International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-3 Issue-4, April 2014

Factors Affecting on Springback in Sheet Metal Bending: A Review

S B Chikalthankar, G D Belurkar, V M Nandedkar

Abstract-Spring-back is a very common and critical phenomenon in sheet metal forming operations, which is caused by the elastic redistribution of the internal stresses after the removal of deforming forces. Spring-back compensation is absolutely essential for the accurate geometry of sheet metal components.

This paper reviews the various parameters affecting spring back such as punch angle, grain direction of sheet metal material, die opening, ratio of die radius to sheet thickness, sheet thickness, punch radius, punch height, coining force, pre bend condition of strip etc.

Keywords: Bending, Die opening, Grain Direction Springback

I. INTRODUCTION

Springback refers to the elastic recovery of deformed parts. Springback occurs because of the elastic relief from the bending moment imparted to the sheet metal during forming [1]. Springback is common and inevitable in each stage of the production process where the material undergoes geometrical changes. Accordingly, factors related to the generation of stress in the material during loading and unloading processes influence the springback behavior of press-formed parts [2]. In every industry, quality and productivity are major issues for being competitive. For example, a car frame needs to be designed to achieve strength requirements and aesthetic aspects; on the other hand, cost of production and repeatability is crucial to the business. A stamping process has been one solution used in practice to achieve these goals in the sheet metal fabrication business. However, springback, a shape discrepancy between the fully loaded and unloaded configurations, undermines the stamping benefits, since a major effort on the tooling design is needed to compensate springback [3]. In many industries, e.g. automotive industries, springback plays an important role in tooling and process designs. Two main branches of springback research have been conducted: to effectively predict springback; and to compensate for springback in tooling design [4].

The aim of presented work is to discuss the various parameters affecting on spring back such as punch angle, grain direction of sheet metal material, die opening, ratio of die radius to sheet thickness, sheet thickness, punch radius, punch height, coining force, pre bend condition of strip etc.

Manuscript published on 30 April 2014.
* Correspondence Author (s)
S.B.Chikalthankar*, Department of Mechanical Engineering, Government College of Engineering, Aurangabad (M.S.), India
G.D.Belurkar, Department of Mechanical Engineering, Government College of Engineering, Aurangabad (M.S.), India
V.M.Nandedkar, Department of Production Engineering, SGGS Institute of Engineering & Technology, Nanded (M.S.), India

II. BENDING AND SPRINGBACK

In simple bending, a portion of the part is flexed along a straight line until a bend is obtained fig. (1). There are three types bending V bending, U bending and edge bending.

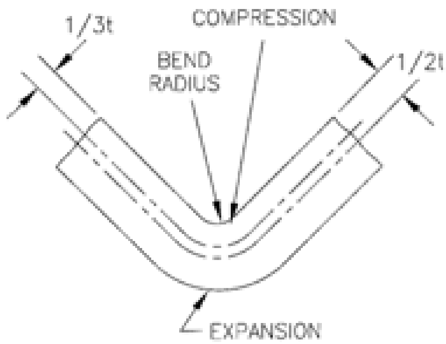

Fig. 1 Simple V bending

Every permanent deformation takes place after the changes in the material structure exceeded the maximum elastic limit of that material. However, this is not the final deformation achieved, as, after release of the applied forming pressure, the material makes an attempt to return to its previous location; we say it springs back. [5]

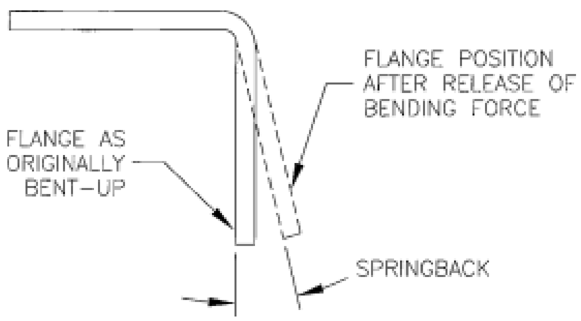

Fig.2 Springback of the bent-up flange.

