Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Analysis of Springback Variation in V Bending

Bhav Gautam*
B. Tech Tool Engineering
D.I.T.E Campus II
New Delhi, India

Praveen Kumar
Asst. Professor
D.I.T.E Campus II
New Delhi, India

Vaibhav Chandra
Asst. Professor
D.I.T.E Campus II
New Delhi, India

Kamal Rawat
M.Tech Tool Engineering
D.I.T.E Campus II
New Delhi, India

***Abstract*— In order to get exact shape and size of components in sheet metal manufacturing, springback effect plays a pivotal role. Prediction of springback angle helps in determining the amount of over-bend (i.e. springback compensation) required so that exact V bend angle can be obtained in the component. In this study an attempt has been done to analyze the springback effect for simple V-bending operation performed on CRDQ (Cold Rolled Draw Quality) with thickness of sheet varying from 2.0 to 4.0 mm. In this work Hyperform software is used for simulating the springback effect in V bending operation. The main objective is to get the variation of amount of springback for different thickness of sheets keeping bending angle (60^0) and punch radius (2mm) constant. The results showed that the value of springback decreases with the increase in sheet thickness (from 2 mm) up till 3.3 mm. Further increase in sheet thickness, from 3.3 mm to 4.0 mm, increases the amount of springback for V-bending of CRDQ sheet. Thus, it is concluded that optimum sheet thickness to encounter minimum springback for CRDQ sheet is 3.3 mm.**

Keywords*— *Springback; Hyperform; V Bending; CRDQ; CAD Model; Unigraphics NX

I. INTRODUCTION

One of the most widely used operations in sheet metal forming is the bending operation. These are very familiar processes used in the manufacturing of panels' of electronic components, drums, components of automobile, vehicle panels etc. Despite being the most inaccurate of all the bending operations, V bending is still widely used throughout the industry. Reasons: simple tool construction and multiple flanges can be formed for more than one part. During V-die bending, the punch slides down, coming first to a contact with the unsupported sheet metal. By progressing farther down, it forces the material to follow along, until finally bottoming on the V shape of the die.

A. Deformation Mechanism

It is important to understand that every permanent deformation occurs 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; called as springback. The complete amount of deformation is therefore equal to the sum of the elastic deformation and the plastic deformation of the operation, i.e.

$$E_{TOTAL} = E_{EL} + E_{PL}$$

Here, it is emphasized that E_{EL} is that segment of E_{TOTAL} which is easily recoverable by the material. Whereas, E_{PL} causes permanent deformation of the material. Thus, out of the total deformation only plastic deformation is responsible for the exact shape and size of the components.

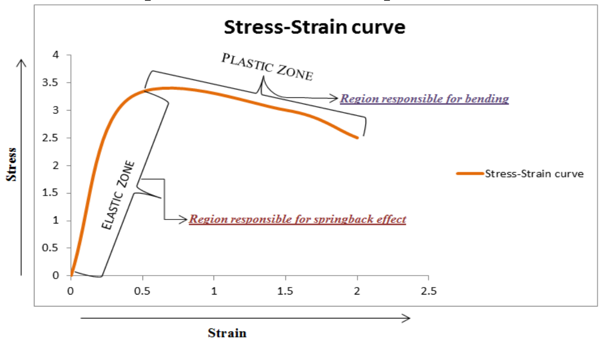

Fig.1: Graph showing the two zones in the stress-strain curve

B. Deformation in Forming

In any forming process, generally two types of deformation can be observed. These can be either localized, or affecting the whole part:

1. *Equal deformation*: It is fairly even and free from excessive deviation from its mean values. It is also unaffected by axial orientation.
2. *Unequal deformation*: In this case, the shape and the size of the formed part are changed unequally. During this type of deformation, many additional stresses, beneficial or detrimental, may develop.

