting from the axial load can be calculated through dividing the axial-load (W) by the minimum area of the "Adjusting Stud" cross-section (Aroot) i.e. area matching the minor diameter (droot).

Direct Stress = W/Aroot (2)

However, when the screw is loaded axially by compression and the un-supported screw length between the load and nut is too large, as a result, the design should obey the column theory supposing suitable end conditions. In such cases, the area of the cross-section consistent to the core diameter possibly will be attained by using the formula of Rankin-Gordon. According to this:

$$\sigma_c = \frac{W}{A_{root}} \left[\frac{1}{1 - \frac{\sigma_y}{4.C.\pi^2.E} \cdot \left(\frac{L}{K}\right)^2} \right] \quad (3)$$

Where;

σy = Yield Stress, L= Screw length., K= Radius of Gyration., C= End-fixity coefficient., and

σc = Induced Stress owing to the load W.

A slight concern shows that when a beam has been exposed to a bending moment, the fibers of the beam on one side will be shortened owing to compression and those fibers on the other side will elongate as a result of tension. It may be perceived that somewhere between both sides of fibers there has been a surface at which the fibers have neither shortened nor elongated. This surface is known as the Neutral Surface. The bending equation has given by:

$$\sigma = y \cdot \frac{M}{I} \quad (4)$$

Where,

I = Cross-sectional moment of inertia about the neutral axis.

M = Bending moment acting at the given section.

y = Distance from the neutral axis to the ultimate fiber.

Sometimes, bolts have been used in order to stop the relative movement of two or more parts, such as a flange coupling, and then the shear stress has been prompted in the bolts. The shear stresses must be avoided as much as possible.

Let d = Bolts major diameter, and

n = the number of bolts.

Shearing load carried out by bolts,

$$P_s = \frac{\pi}{4} \cdot d^2 \cdot \tau \cdot n \quad (5)$$

III. Springback Evaluation Method

This article represents the method of springback calculation that is uploaded into the microcontroller. The terminology has been expressed obviously throughout the upcoming figures. Firstly, let's figure out the different parameters which are shown through figures (2) and (3):

V1 = the desired angle of the final shape.

L = V1 / 2

Q = 90 – L,

X/2 = [P / tan (Q)],

H/2 = [5-5 cos (L)],

P = 40 – I,

I = 5-5 cos (Q),

J = X + H,

W = J / 2,

$$T = \sqrt{P^2 + W^2} \quad (6)$$

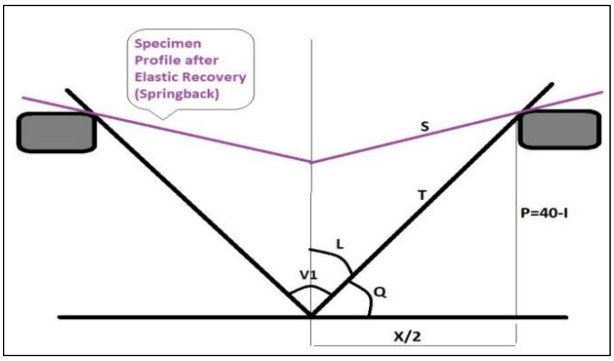

Figure 2. The specimen before and after springback.

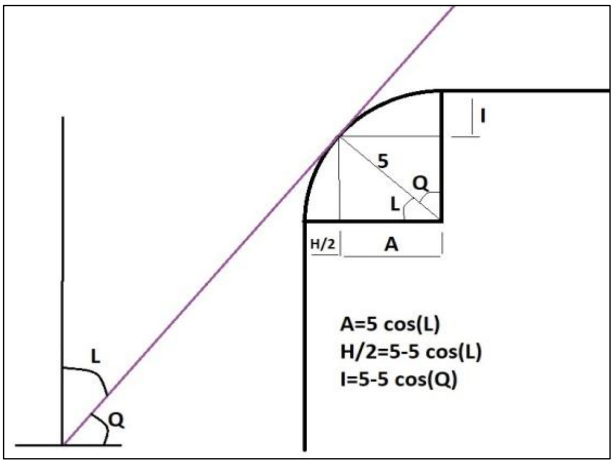

Figure 3. The effect of jaw fillet.

