Experimental Investigation of Hold Time Effect on Springback in V-Bending Sheet Metal Forming Process

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Abstract. Springback is considered as one of the most common problems in metal forming processes, which poses an inaccuracy of product angle during assembling of parts. The estimation of the springback is difficult to predict for formed parts, since it depends on many factors such as the mechanical properties, the sheet thickness and the die angle. In this work, experimental investigation for different thickness and holding time have been studied and analysed. Samples of (Aluminium, brass, and C1004 Steel) specimens with 80 mm length, 50 mm width and 2, 3 and 6mm of thickness selected in this study. Using bending die with angle value (73° and 90°) pulled three pieces of each different holding times. Three pieces for each metals were hold with three times (2, 4, 6 minutes). The results show that in a given thickness configuration, the springback reduced with increasing of the punch hold time for all thicknesses selected.

1. Introduction
Springback considered inaccuracy in the dimension of the formed solid parts, this occurs after unloading as the elastic recovery of the part. Springback causes deviation from the designed target and causes difficulty through the assembly of the formed part. Generally, the elastic recovery after the unloading called a spring back phenomenon, this phenomenon related to many factors. In most researches, the materials exhibited to high springback after unloading have a lower elastic and high strength. In the same stat, the ratio of the width to thickness has an important influence on this phenomenon. In industries, springback considered an influencing phenomenon in tooling and process designs. Two main branches of springback research have conducted: effectively predict springback and to compensate for springback in tooling design [1].

M. A. Farsi and B. Arezoo (2011) experimentally study of the spring-back for low carbon steel sheet metal parts with rectangular cutting holes that located on the bending surfaces for V-dies. This work deals with many effective parameters on the springback, such as die angle, die width, punch radius, material thickness and the magnitude of cutting forces. The results have shown that the springback is the most important. They observed that the bending forces in the parts with and without holes are not similar [2]. A. H. Abed (2013) applied the TAGUCHI method to optimum bending parameters to reduce the springback of aluminium- silicon (Al- Si) alloy. The most important parameters used in this work are punch speed, holding time and material orientation. The experimental results exhibit that the significant factors are the orientation of metal, punch speed and holding time, respectively. Finally, the experimental results have a good agreement with that have selected in this case study [3].

G. Sharad, V. M. Nandedkar (2014) predicted the springback for two different materials by using finite element analysis for various die radii, sheet thicknesses, R/t ratios, and strength coefficients. The
neural network utilized to map the springback obtained from finite element analysis. The results obtained by FE simulations compared with the neural network shown a good agreement. [4].

D. AW and T. Gebresenbet T (2017) used a mathematical model to optimize the bending process. They considered many parameters that effect on the springback includes plate metal, plate thickness, tool radius, tool shape and friction during the bending process. Four types of metals have analysis, high strength steels, Aluminium, mild steel, and copper. Their results show that increasing of sheet metal thickness from 0.8 mm to 4.5 mm leads to reduce in the springback of about 16% and 20.35%. In addition, increasing of yield strength of the sheet metal leads to an increase in the springback [5]. İ. Karaağaç (2016) studied the influence of forming pressure, holding time and die angle on the springback, also experimentally investigated for V-bending using the flex forming process. Furthermore, a fuzzy logic system based on unexecuted break-test parameters used to predict springback behavior. The results found that decrease of springback when an increase holding time with 10 seconds for AL1050-0 and AL5754-0. They obvious that there were no forming defects on the part surfaces through the flex forming process [6].

A. Alhammadi, et al (2018) studied experimentally the springback phenomena for different materials and process parameters. Additionally, this work was dealing with loading time effect using the multistage bending technique (MBT). Artificial neural network (ANN) used to predict a springback according to experimental results [7]. J. Gattmah, et al (2019) studied a plate bending process using three-dimensional explicit finite element model for simulating the V shaped die bending process. Two materials have investigated of Hy-80 steel and 304 stainless steel plates at different punch radiusses and plate thicknesses. The results show that the springback is reduced when the punch radius decreases and plate thickness increases [8].