The occurrence of localized stresses within the material during unequal deformation is caused mainly by:

1. Unequal friction between the forming tool and the part
2. Unequal temperature distribution within the part
3. Too complex geometry of a product
4. Chemical differences within the material
5. Mechanical properties of the material

C. Springback Effect

The major problem in bending process is the springback. It is a complex phenomenon and depends on process and material parameters. Springback is the amount of elastic distortion a material has to go through before it becomes permanently deformed, or formed. It is the amount of elastic tolerance, which is to some extent present in every material, be it a ductile or annealed metal.

In ductile materials, the springback is much lower than in hard metals, with dependence on the modulus of elasticity (also called Young Modulus) of a particular material. The amount of springback increases with greater yield strength or with the material's strain-hardening tendency. Cold working and heat treatment both increase the amount of springback in the material.

Comparably, the springback of low-strength steel material will be smaller than that of high-strength steel and springback of aluminum will be two or three times higher yet. Springback occurs in all formed or bent-up parts on release of forming pressure and withdrawal of the punch. The material, previously held in a predetermined arrangement by the influence of these two elements, is suddenly free from outside restrictions and immediately makes an attempt to return to its original shape and form.

D. Springback Removal

There are several methods of springback removal in bending, most of them utilizing either over-bending or coining. The easiest and most widely used method is the over-bending technique wherein the sheet is bended beyond the required value. Due to springback effect the sheet comes back to its required dimension. This amount of over-bend is determined using trial and error method which is further verified by the simulation software.

Another method to avoid springback is coining. In this either the surface or edges of the punch undergo coining. Sometimes the coining is done on the edges of die or both die and punch. The effect of the coining process is that of interruption of the flow of stress lines that would normally be present there, a residue from bending operation.

II. Literature Review

The accuracy in dimensions of sheet metal bending process is always a major concern, depending upon the amount of elastic recovery during unloading, which leads to spring back. It is an important parameter in designing bending tools in order to obtain the desired geometry of the part; hence springback prediction is a considerable issue in sheet metal forming. Springback is measured in terms of difference between the dimension of fully loaded and unloaded configuration. The major parameters that affect the springback are tool shape and dimension, contact friction condition, material properties, thickness of sheet, sector angle.

In past various researches have been done to determine the amount springback by means of trial and error technique which not only was an expensive process for the manufacturing and repair of the tool but also required a lot of time, causing delay in the development of the product. Another method for the prediction of springback using numerical simulation based on Finite Element Analysis (FEA) has emerged as a powerful tool which is now being used worldwide. Simulations lead to a less time consuming and more economical way in designing and analysis of the process.

In [1], Finite Element software was used to predict the springback in a typical sheet metal bending process. Further, a total-elastic–incremental-plastic (TEIP) algorithm, for large deformation and large rotational problems, was incorporated in indigenous Finite Element software to investigate the influence of these parameters on springback. They concluded that springback highly depends on material properties (yield stress, Young’s modulus, and strain hardening) and geometric parameters (thickness of sheet, die radius, sector angle). Also, they found that springback increases with increase in yield stress, strain hardening but it decreases with increase in Young’s modulus and it increases with increase in sector angle. In Reference [2], for modelling a typical sheet metal bending process, a large deformation algorithm based on Total-Elastic-Incremental-Plastic Strain (TEIP) was used. In their investigation, the prediction of springback was carried out as numerical experiment and the results were presented in terms of springback ratio. The study examined the effect of load on springback varying the thickness as well as the radius of the die.

