# Analysis of Springback in Flanging Process at Higher Velocity using FEM

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***Abstract*-Springback always remains a major concern in the sheet metal forming industry. In this paper, springback analysis is presented in flanging process considering various parameters. In this process, it is difficult to get the flange leg of desired angle with a controlled shape due to elastic recovery of material. Springback generally depends on the forming velocity, geometric parameters and material of sheet. At high velocity the forming of sheet increases and springback decreases but it is difficult to predict springback analytically due to complex material deformation. In this study, commercially available Finite Element software is used to see the effect of higher velocity on springback and other parameters.**

***Keyword- Springback; FEM; Flanging***

## I. INTRODUCTION

Flanging is an important sheet metal bending process widely used in manufacturing and automotive industries. It is a process in which, one edge of the sheet is bent to the desired angle while the other end is restrained either by material itself or force of a blank holder or pad. It is generally used to increase the stiffness of the sheet panel and to create the mating surface for subsequent assembly. In flanging process, springback is one of the important design problem. During the loading phase a large amount of elastic strain energy stored in the blank, is subsequently release with removing the forming load. It results in deflection of flange leg from loaded shape towards the original and this phenomenon is called as springback. The amount of elastic energy stored is a function of many process parameters such as material properties, sheet thickness, tooling geometry, forming velocity, etc. Therefore, it is important to predict springback considering above mention parameters to achieve the desired shape.

In the past, various researches have been work for prediction of springback in flanging operation using FEM. For instance Livatyali & Altan [1, 2] presented experimental investigation to determine the influence of process variables on springback in straight flanging. Nan Song et al. [3] evaluated the reliability of different methods in prediction of springback in flanging, such as an analytical model, numerical simulation using the Reproducing Kernel Particle Methods (RKPM), and results were compared with experimental results. Livatyali et al. [4] developed a mathematical model for the straight flanging process and predicted the springback. Cao and Buranathiti [5] developed an effective analytical model to predict springback for a straight flanging process. This model evaluates the final springback angle by conducting bending moment computation, geometry and configuration calculation. Workswicsk and Finn [6] represented that the classical FLD approach was overly conservative in estimating the formability in stretch flanging process. Luo and Ghosh [7] investigated the effect of Young’s modulus and Poisson’s ratio on Springback. Zhang [8] used a special two-fold approach to analyzing the flat straight hemming operation. Kim et al. [9] developed an analytical model to predict springback and bend allowance simultaneously in air bending, and a user-friendly computer program, BEND (Version3.0). M. Firat [10] presented the finite element procedures for stamping process simulation and investigated the performance of the shell element formulation in the prediction of blank plastic strains, forming loads. Zhu and Stelson [11] developed a closed loop control method for springback in stretch bending of aluminum rectangular tubes. Ling et al. [12] introduced step within the die to reduce springback in L bending. Chou and Hung [13] analyzed several springback reduction techniques used in the U channel bending process. XuFeng [14] et al. studied the influence of geometrical parameter on the formability of stretch curved flanging using AutoForm. R. Ruffini [15] and J. Cao [16] presented a neural network control system for springback minimization. Zhang et al. [17] presented experimental and analytical studies to predict the circumferential strain along the flange edge on shrink flanging with surface curvature.

Springback has been always an issue in fabrication, whether it's automakers, the aerospace industry or appliance makers. Therefore by understanding springback, a manufacturer can reduce the number of die redesigns, and time-to-market is shortened significantly. At the same time, costs are also decreased. In this study, FEM of straight flanging was carried out to study the springback using commercial software, ANSYSLsdyna. Various velocities, geometrical and material parameters were considered to predict the effect on the springback.

