

Factors Affecting on Residual Stresses & Springback in Sheet Metal Bending: A Review

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Abstract— In sheet metal bending, the springback phenomenon leads to undesired effects on the geometry and dimensions of the formed parts. One of the main causes that lead and influence the intensity of this instability phenomenon is the state of residual stresses generated by the bending process in the deformed material. To establish an interaction between springback and distribution of stresses it must be known the law of variation of their parameters, their factors of influence and their causes. The magnitude of residual stresses significantly affect the load carrying capacity and the fatigue strength of the formed member, so residual stresses distribution is essential to be find out. This paper reviews the various parameters affecting on residual stress & spring back such as punch angle, sheet thickness, punch tip radius, punch height, bending force, clearance between punch and die, sheet anisotropy etc.

Key words: Residual Stress, Bending, Springback

I. INTRODUCTION

One of the most sensitive features of the sheet metal forming is the elastic recovery during unloading called spring back. Sheet metals are prone to some amount of spring back depending on elastic deformation. Obtaining the desired size, shape depends on the prediction of spring back. Accurate prediction and controlling of spring back is essential in the design of tools for sheet metal forming. The spring back is affected by the factors such as sheet thickness, material properties, tooling geometry etc. [1]

One of the main causes that lead and influence the intensity of this instability spring back phenomenon is the state of stresses generated by the forming process in the deformed material. To establish an interaction between springback and distribution of stresses it must be known the law of variation of their parameters, their factors of influence and their causes. If the determination of springback parameters can be performed without difficulty, the determination of stresses can be done easily.

Stress and residual stress distributions in bending are important in calculating springback and loading capacity of a sheet-metal bending part. The stress distribution in a sheet-metal bending part before unloading decides the magnitude and direction of springback of the part after unloading. The residual stress distribution of a sheet-metal part formed by bending will affect the loading capacity or the strength of the part. If this part is to be further formed at a subsequent operation, this residual stress distribution left by a previous operation will affect the stress distribution of the part in the subsequent operation, and hence the springback of the part after the last operation.

The residual stresses may have an important effect on the mechanic behavior of the material. Analysis of the residual stresses in a bent specimen is generally very complicated, since the residual stresses induced in the forming process depend not only on the process parameters,

but also on material properties, e.g. work-hardening ability. Analysis of residual stress is very important, because it affects performance of the product [3]. As compressive stresses are beneficial because it increases the fatigue strength and life of the product, where as tensile stresses are dangerous because it decreases the fatigue strength and life of product. All forming process will take places in the plastic region.

The aim of presented paper is to discuss the various parameters affecting residual stress distributions and springback in bending such as punch angle, sheet thickness, punch tip radius, punch height, bending force, clearance between punch and die, sheet anisotropy etc.

A. Bending and Spring Back

There are three types of bending, V bending, U bending, and edge bending. In sheet metal after plastic bending, unloading takes place and punch removes from the workpiece to the initial position. Final shape of the workpiece after unloading differs from the punch /dies configuration in closed position. Occurrence of this difference is called “spring back”.

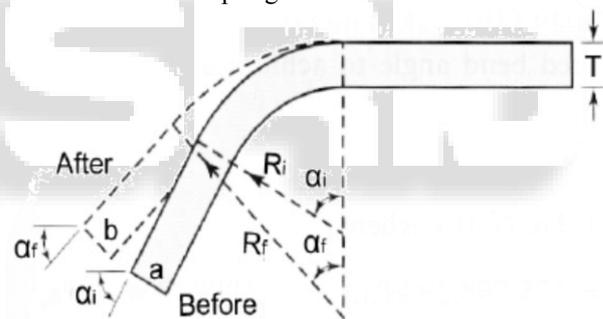


Fig. 1: Illustration of spring – back phenomena

In fig.-1 bent material is shown in two positions: a) bent and closed in the die (angle α_i) and b) after unloading (angle α_f). As it can be seen, after unloading bend angle is smaller than when being closed in the die ($\alpha_i > \alpha_f$).