U = Serial data taken from the potentiometer signals which in turn will be converted to a displacement data by means of empirical formula.

$$D = \frac{U - 91.25}{63.176} \quad (7)$$

D has been formulated empirically through the conversion of potentiometer signals into a displacement unit. Figure (4) explain the way the displacement has been taken in the calculation.

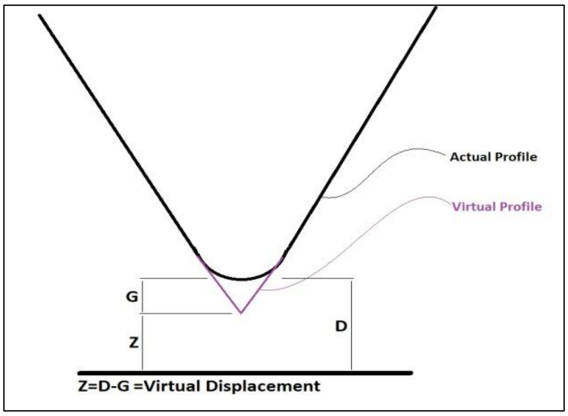

Figure 4. The idea of virtual displacement.

$$G = -0.38\, D^2 + 6.3\, D - 19 \quad (8)$$

$$Z = D - G \quad (9)$$

Z = virtual displacement that will be used throughout the coding.

Figure (5) represents the way the springback can be found in term of angles. To derive a formula for springback we have to trace the following:

$S = \sqrt{W^2 + (P - Z)^2}$,

sin(Q) = P / T,

sin(Alpha) = (P-Z) / S,

T sin(Q) = S sin(Alpha) + Z,

$Alpha = \sin^{-1}\left[\frac{T\sin(Q) - Z}{S}\right]$,

M = 90 – Alpha,

Measured Angle = 2M,

Springback Angle = 2M-V1 (10)

IV. Electronic Measuring Device (EMD)

A C++ based Arduino code dependent microcontroller type "UNO" had been used integrally with the following items which all together construct the EMD shown in figure (6). The EMD has 4 bottoms chosen to execute different tasks. These bottoms are (A, B, C and D). Each one of them represents a case lead to perform certain codes.

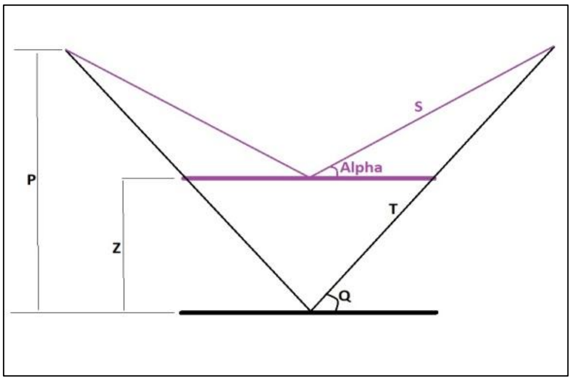

Figure 5. The concept of springback phenomena.

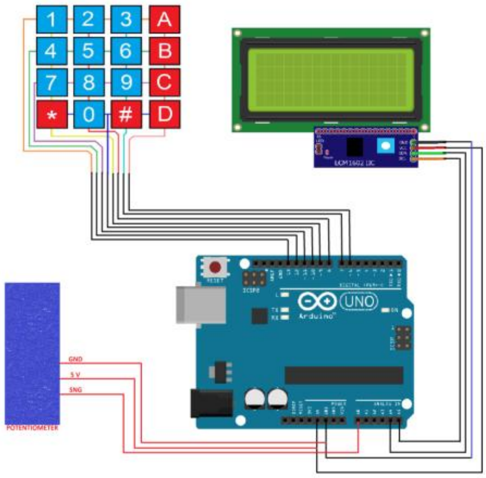

Figure 6. Internal Connections of (EMD).

V. Results And Discussion

The bending test EMD results for 4 different angles (60, 75, 90, and 100) and 2 different specimen materials (Al, Br) had been expressed and compared to those extracted numerically by ANSYS version (15) as well as to those measured using protractor.