An analytical model for predicting sheet springback after U-bending was developed in [3]. The model took into account the effects of deformation history, thickness thinning and neutral surface shift on the sheet springback of U-bending. They utilised three rules for material hardening i.e. kinematic, isotropic and combined hardening, to consider the effect of complex deformation history that has undergone stretching, bending, and unbending deformations on the sheet springback. It indicated that the springback is overestimated when isotropic hardening is applied, while is underestimated when kinematic hardening is applied. In addition to that, the effects of blank holding force, friction coefficient between sheet and tools, sheet thickness and anisotropy have also been investigated. They found that when the shifting distance of neutral surface exceeded one-fourth of sheet thickness, the springback could be reduced effectively by increasing the blank holding force and friction between sheet and die. Further, they concluded that, springback increases with anisotropy and friction between sheet and punch, and decreases with the sheet thickness. In [4], a study was done on the bending of High Strength Steels (HSSs) sheets due to their wide applicability in the automobile industries. Two sets of experiments were conducted to analyse the influence of the material property (dual-phase steels from different suppliers), lubrication, and blank holder pressure on the springback variation. The experimental results showed that, the thicker the blank is, the less the springback variation. On the other hand, blanks without a coating show less springback variation. The application of lubricant helped to reduce springback variation, although it actually increased the springback itself. The more uniform the friction condition, the less the springback variation. In [5], they studied, using the finite element method (FEM), the effects of punch height on springback. The FEM simulation results revealed that 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, which resulted in achieving the required bending angle.

In [6], a prediction model for springback in wipe-bending process was developed using artificial neural network (ANN) approach. Here, several numerical simulations using finite element method (FEM) were performed to obtain the teaching data of neural network. They concluded, based on data obtained from FEA, that consistency between FE simulator and the network model results achieved by relative error less than 0.8% and 9%, respectively, therefore neural network model can be used for such engineering problems.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

In another study, the effect of temperature gradients on the final part quality (i.e., springback) in warm forming of lightweight materials was investigated [7]. By accurately measuring the springback amount in three distinct tooling regions (i.e., die corner, punch corner, and side wall), the effect of forming temperature distribution on the part quality was also analysed. In addition, the dependence of springback on blank holder force (BHF), friction condition, and forming rate was also analysed. In [8], research had been conducted to determine experimentally spring-back of sheet metals on bending dies. The amount of spring-back in sheet metals at different bending angles had been obtained by designing a modular "V" bending die. The results showed that holding the punch longer on the material bent reduces springback whereas an increase in the thickness of the material, and bending angle increase springback values. Spring-back values varied between 0.5° and 5°.

In another research, the effects of significant parameters on spring-back in U-die and V-die bending of anisotropic steel sheet were studied by experiments and numerical simulations [9]. In [10], the results of spring back evaluation of AA3105/polypropylene/AA3105 sandwich sheet materials have been done after being subjected to double-curvature forming. The influence of some geometrical parameters on springback such as thickness of sandwich sheet and tool curvatures radii has been evaluated.

In [11], a new analytical model was developed to predict springback and bend allowance simultaneously in air bending, and a user-friendly computer program, BEND (Version 3.0), was developed. Results obtained from the BEND program were compared to other analytical predictions and experimental results available in the literature. It was concluded that the proposed analytical model and the computer program predicted bend allowance and springback within acceptable accuracy. In [12], the influence of coining force on the spring-back reduction in the V-die bending process was done.

III. HYPERFORM SIMULATION AND CALCULATIONS

A. Hyperform analysis simulation procedure

Hyperform analyses software was used for simulation. A full V-bending simulation model with a die radius (R_d) of 5 mm was used. The 3D model of punch, die and blank was prepared in Unigraphics NX as shown in fig.6. This 3D model was then converted to IGES format for simulation in hyperform software.

Punch, Die and Blank surface CAD data generated by Unigraphics NX were the three inputs to the hyperform, using these inputs Crash Forming was performed to get the desired data. The punch, die and blank were meshed with the following data.

Meshing parameters for Blank, Die and Punch, used in Hyperform analyses, is shown in table 1 and table 2.