II. LITERATURE REVIEW

A. Effect of Bending Radius on Residual Stress

Z. T. Zhang and S. J. Hu [4] presented that stress and residual stress distributions in bending are important in calculating springback and loading capacity of a sheet-metal bending part. Stress and residual stress calculation methods in plane strain bending are briefly developed. The influence of deformation theory and incremental theory, repeating bending, unbending and re-bending, cyclic material models and springback calculation methods on the stress or residual stress distributions are examined. This emphasizes the importance of careful selection of these variables in a simulation model in addition to other general input variables, such as material properties, tool geometry and friction condition. In pure bending without a stretching

force, the stress distributions are shown in Fig. 2 Stress increases with increase of bending radius. The neutral surface deviates from the original middle surface gradually.

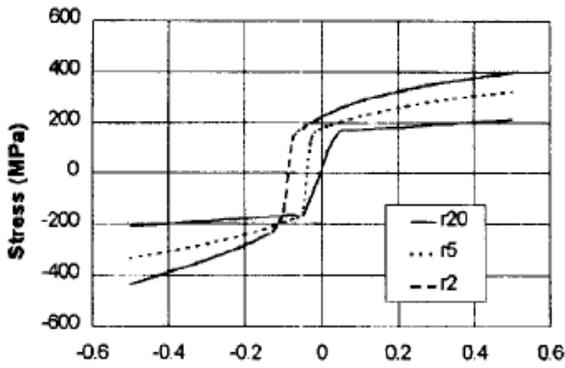


Fig. 2: Effect of bending radius on residual stress

B. Effect of Sheet Thickness on Residual Stresses

M. El Sherbiny [2] developed the model which can predict the thickness distribution, thinning, and the maximum residual stresses of the blank at different die design parameters, including both geometrical and physical parameters. Furthermore, it is used for predicting reliable, working parameters without expensive shop trials. Predictions of the thickness distribution, thinning and the maximum residual stresses of the sheet metal blank with different design parameters are reported. Frictional limitations and requirements at the different interfaces are also investigated.

The original blank thickness also has some effect on the maximum residual stresses of sheet metal blank in the deep drawing processes. The graph 3 shows the maximum residual stresses with several values of the blank thickness (t). From this graph it can be clearly observed that the maximum residual stresses increases with increasing the blank thickness.

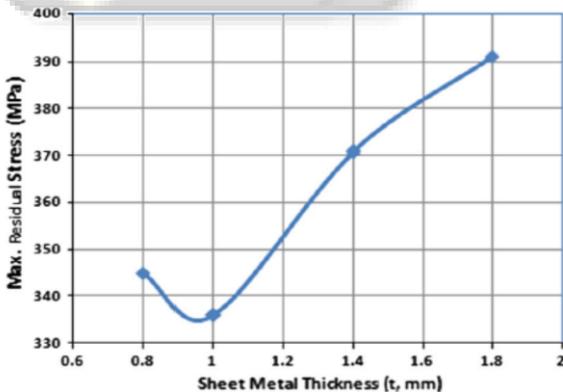


Fig. 3: Effect of sheet metal thickness on residual stresses

C. Effect of Punch Tip Radius on Residual Stresses

The geometry of punch influences the maximum residual stresses of sheet metal blank in the deep drawing processes[2]. Fig. 4 shows the maximum residual stresses with different values of the punch nose radius (r_p). It is shown that for a punch nose radius (r_p) that is greater than six times the thickness of the blank (t), the cup fails due to increased maximum residual stress, whilst for (r_p) selected between (3t) and (5t), the maximum residual stresses are somewhat reduced.

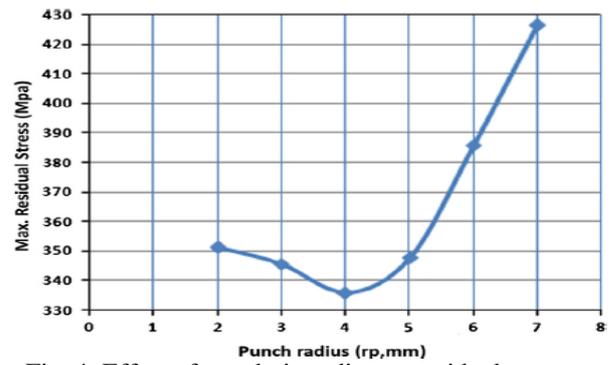


Fig. 4: Effect of punch tip radius on residual stresses.