The main objective of this study is experimental investigation of V-bending process. Various parameters have studied and analysed which effect on the springback phenomena for three different metals (Aluminium, brass, and C1004 Steel), using two dies angles, material thickness and various holding time.

2. Experimental setup
Estimating springback value by performing a series of experiments has been the basis of this experimental investigation. In order to perform the experimental work V-die and rectangular sheet of 50 mm of width, (2, 3 and 6 mm) thickness and 80 mm of length for three different metals (Aluminium, brass, and C1004 Steel), as listed in tables 1, 2 and 3 respectively.

Table 1. The chemical composition for Aluminium

| Element | Composition |
|---------|-------------|
| Fe %    | 0.437       |
| Si %    | 0.124       |
| Mn %    | 0.129       |
| Cu %    | 0.026       |
| Mg %    | 0.004       |
| Al %    | Balance     |

Table 2. The chemical composition for Brass

| Element | Composition |
|---------|-------------|
| Zn %    | 40          |
| Cu %    | 60          |
| Element | Tested sheet | C1004 |
|---------|--------------|-------|
| C %     | 0.06 Max     | 0.047 |
| Cr %    | ….           | 0.0153|
| Cu %    | ….           | 0.032 |
| Mn %    | 0.25 Max     | 0.199 |
| Ni %    | ….           | 0.0104|
| P %     | 0.04 Max     | 0.013 |
| S %     | 0.04 Max     | ….   |
| Si %    | 0.35 Max     | 0.0175|

Instron tensile instrument (model WDW – 200 E) was used with V-die adapter to execute the experimental work for the specimens under V-bending with speed 50 mm/min and different holding time (2, 4, 6), as shown in Figure 1.

![Instron tensile instrument](image)

**Figure 1.** Experimental setup for the V-bending process

The die and punches used in V-shape are with angles 900 and 730 respectively, these dies designed under standard specification, they consist of two parts, typically punch and die both are made from CK45 as shown in figure 2. It additionally gives the parameters (hold time, die angle) for three different thicknesses to study their effect on springback. The punch downs at some point of the loading stage to form the require angle, and then the force is holding for a selected time. The test was performing for different times, and the effect of different hold time on the springback was once investigated.
3. Results and Discussion
The results have analysed from point of view about the effects of punch hold time and thickness of the specimen on the springback in V-bending process. In term of the punch force for various thickness with the same material, the load increases as the thickness changes to be increase. During bending of the specimen, both outside side and the inside of the specimen subjected to elastic stress. When the load reaches the yield point, then the specimen undergoes to plastic deformation and strain-hardening phenomenon. Unloading and removal the punch, the specimen has an elastic recovery. This phenomenon can attribute to the difference in the residual strain value between the tension in the lower surface and the compression in the lower surface of the specimen.

![V-Bending die](image1)

**Figure 2. V-Bending die**

![V-Bending die](image2)

**Figure 3. Load-displacement curves for different holding time and thickness of Al specimen (a) 2 mm, (b) 3 mm, and (c) 6 mm**
3.1. Influence of holding time effect
Holding time is another influence parameter that effect on metal springback. As increasing the holding time, the internal stress decreases and leads to a decrease in the elastic strain. This observed clearly in the Al specimen with different angles and thicknesses. Springback depends on the properties of materials such as Young’s modulus, strain hardening, yield strength and the plastic strain ratio. In the same bending conditions, the material that has a higher elastic modulus, the internal stress reduced and then the springback decreases as the material remains to keep more elastic recovery. The longer holding time can be reduce the springback with specimen thicknesses of 2 and 3mm. Differently, a specimen traces an opposite behavior with thickness of 6mm. Normally, the springback increases as the specimen thickness increases [9].