## II. FINITE ELEMENT ANALYSIS OF PROCESS

### A. *Material Modeling*

Aluminum is considered as material for sheet. The flow of material is assumed to follow the power law.

$$\sigma = K\,\varepsilon^{n} \tag{1}$$

Where σ, ε, K and n are as true stress, true strain, strength coefficient and exponent coefficient respectively. The material properties of the sheet and the process variables are as follows:

Young's modulus-72 GPa

Yield stress-146 MPa

Poisson's ratio-0.3

Stain Hardening coefficient-0.3

*B. Numerical Simulation*

Straight flanging process is modeled using commercial finite element software ANSYS LSDyna. 3D geometry of the model with FE mesh is shown in Fig. 1. A flat blank with 100 mm in length, 50 mm in width and 1 mm in thickness initially placed between the die and the blank holder. Shell element with 5 integration points is employed to model the deformable body while shell element without integration point is considered for punch, die and blank holder. In this simulation punch, die and blank holder (binder) are considered as rigid body. Surface to surface contact was defined among punch, die, blank holder and blank. The die and the blank holder is constraint in all translational and rotational direction while the punch is constrained in z and x direction and all rotational direction. This simulation is performed in two stages, explicit (loading) and implicit (unloading). In explicit analysis, the sheet is resting on die while punch is allowed to move downward by describe suitable y–displacement to bend the sheet by 90 degrees and the blank experiences elastic-plastic deformation. The entire simulation of flanging process is carried out in a number of timesteps. After the explicit analysis thickness and stress results are transferred into ANSYS to carry out the implicit analysis. For performing implicit analysis the edge node of the blank as shown in Fig. 2 is restrained in y direction and only elastic properties of the sheet are considered.