III. LITERATURE REVIEW

A. Springback based on residual differential

H K Yi, [6] studied a model based on differential strains after relief from the maximum bending stress , derived for six different deformation patterns in order to predict spring back analytically.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The spring back for each deformation pattern is estimated by the residual differential strains between outer and inner surfaces after elastic recovery. Each of the six deformation patterns has a valid region of applicability, based on elastic modulus, yield strength, applied tension, and bending geometry. These patterns are elastic–elastic, plastic–elastic, and plastic–plastic for the outer and inner surfaces when $\sigma_0 / E \geq t / 2\rho$ and plastic–plastic with an elastic core, elastic–plastic, and plastic–plastic for the inner and outer surfaces when $t / 2\rho \geq \sigma_0 / E$. Analytical equations for the spring back of the sheet deformed under these six deformation patterns are derived. He has also studied traditional analytical models for spring back prediction based on elastic unloading from a bending moment. Traditional models also require the knowledge of the stress distribution through the thickness of the sheet, whereas the residual differential strain model only requires the stress state on the outer and inner surfaces of the sheet. He also compared the residual differential strain model with the traditional bending moment model for the same exact deformation patterns and compared results from the two models for various materials. Both models showed that spring back decreases with increased strip thickness and with decreased radius of curvature.

B. Effect of ratio of die radius and the sheet thickness on spring back angle

Aysun Egrisogut Tiryaki et al. [7] studied the effect of ratio of die radius and thickness of the sheet. Ratio of the die radius and thickness of the sheet verses spring back angle, are plotted as shown in the figure 3. It is observed that after certain level the spring back effect increases as the R/t ratio increases. In order to investigate the effect of die radius and blank thickness on the spring back angle of flanging process, the following strategy was employed. Two groups of FE simulation models are generated with the identical R/t ratio that range between 1.0 and 5.0. In this investigation, the first group the thickness is taken a constant and equal to 0.7 mm and the die radius is increased from 0.7 mm to 5.0 mm. In the second group the die radius is taken equal to 5 mm and the blank thickness is changed from 1.0 to 5.0. The material used in finite element simulation is High Strength Low Alloy (HSLA). The FE simulation response of spring back angle according to the determined sheet thickness and shoulder radius is reported. Also, using the result from the Case-G1 and Case-G2 of simulations, the graph of spring back angle against ratio of the die shoulder radius to sheet thickness is plotted, as shown in figure 3.

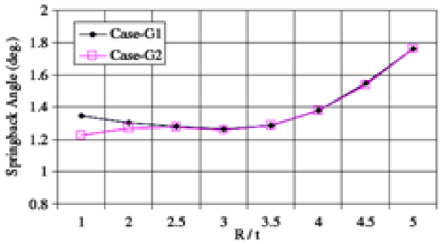

Fig. 3. Effect of R/t on Spring back.

C. Effect of Punch Height

The effect of punch height on V bending angle was examined in Ref. [8] using finite element model and results were validated through experiments. The FEM simulation results revealed that the effects of punch height on the bending angle were clearly theoretically clarified based on the material flow analysis and stress distribution. The punch height affected the gap between the workpiece and the die, as well as the reversed bending zone, which resulted in a non-required bending angle. Therefore, applying a suitable punch height created a balance of compensating the gap between the workpiece and the die, and the stress distribution on the bending allowance and the reversed bending zone. This resulted in achieving the required bending angle. He found that too-small punch height resulted into smaller bending angle than required. The application of a too-large punch height resulted in a large reversed bending zone and no gap formation between the workpiece and the die; therefore, the spring-go occurred. Thus, the obtained bending angle was smaller than the required bending angle. However, in the case of no gap formation between the workpiece and the die, if the stress distribution generated on the reversed bending zone was not suppressed, the stress distribution generated on the bending allowance zone caused the spring-back to occur. Thus, the obtained bending angle was larger than the required bending angle. Hence the conclusion was made, to obtain the required bending angle, the balance of compensating the gap between the workpiece and die and the stress distribution on the bending allowance and reversed bending zones was a vital necessity. Therefore, the required bending angle could be achieved by the application of a suitable punch height. In fig. (4) comparison of bending force between FEM simulation and experimentation for different punch heights is shown.

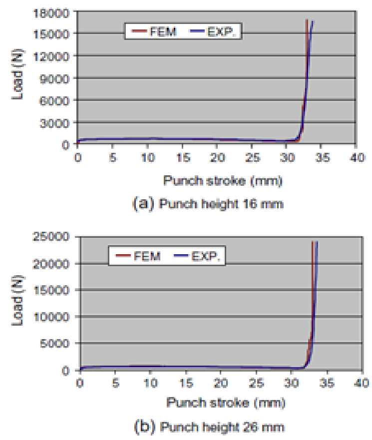

Fig. 4. Comparison of the bending force between FEM simulation and experiment

D. Effects of punch load

Process variables on V-die bending process of steel sheet were discussed in Ref.[9]. The investigation deals with a model which predicts the correct punch load for bending and the precise final shape of products after unloading, in relation to the tensile properties of the material and the geometry of tools.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The process variables are punch radius (R_p), die radius (R_d) punch width (W_p) punch speed (V_p), friction coefficient (μ), strain hardening exponent (n) and normal anisotropy (R). The investigation was carried out by performing some experiments and by finite-element simulation.