![Figure 4. Holding time effect on spring back of Al specimen](image)

3.2. Influence of die angle effect and material type
The springback factor was determined using the required design angle and the final angle as shown in figure 5 and according to the equation below:

\[
K = \frac{\alpha_f}{\alpha_i}
\]

Where:
K : springback factor
\(\alpha_f\) : final angle
\(\alpha_i\) : initial angle

![Figure 5. Springback phenomena](image)
The experimental setup and results for the three different metals (Aluminium, Brass, C1004 Steel) used in this work and the parameters studied (holding time, two dies angles 90°, 73°) are summarized and listed in table (4) and Figures (6, 7) respectively.

It was observed that increasing the springback as increases in die angle increased the values of stresses formed in bending processes.

### Table 1. Experimental conditions and springback results

| No | specimen  | Thickness (mm) | Speed (m/min) | Holding time (min) | Initial angle | Final angle | Springback factor |
|----|-----------|----------------|---------------|--------------------|--------------|-------------|------------------|
| 1  | Al        | 3              | 50            | 2                  | 90           | 96          | 1.066            |
| 2  | Brass     | 3              | 50            | 2                  | 90           | 100         | 1.111            |
| 3  | C1004 Steel | 3            | 50            | 2                  | 90           | 90          | 1                |
| 4  | Al        | 3              | 50            | 4                  | 90           | 94          | 1.044            |
| 5  | Brass     | 3              | 50            | 4                  | 90           | 92          | 1.022            |
| 6  | C1004 Steel | 3            | 50            | 4                  | 90           | 92          | 1.022            |
| 7  | Al        | 3              | 50            | 6                  | 90           | 95          | 1.055            |
| 8  | Brass     | 3              | 50            | 6                  | 90           | 93          | 1.033            |
| 9  | C1004 Steel | 3            | 50            | 6                  | 90           | 96          | 1.066            |
| 10 | Al        | 3              | 50            | 2                  | 73           | 76          | 1.041            |
| 11 | Brass     | 3              | 50            | 2                  | 73           | 81          | 1.109            |
| 12 | C1004 Steel | 3            | 50            | 2                  | 73           | 70          | 0.958            |
| 13 | Al        | 3              | 50            | 4                  | 73           | 76          | 1.041            |
| 14 | Brass     | 3              | 50            | 4                  | 73           | 82          | 1.123            |
| 15 | C1004 Steel | 3            | 50            | 4                  | 73           | 71          | 0.972            |
| 16 | Al        | 3              | 50            | 6                  | 73           | 77          | 1.054            |
| 17 | Brass     | 3              | 50            | 6                  | 73           | 80          | 1.095            |
| 18 | C1004 Steel | 3            | 50            | 6                  | 73           | 75          | 1.027            |

**Figure 6.** Holding time and springback at 90° Die
Other parameters influence on the springback that can be decrease the yield strength of sheet material. Increase the temperature can reduce the yield strength. Consequently, reduce the springback. In addition, subject the component to the tensile loading can be also reduced springback phenomenon.

4. Conclusions

In this work, experimental investigation of V-bending system implemented. The research dealt with many influencing parameters that have an impact effect on metal springback during many sheet metal forming process. From the outcomes above, it can acquire some of the essential conclusions:

1. The values of springback for all metals is increased except for some cases that are C1004 steel it stays the same at two minutes holding time with angle $90^\circ$, reduce at the holding time in $(2,4)$ minutes with angle $73^\circ$.
2. Increasing modulus of elasticity, of metals used in his work, lead to decrease the springback due to increasing the resistance to elastic bending.
3. The specimen thickness had an important influence on the punch load and springback.
4. The elastic recovery can attributed to the difference in the residual strain value between the tension in the lower surface and the compression in the lower surface of the specimen.
5. The strain hardening increased with longer holding time, the springback will reduced.
6. The maximum springback at Brass in holding time (4 min.) with $(73^\circ)$ angle die.
7. The minimum springback at C1004 steel in holding time (2 min.) with $(73^\circ)$ angle die.

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