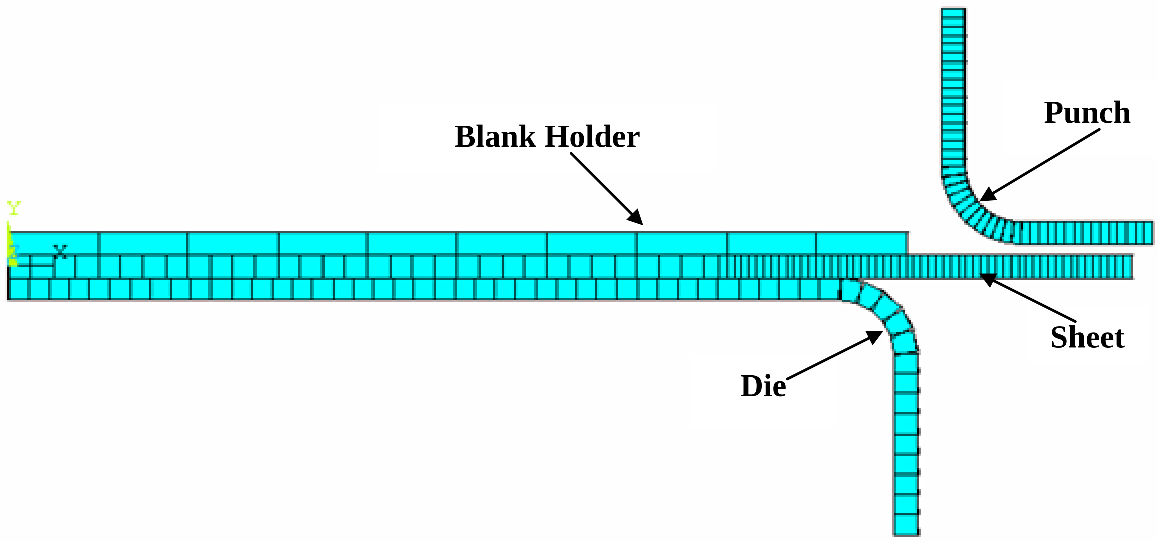



Fig. 1 Initial geometry of flanging process

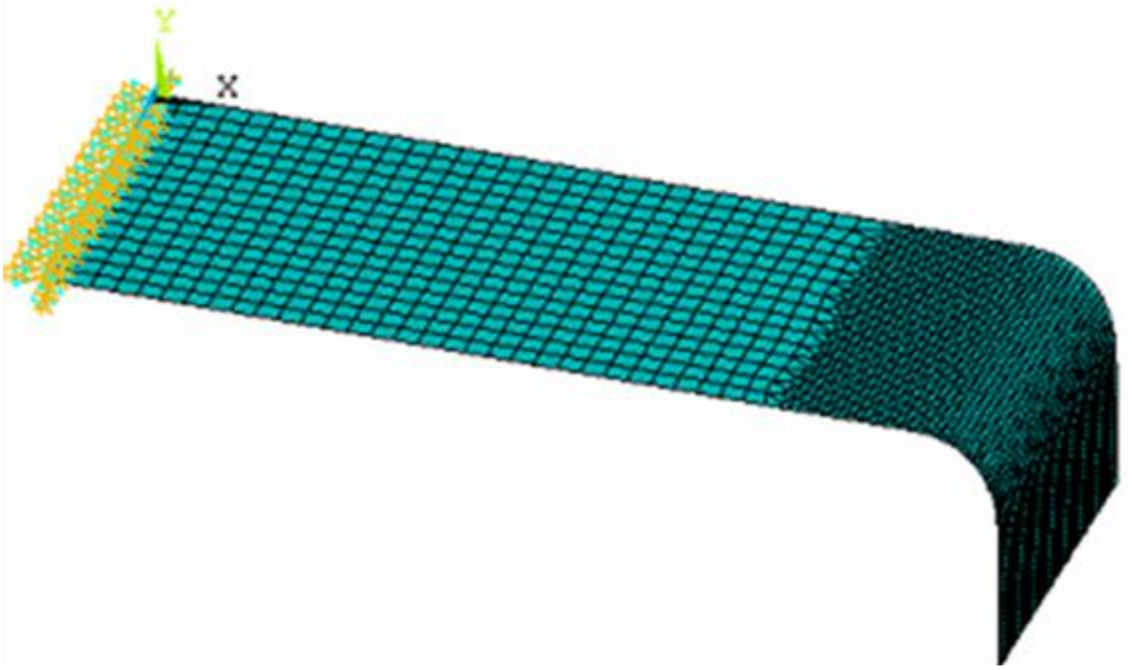



Fig. 2 Deformed shape of the flange

The simulation was carried out at different die radius, gap, thickness of the sheet, flange length and velocity. In this study, flange length is referred to length of the sheet, which is bent to a specified angle and gap is the difference between thickness of sheet and distance between the punch and die. The following parameters as given in Table 1 are considered in the simulation.

TABLE 1 GEOMETRIC AND PROCESS PARAMETERS USED IN THE SIMULATION

| S. No. | Parameter | Value considered in simulation |
|---|---|---|
| 1 | Thickness (mm) | 1, 2, 3 |
| 2 | Die Radius (mm) | 2, 3, 5 |
| 3 | Gap (mm) | 0.1, 0.2, 0.4, 0.6 |
| 4 | Flange length (mm) | 10, 13, 15 |
| 5 | Velocity (mm/sec) | 1, 2, 10, 25, 50, 100 |

### *C. Measurement of Springback Angle*

After release of the punch, there is a considerable springback due to elastic recovery. The springback angle of the released sheet is calculated as follows:

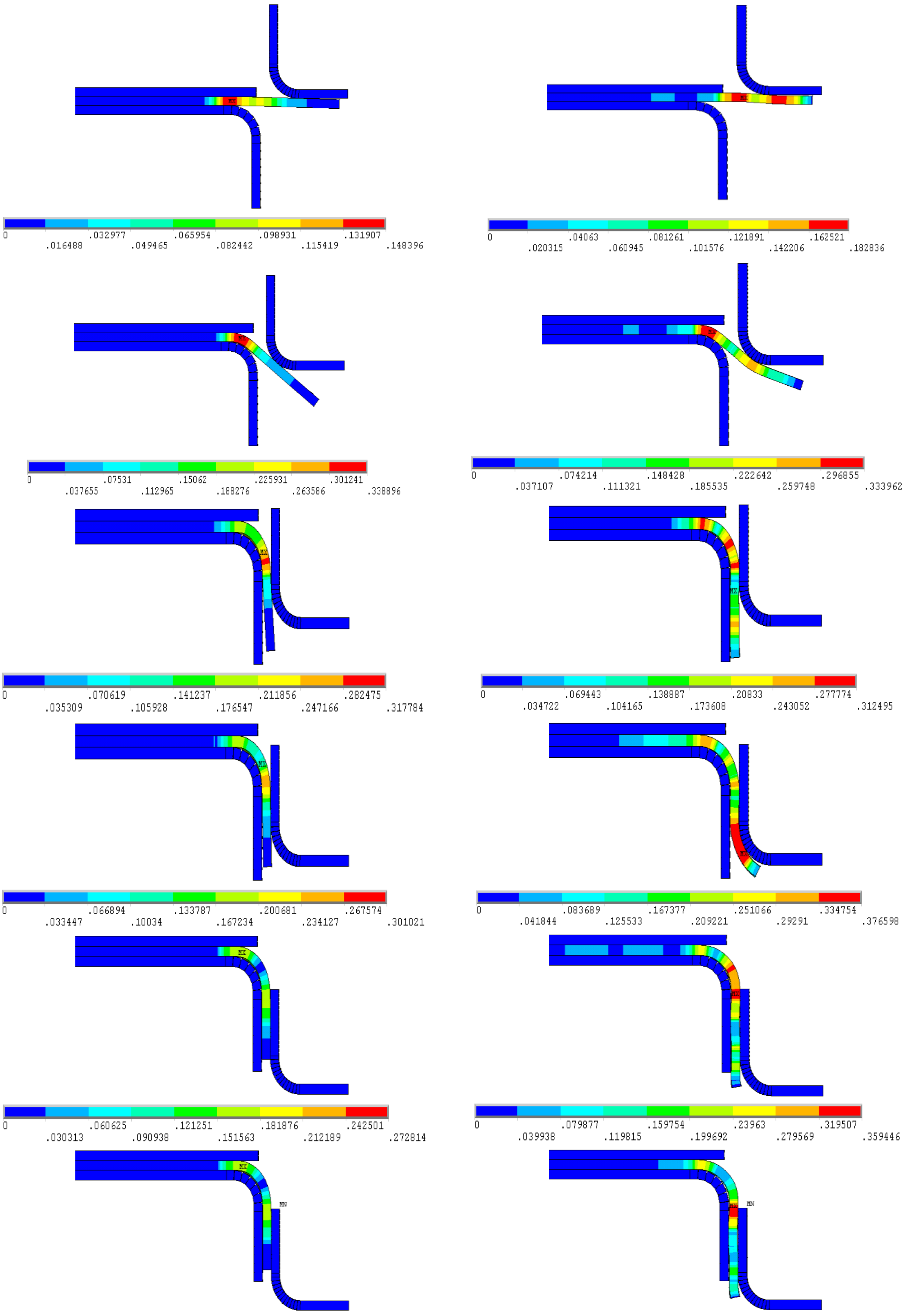
If ($X_1$, $Y_1$) and ($X_2$, $Y_2$) are the co-ordinates of two nodal points on the bent sheet thenspringback angle may be calculated by Eq. (2).

$$\text{Springbackangle } (\theta) = \tan^{-1} [(X_2 - X_1) / (Y_2 - Y_1)] \quad (2)$$

## III. RESULTS AND DISSCUSSION

### *A. Influence of Velocity on Springback Effect*

The springback angle at different velocity is predicted by considering the following process parameters i.e. thickness of the sheet, flange lengthand die radius 1 mm, 10 mm and 3 mm respectively. The simulation is carried out at velocity 1, 2, 10, 50, 60, 80, 90 and 100 mm/sec. The deformed sheet at different percentage of punch displacement for 10 and 100 mm/sec velocity is shown in Fig. 3. It is represented in Fig. 3, initial deformation of sheet in both cases is equal up to 30% of given time step. After the displacement of 30% sheet at low velocity approximately less than 50mm/sec is rotate linearly upto 100% of given time step. But in case of sheet bend by high velocity, flange bend towards punch corner at approximately 38 % of given time step. With anincrement of time step, first deformed sheet impact on die surface at high velocity and it subsequent returns back and it takes the shape of the punch which, results in sliding of sheet with an increase in punch displacement. As the punch moves downward, flange starts to take die shape but shape of the flange remains slightly distorted. The flange length increases due to sliding of the sheet.A plot between springback angle and gap is shown in Fig. 4 at different velocity (1, 2, 10, 25, 50 mm/sec). It can be seen from Fig. 4 that springback angle at velocity between 1 to 10 mm/sec does not show a significant variation with respect to the gap but it increases with an increase in velocity. Springback angle is not presented in figure at higher velocity i.e. greater than 50 mm/sec due to shape distortion of the sheet.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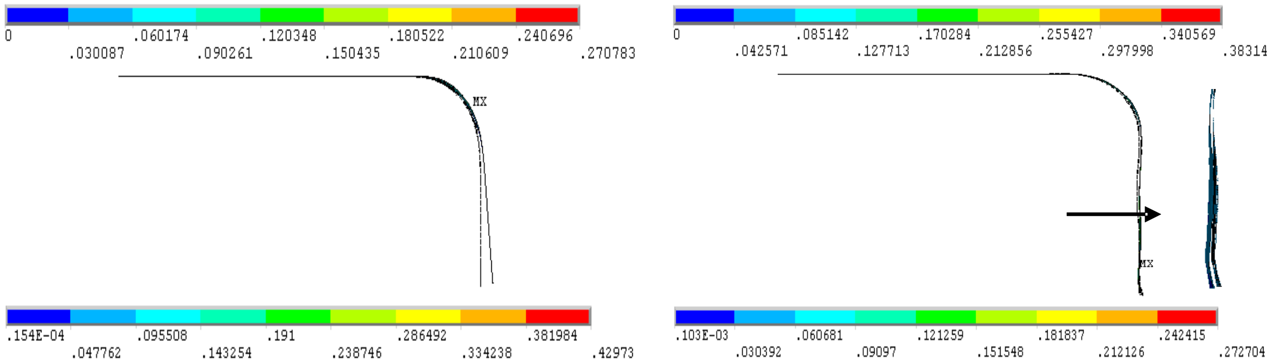