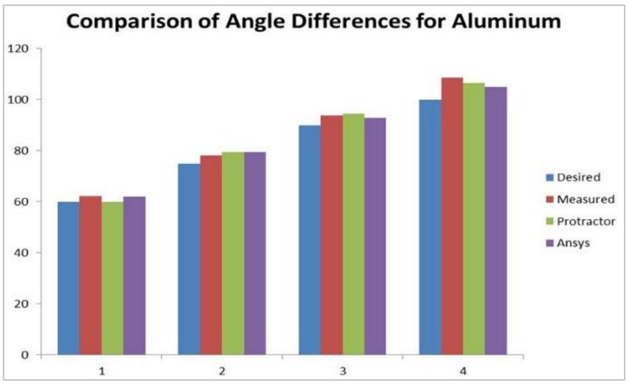

Figure 7. Comparison of Angle differences for Aluminum.

The data showed that Aluminum and Brass springback results for the different cases had a very good agreement with those extracted from the actual model. For more illustration see figures (7) and (8).

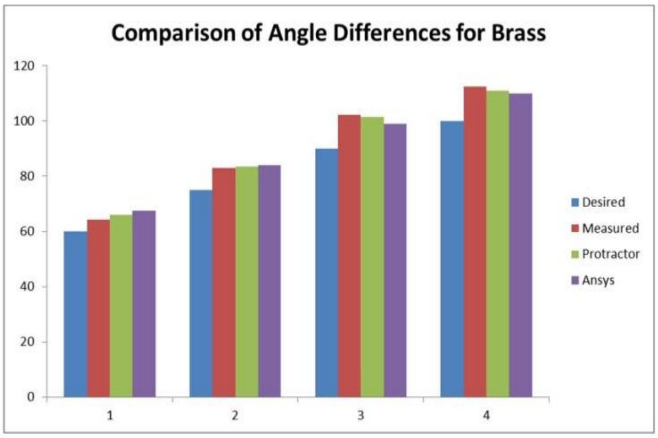

Figure 8. Comparison of Angle differences for Brass.

Figure (9) expresses the error averages for both materials as well as for both EMD and ANSYS data. The error average data endorses that the EMD had approved the springback predictions.

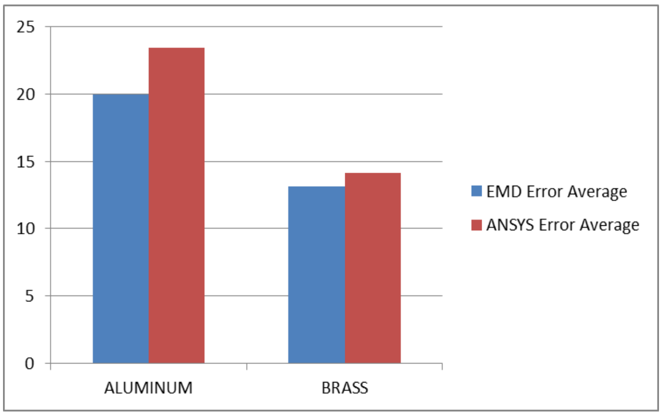

Figure 9. Error Averages for Aluminum and Brass.

Figure (10) demonstrates the meticulous conformity of both the result extracted from the numerical program and the result taking from the experimentations of a 90 degree V-shaped Brass specimen. In addition, the aforementioned figure explains the benefits of using the numerical analysis programs in simulating a process before the commencement of a prototype initiation. This absolutely will lead to a time saving as well as effort and cost.

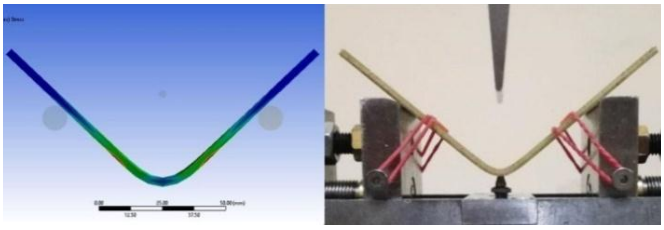

Figure 10. Actual and numerical result for a 90-degree V-shaped specimen.

The maximum applied load by the punch has been recorded by the TESTOMETRIC as (2750N) on a brass specimen at (60 degree) desired. The S.F for **reinforcing stud** is found to be (49) according to these conditions assuming that the material has an isotropic pattern. See figure (11).