D. Effect of Blank Holder Force on Residual Stresses

The blank holder force (BHF) required to hold a blank flat for a cylindrical draw which varies from very little to a maximum of one third of the drawing pressure [2]. Fig. 5 shows the maximum residual stresses with different values of the blank holder force (BHF). It is shown that the maximum value of the residual stresses is decreasing with increasing of blank holder force (BHF) when BHF is smaller than or equal 3 ton. But the maximum value of the residual stresses is increasing with increasing of BHF above this value.

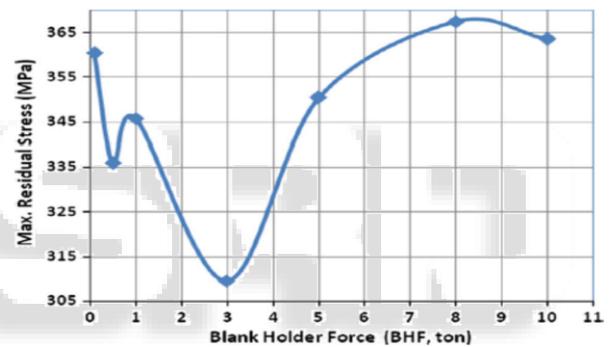


Fig. 5: Effect of blank holder force on residual stresses

E. Effect of Radial Clearance on Residual Stresses

Radial clearance is an important parameter, formulated as the difference between die radius and punch radius [2]. Fig. 6 shows the variation of the maximum residual stresses with different values of the radial clearance (w_c). It is shown that the maximum residual stress is reducing with increasing the radial clearance (w_c). In addition, for the radial clearance (w_c) that is less than the blank thickness (t), the cup fails due to increased the maximum value of the residual stresses. Whilst for the radial clearance (w_c) greater than (2t) of the blank thickness, the maximum value of residual stress is reduced.

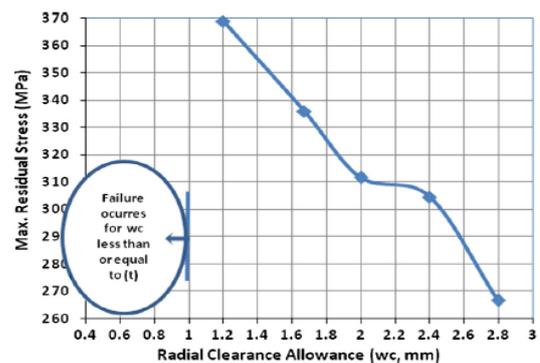


Fig. 6: Effect of Radial clearance on residual stresses

F. Effect of Punch Height on Springback

The effect of punch height on spring back in V bending examined in Ref. [5]. In this the finite element method (FEM) was used to investigate the effects of punch height. 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. Fig. 7 shows the comparison of the bending angle with respect to the punch height. On comparing with the required bending angle of 60°, the FEM simulation results revealed that the suitable punch heights to achieve that required bending angle were approximately 21 mm and 30 mm.

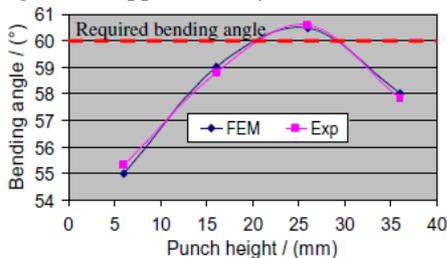


Fig. 7: Effect of punch height on spring back

G. Effect of Bending Angle on Springback

Sutasn Thipprakmas, [7] studied process parameters of bending angle, material thickness and punch radius on spring-back. The finite element method (FEM), in association with the Taguchi and the analysis of variance (ANOVA) techniques, was carried out to investigate the degree of importance of process parameters in V-bending process. The results revealed 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. Fig. 8 shows the amounts of spring-back and spring-go analyzed by FEM with respect to bending angle, material thickness, and punch radius. The results showed the tendency of spring back and spring-go for the punch radius of 2.5 mm, as shown in Fig. Specifically, as the bending angle increased, the amount of spring-back decreased and the amount of spring-go increased. In addition, as the material thickness increased, the amount of spring-back decreased whereas the amount of spring-go increased. As the punch radius increased, the amount of spring-back increased whereas the amount of spring-go decreased.