Fig. 3 Deformed shape of the flange at the various percentage of punch displacement for 10 and 100 mm/sec velocity

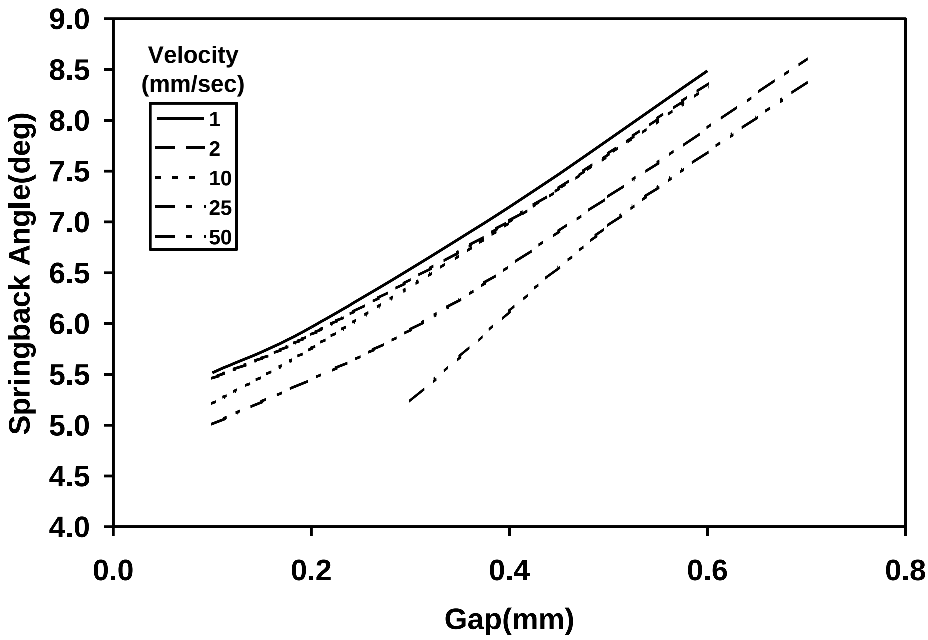


Fig. 4 Effect of punch velocity on springback

*B. Influence of Material Parameter on Springback*

Springback always depends on the material properties of the sheet even a small change in these results in the large deviation in springback. Therefore, this study is carried to see the effect of material properties on the springback in terms of springback angle. In this simulation the following parameters are considered: thickness of sheet 1 mm, die radius 3 mm, flange length 10 mm, velocity 10 mm/sec with different young's modulus and yield stress i.e. 75, 100, 146, 200, 225 MPa and 75, 100, 125 and 146 MPa respectively. It can be seen from Fig. 5 that springback angle increases with increase in yield stress while it decreases with increase in young's modulus of material as shown in Fig. 6.