Table 1: Meshing parameters for blank

BLANK Meshing Parameters	
Average Edge length	30.0
Material	CRDQ
Thickness	2 mm

Table 2: Meshing parameters for punch and die

PUNCH and DIE Meshing Parameters	
Minimum edge length	0.5
Maximum edge length	30.0
Chordal deviation	0.1
Fillet angle	15.0

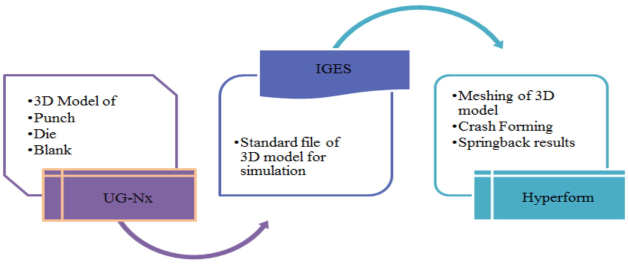

Fig.2: Simulation process for V bending

The simulation process, used to estimate the springback effect in V bending, followed in this study is summarised in fig.2.

Fig.3 and fig.4 shows the 3D imported file in IGES format and the meshing of the 3D assembly model, respectively.

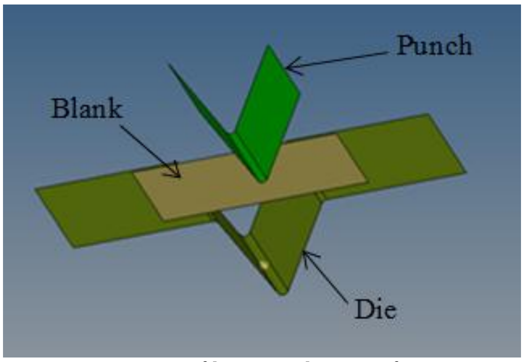

Fig.3: IGES file imported to Hyperform

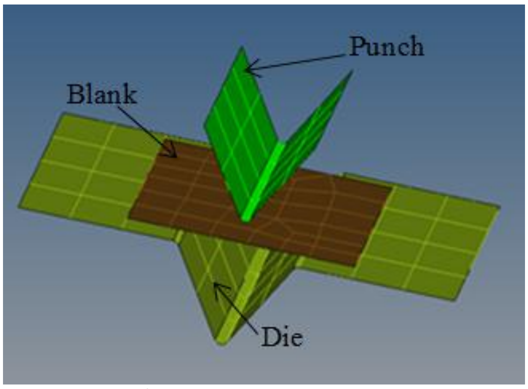

Fig.4: Meshing of punch, die by R-Mesh and blank by B-Mesh

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

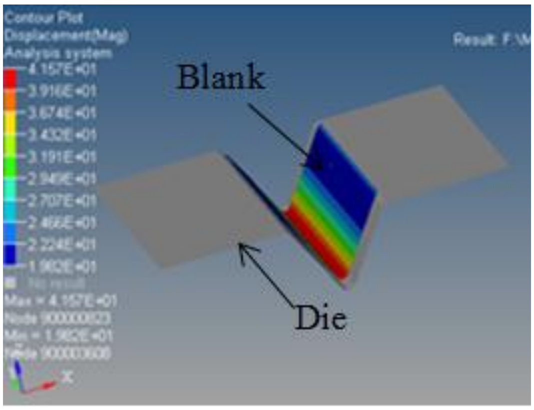

Fig.5: Crash forming simulation using hyperform

In this study, the punch diameter (P_d) is 2 mm and the bending angle of 60^0, were constant. Fig.5 shows the crash forming simulation done in hyperform.

Calculations

Bending force for V-Bending:-

$$F = \frac{k \times L \times T_S \times t^2}{W}$$

Where

F: Bending force (kgf)

L: Bending line length (mm)

t: Plate thickness (mm) = 2.0 to 4.0 mm

W: die shoulder width (mm)

T_S: Tensile strength (kgf/mm²)

Bending radii (R_2) = 3 mm

Die shoulder width (W) = 35 mm

Bending Coefficient (k) =

i. 1.33 {when the die shoulder width (W) is 8 times the material plate thickness (t)} ,
ii. 1.5 {when the die shoulder width is about 5 times the plate thickness (t)}, and
iii. 1.2 {when it is about 16 times the plate thickness (t)}

Therefore, F = 39520 kgf

B. 3D CAD Model

3D CAD model using part modeling module is made in UG NX, and this surface data (IGES Format) is imported to Altair hyperform from UG NX software.