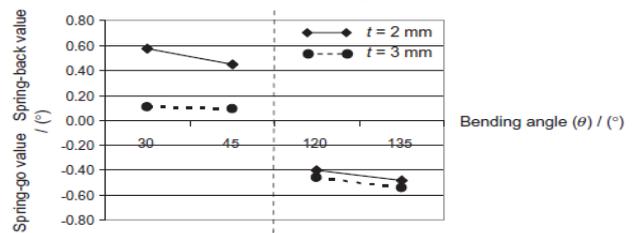


Fig. 8: Effect of bending angle on spring back

H. Effect of Bending Load on Springback

H.A.Al-Qureshi [8] predicted a theoretical method for the spring-back factor in bending with compressible dies from the basic properties of the sheet metal, the tool geometry and the frictional behaviour of the elastomer die. Various relevant parameters are examined within the framework of the present investigation. Experiments were conducted on a variety of sheet metals having widely different work-hardening characteristics. An approximate analysis for predicting the total bending load required is also presented. It can be seen that the spring-back factor (K_p) depends upon the mechanical properties of the materials (σ_y/Et), the punch radius (R), and the frictional properties of the elastomer pad (P_f). The development of a family of curves for various loads and friction conditions, keeping tool and material parameters constant, is shown in Fig. 9. It appears that the spring-back varies considerably with the applied load and the coefficient of friction. That is, as the load increases, the tensile frictional stress will increase accordingly, thus making the material less springy, i.e. the increase of the applied load or the coefficient of friction affords substantial contribution in the reduction of the anticipated spring-back value. This can be seen clearly from Fig. 9.

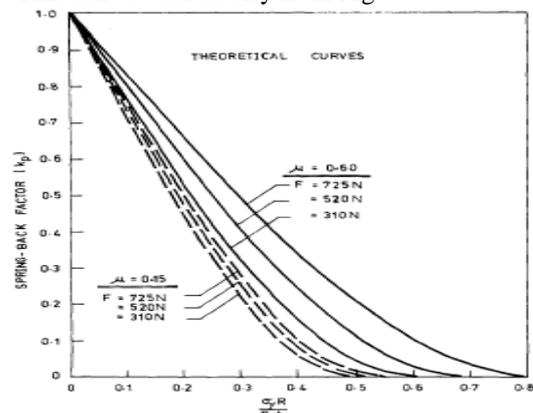


Fig. 9: Effect of load on spring-back factor.

I. Effect of Sheet Anisotropy

The effect of sheet anisotropy on the spring-back for punch tip radius 2 mm with 0.5 mm thickness in V-die bending is shown in fig 10. As it is shown in the figure, in general, increasing the bending direction to the rolling direction resulted in an increase in the spring-go. In this also studied the effect of this parameter on spring-back for V- and U-die shapes in similar conditions. Accordingly, it was concluded that the bending of the sheet at orientation 0° was a suitable condition for spring-back or spring-go reduction in V- and U-die bending processes [1].

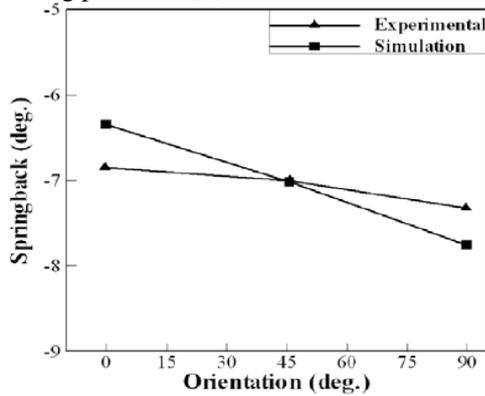


Fig. 10: Effect of sheet anisotropy on spring back; V-die bending.