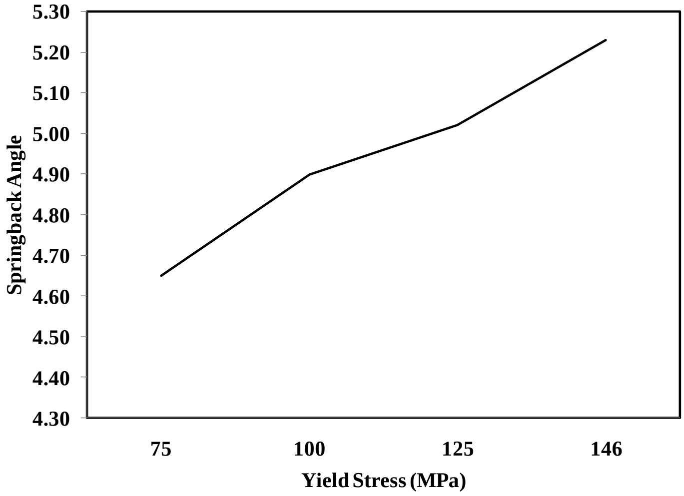


Fig. 5 Effect of yield stress on springback angle

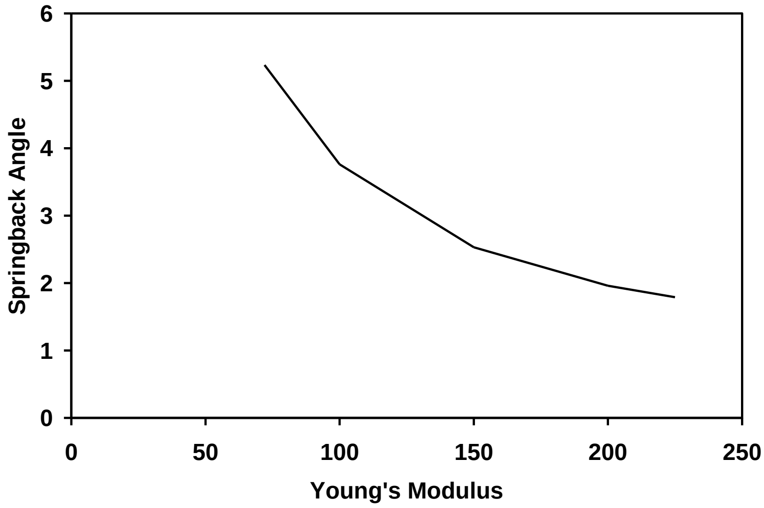


Fig. 6 Effect of Young's modulus on springback

### *C. Influence of Geometric Parameter on Springback*

To see the effect of geometrical parameters such as sheet thickness, die radius and flange length on springback graphsare plotted between springback angle and gap for each parameter. Simulation is performed to study the effect of thickness (1, 2 and 3 mm) on springback with flange length 10 mm, die radius 3 mm, velocity 2 mm/sec. It can be seen from Fig. 7 that springback angle decreases with increase in thickness of the sheet and it increases with increases in the gap. To show the effect of flange length on springback a Fig. 8 is plotted between springback angle and gap. The springback angle is calculated for different flange length (10, 13, 15 mm) by considering the following process parameters; thickness of the sheet, velocity and die radius 1 mm, 2 mm/sec and 3 mm respectively. From the Fig. 8 it is illustrated that springback angle decreases with an increase in flange length. A plot between the springback angle and the gap for the die radii (2 mm, 3 mm and 5 mm) keeping thickness of the sheet 1 mm is shown in Fig. 9. This simulation is carried out at gap 0.1 mm, 0.2 mm, 0.4 mm and 0.6 mm. The flange length, die radius and velocity were considered as 10 mm, 3 mm and 1 mm/sec respectively. The Fig. 9 illustrates that the springback increases with an increase in die radius.