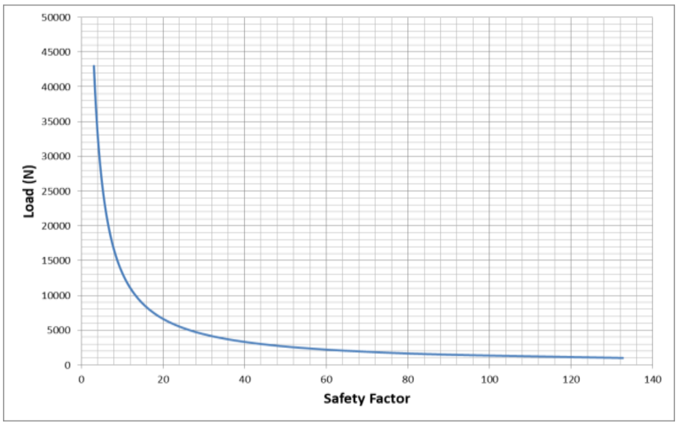

Figure 11. Safety Factor of Reinforcing Stud (49)

Considering the same conditions and the same load that is been applied by the punch will force the **supporting plate** to bend. The Factor of Safety for the supporting plate is found to be (3.1) as shown in figure (12).

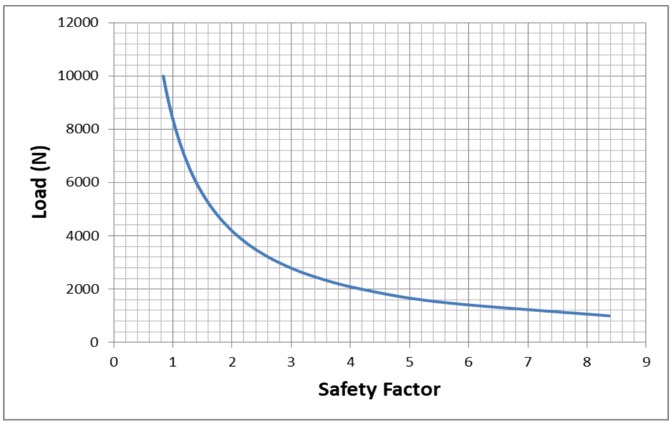

Figure 12. Safety Factor of Supporting Plate (3.1).

Figure (13) represents the safety factor curve for the **fastening threads**. By means of applying the same conditions that is going to shear the threads, the factor of safety regarding the fastening thread is found to be (7.3).

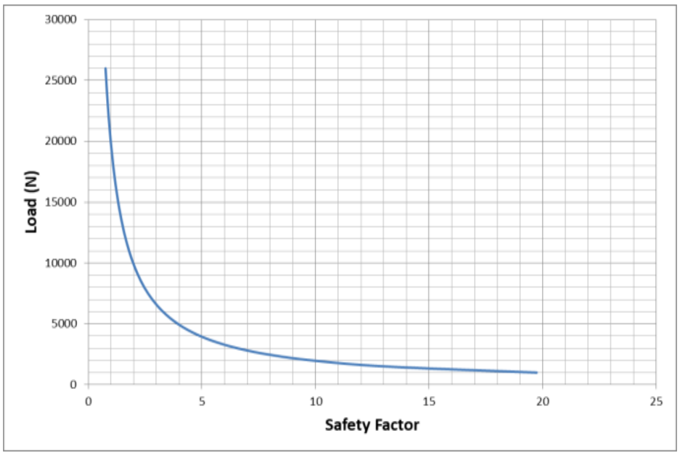

Figure 13. Safety Factor of Fastening Threads (7.3).

VI. CONCLUSIONS

Springback angles for Brass are bigger than that for Aluminum because Brass experiences a lower amount of plastic deformation than Aluminum for the same load exertion due to the high strength of Brass. The bigger the bending angles, the bigger the springback angles due to the least amount of plastic deformation in the area of stress formation that copes with the large bending angles in comparison with small bending angles. This work proves that the EMD has a good agreement with the actual data depending on the error calculations which state clearly that EMD has better predictions than ANSYS. The safety factor for the different parts of the die has shown a moderately good withstanding of the applied load. Moreover, the S.F. has been concluded depending on the maximum force applied on a Bronze specimen that is intended to be punched into a (60 degree) desired angle. The force maximum amount that is been applied by the TESTOMETRIC hydraulic device is found to be (2750N).

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