An elasto-plastic incremental finite-element computer code based on an updated Lagrangian formulation was developed to simulate the V-die bending process of sheet metal under the plane-strain condition. By performing some experiments and by finite-element simulation it was concluded that ; the punch load increases when one process variable, i.e. lubrication, punch radius or punch speed, increases or the strain hardening exponent decreases. When the die radius increases, the punch load increases in the early bending stage and then decreases during the final bending stage. When the punch width varies, the punch load is constant. When the normal anisotropy increases, the punch load slightly decreases. The influences of all of the process variables on the final bend angle of the bent parts of sheet after unloading were also evaluated. The effects of process variables except die radius on the bend angle after unloading were also limited. The angle of spring-back was found greater for tools with larger die radius. Fig 5 shows the experimental data and simulation springback after loading at different punch strokes.

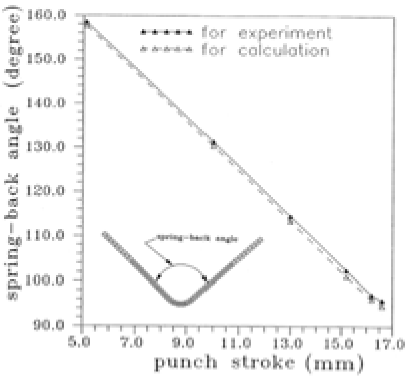

Fig. 5 Experimental data and simulation results of spring-back angle after unloading at different punch stroke in a V-bending process

E. Effect of punch radius, punch angle and die-lip radius

W.M. Chan [10] also focused on Finite element analysis of spring-back of V-bending sheet metal forming processes where he investigated spring-back in the V-bending metal forming process with one clamped end and one free end. Different die punch parameters such as punch radius, punch angle and die-lip radius were varied to study their effect on spring-back. Also, the effect of the punch displacement on spring-back was investigated. FEA simulation was done with the help of Softwares like Patran, Abaqus/Standard and Abaqus/CAE. Patran was used to model the nodes of the sheet metal and rigid surfaces of the die, pad and punch. Abaqus/Standard was used to simulate the punching process. The results were analyzed using Abaqus/CAE. The analysis showed that spring-back angle of the valley region decreases with increment of punch radius and punch angle. Spring-back is dependent on punch radius, punch angle and die-lip radius.

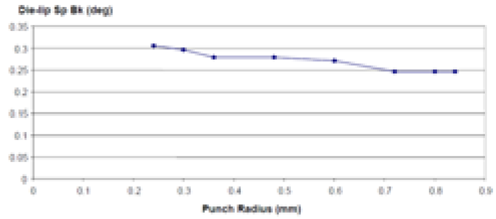

Fig. 6 die-lip spring-back vs. punch radius.

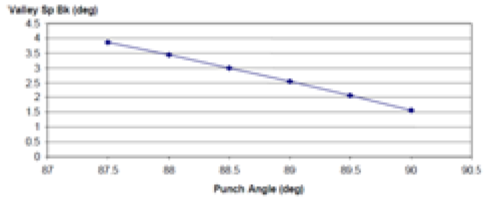

Fig. 7 valley spring-back vs. punch angle.

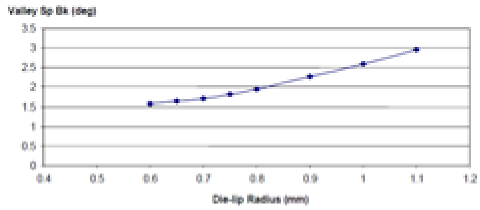

Fig. 8 die-lip spring-back vs. punch angle

F. Effect of bending angle, material thickness and punch radius Spring-back and Spring-go

Sutasn Thipprakmas and Wiriyakorn Phanitwong [11] used Taguchi technique for Process parameter design of spring-back and spring-go in V-bending process. Where three process parameters of bending angle, material thickness and punch radius were investigated. The finite element method (FEM), in association with the Taguchi and the analysis of variance (ANOVA) techniques, was also carried out to investigate the degree of importance of process parameters in V-bending process. It was found that the degree of importance of process parameters in V-bending process depended on the spring-back and spring-go. The material thickness has a major influence on the spring-back. In contrast, in the case of spring-go, the bending angle has a major influence and closely followed by the material thickness. In addition to predicting the degree of importance of process parameters by the combination of the FEM simulation, the Taguchi technique, and the ANOVA technique, by facilitating an improvement in the quality of the required bending angle was strictly considered by optimization of these process parameters corresponding with the spring-back and spring-go.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