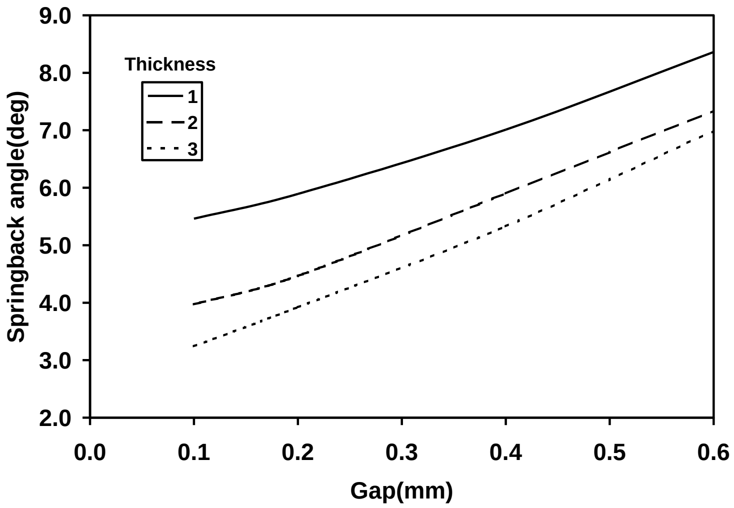


Fig. 7 Effect of thickness of sheet on springback

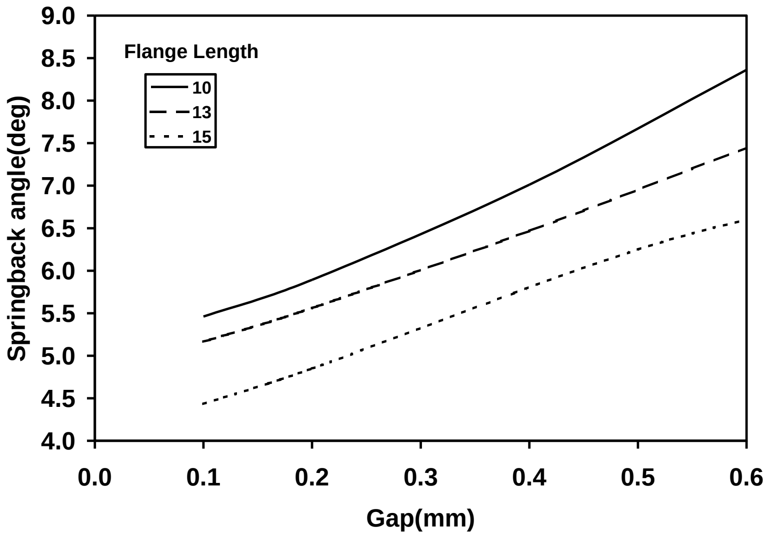


Fig. 8 Effect of flange length on springback

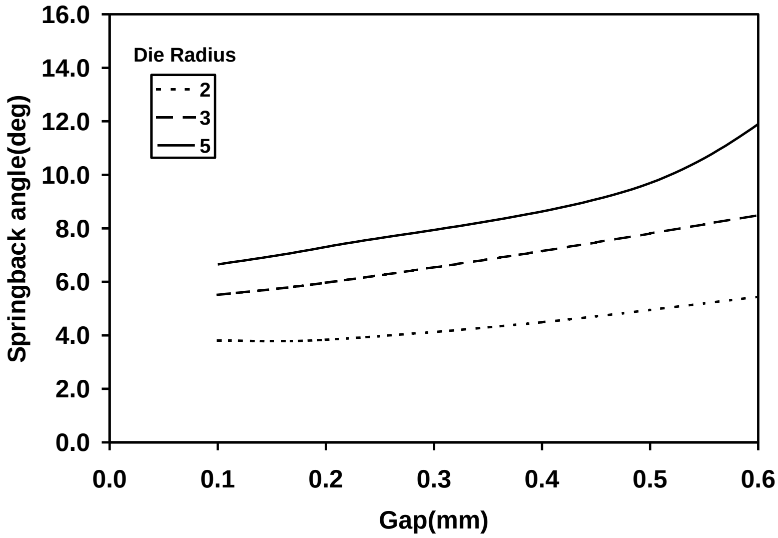


Fig. 9 Effect of radius of die on springback

## IV. CONCLUSIONS

The following conclusion emerges from the study:

1. It can be concluded from this study that springback decreases with an increase in velocity but it is useful upto a certain limit of velocity (~50 mm/sec) because shape distortion occurs at higher velocities. It is also observed that at high forming velocity flange length increases due to sliding of the sheet.
2. Springback angle decreases with an increase in thickness of the sheet and it increases with increases in the gap.
3. Springback angle decreases with an increase in flange length.
4. Springback increases with an increase in yield stress and decreases with an increase in Young's modulus.

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