J. Effect of Sheet Thickness, Punch Tip Radius, Load on Spring Back on Deep Draw Steel (IS 1079-1994)

The effect of sheet thickness, punch tip radius, load 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 sheet thickness on springback. It is observed that sheet thickness is a very important parameter affecting on springback. Lower sheet thickness is creating lower plastic zone which tends to higher spring back as compared to higher sheet thickness.

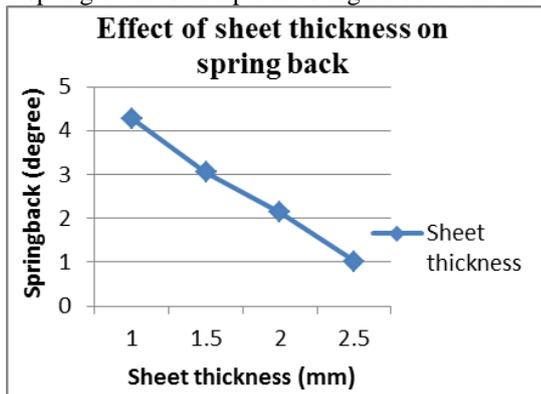


Fig. 11: Effect of Sheet Thickness on Spring Back

Punch tip radius has significant effect on springback. Punch tip radius of 2mm, 4mm, 6mm and 8mm were used. It is observed that as punch tip radius increases cross sectional area increases. Since increasing cross sectional area effectively transfers the amount of applied load, because of which bottoming force increases, which increases the yielding of material, so the amount of spring back decrease with increasing punch tip radius which is shown in fig.12.

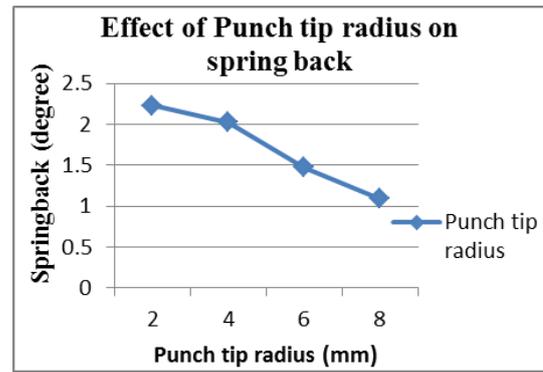


Fig. 12: Effect of Punch tip radius on spring back

Fig. 13 shows the effect of load on spring back. As the load increases spring back decreases because as load increases yielding of material increases which decreases the springback.

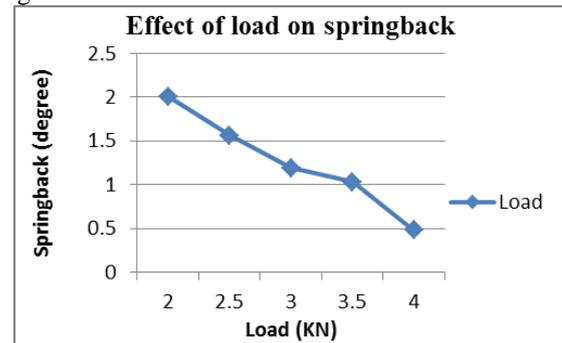


Fig. 13: Effect of load on springback

III. CONCLUSIONS

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

In sheet metal bending spring back phenomenon leads to undesired effects on the geometry and dimensions of the formed parts. One of the main causes that lead is the state of residual stresses generated by the bending process in the deformed material. The magnitude of residual stresses significantly affect the load carrying capacity and the fatigue strength of the formed member, so residual stresses distribution is essential to be find out.

Residual stresses & Springback in sheet metal bending depends upon different variable parameters like punch angle, sheet thickness, punch tip radius, punch height, bending force, clearance between punch and die, sheet anisotropy etc. It is observed that sheet thickness is a very important variable parameter affecting on spring back and residual stresses. Lower sheet thickness is creating lower plastic zone which tends to lower residual stresses and higher springback as compared to higher sheet thickness. For the bending load, it is observed that the spring-back varies considerably with the applied load and the punch tip radius is also affecting on spring back and residual stress due to yielding of material.

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