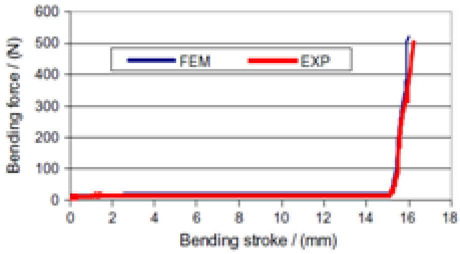

Fig. 9. Comparison of the bending force between FEM simulation and experimental results

G. Effects of punch profile radius and localized compression

In [12] effects of punch profile radius and localized compression on springback in v-bending of high strength steel were determined using Taguchi method. In the study an experimental investigation was carried out to determine the effect of punch corner radii on springback in free V- bending operation. The springback compensation was done by localized compressive stresses on bend curvature by the application of compressive load between punch and the die. In order to determine spring-back in V-bending operation, six numbers of ''V'' shaped dies and punches with required clearances were designed and fabricated with included angle of 90° for bending of high strength sheet metal with thicknesses: 0.85, 1.15 and 1.55mm. Keeping other parameters same increase in punch corner radius increases the springback and increase in sheet thickness reduces the springback. Springback compensation by localized compressive stress showed negligible springback and the same results were supported by FEA simulations.

H. Effect of sheet thickness on spring back

The effect the sheet thickness on spring back is shown in the figure 10. Here the comparison of the experimental and the FEM result is shown. It is seen that the spring back increases as the sheet thickness increases. The results of the FEM are obtained by using hyper form software with Ls-dyna as a solver and the experimental results are obtained on U shape bending machine [13].

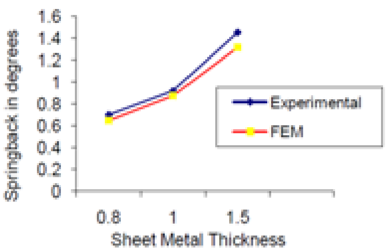

Fig. 10. Effect of Sheet thickness on Spring back.

I. Effect of punch angle, die opening, grain direction of sheet metal material and pre bend strip condition on springback on Deep Draw Steel (IS 1079-1994)

The effects of punch angle, die opening, grain direction of sheet metal material and pre bend strip condition on springback on deep draw steel (IS 1079-1994) are studied keeping all other affecting variable parameters constant.

The characteristics trends coming out from the initial experiments are represented as follows.

Fig. (11) shows the effect of punch angle on springback. It is observed that as punch angle is a very important variable parameter affecting on springback. Lower punch angle is creating lower plastic zone which tends to higher springback as compared to higher punch angle.

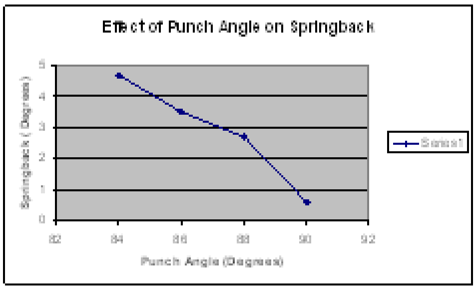

Fig.11 Effect of Punch angle on springback

Die opening has very significant effect on springback. Die opening of 8t, 12t, 16t and 20t were used. It is observed that the supporting flange area is increasing from lower die opening to higher die opening, which resulted on springback as shown in fig (12).

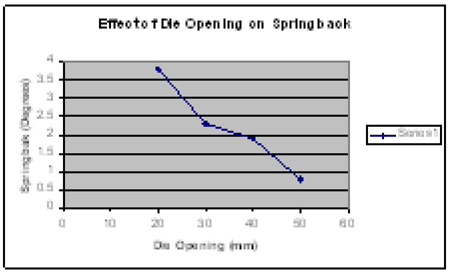

Fig.12 Effect of Die Opening on springback

Sheet metal with different grain direction is associated with different yield strength value. Sheet metal with 00, 450 and 900 were studied. Yield strength of the material also plays very important role on springback. From the results it is observed that there is gradual change on springback with respect to grain direction as shown in fig.(13).

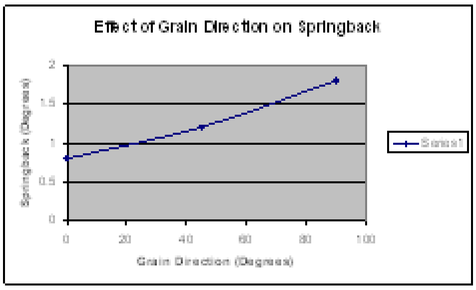

Fig.13 Effect of grain direction on springback

One important parameter which is investigated in this experiment is the pre bend strip condition. Strip condition means samples are taken from both sides i.e. tension side and compression side.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

One sample is taken from flat sheet. It has been observed that the pre bend condition of strip is also one of the prime factors which influences on springback. It was observed that springback is less for flat sheet. The residual stresses in pre bend strip showed more impact on springback as compared to flat strip.

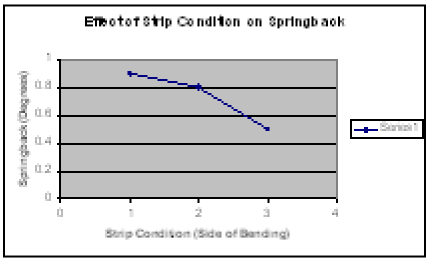

Fig.14 Effect of pre bend strip condition on springback

IV. CONCLUSIONS

Following conclusions are drawn from the above literature review and pre experimentation.

Springback in sheet metal bending depends upon different variable parameters like sheet metal material, sheet metal thickness, punch angle, punch height, punch radius, punch load, die opening, die lip radius, sheet metal material grain direction, pre bend strip condition etc. From pre experimentation it is observed that punch angle is a very important variable parameter affecting on springback. Lower punch angle is creating lower plastic zone which tends to higher springback as compared to higher punch angle. It is also observed that the supporting flange area is increasing from lower die opening to higher die opening causing higher springback for low die opening and vice versa. Grain direction of sheet metal material is also affecting on springback due to its different yield strength along different grain direction. It has been observed that the pre bend condition of strip is also one of the prime factors which influences on springback. It was observed that springback is less for flat sheet. The residual stresses in pre bend strip showed more impact on springback as compared to flat strip. However further detailed experimentation is to be carried out for precise prediction of behavior of above said variable parameters and to formulate the mathematical model of the same.

REFERENCES

[1] Huang, H. M., Liu, S. D., and Jiang, S. Stress and strain histories of multiple bending–unbending springback process. Trans. ASME, J. Eng. Mater.and Technol.,2001, 123, 384–390.
[2] Seo, D. G., Chang, S. H., and Lee, S. M. Springback characteristics of steel sheets for warm U-draw bending.Metals Mater. Int., 2003, 9, 497–501.
[3] D'Acquisto, L. and Fratini, L. Springback effect evaluation in three-dimensional stamping processes at the varying blank holder force. J. Mech. Eng. Sci., 2006,220, 1827–1837.
[4] Carden, W. D., Geng, L. M., Matlock, D. K., and Wagnor, R. H. Measurement of springback.Int. J. Mech. Sci., 2002, 44, 79–101.
[5] Ivina Suchi, Die Design Hnadbook, Edition Second
[6] H K Yi1, D W Kim1, C J Van Tyne2, and Y H Moon1, Analytical prediction of springback based on residual differential strain during sheet metal bending.Int. J. Mech. Sci., 2008, 117-129
[7] Recep Kazan, Mehmet Fırat, Aysun Egrisogut Tiryaki, "Source-Prediction of spring back in wipe-bending process of sheet metal using neural network", Materials and Design 30 (2009) 418–423.
[8] SutasnThipprakmas, Finite element analysis of punch height effect on V-bending angle, Materials and Design 31 (2010) 1593–1598
[9] You-Min Huang and Daw-KweiLeu, effects of process variables on v-die bendingprocess of steel sheet, Int. J. Mech. Sci. Vol. 40, No. 7, 631 - 650, 1998
[10] W.M.Chan*, H.I. Chew, H.P.Lee, B.T.Cheok Finite Element analysis of springback of V bending sheet metal forming processes, Journal of Materials Processing Technology 148 (2004) 15-24
[11] Sutasn Thipprakmas, Wiriyakorn Phanitwong, Process parameter design of springback and spring-go in V bending process using Taguchi Technique, Material and Design 32 (2011) 4430-4436.
[12] Vijay Gautam, Parveen Kumar, Aadityeshwar Singh Deo, Effect of Punch Profile Radius and Localised Compression on Springback in V-Bending of High Strength Steel and its FEA Simulation, International Journal Of Mechanical EngineeringAnd Technology (Ijmet) , Volume 3, Issue 3, (2012), 517-530
[13] Luc Papelux, Jean-Philippe Ponthot, "Finite element simulation of spring back in sheet metal forming", Material Processing Technology, 125-126 (2002) 785-791.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)