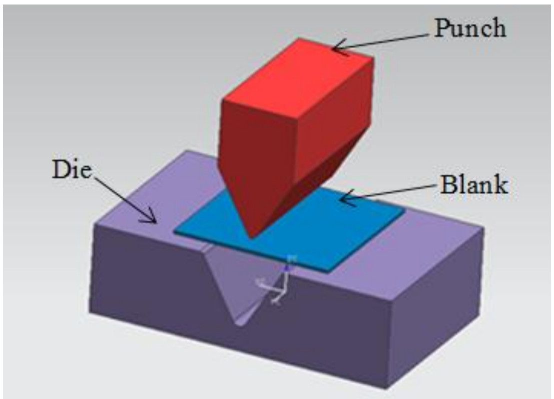

Fig.6: 3D model of the tool used for simulation

Fig.6 and fig.7 shows the 3D model of Tool and V bended component in UG-Nx, which was used for simulation in hyperform analyses.

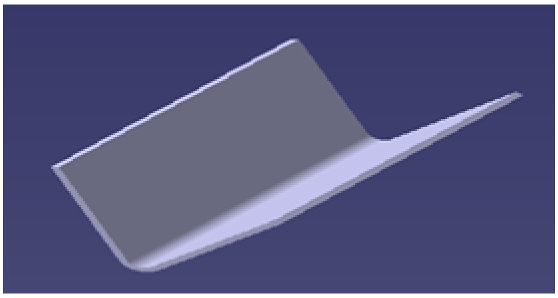

Fig.7: 3D model of blank after V bending

IV. Results and Conclusions

A. Results

The results of springback effect on sheet, after V bending, obtained from the hyperform analysis are shown in the following figures.

Fig.8 to fig.17 shows the data obtained through the hyperform software, depicting the springback angle in the V bending operation.

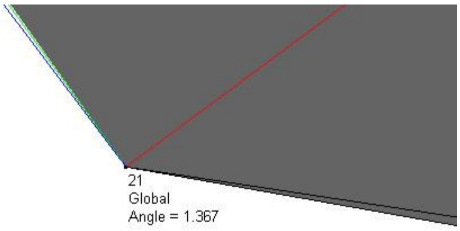

Fig.8: springback angle 1.367^0 for sheet thickness 2.0 mm

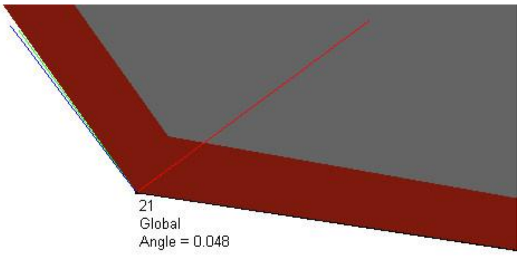

Fig.9: springback angle 0.048 for sheet thickness 3.2 mm

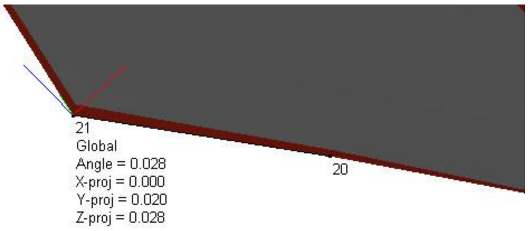

Fig.10: springback angle 0.028^0 for sheet thickness 3.3 mm

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

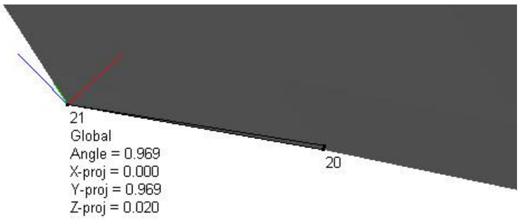

Fig.11: springback angle 0.969^0 for sheet thickness 3.0 mm

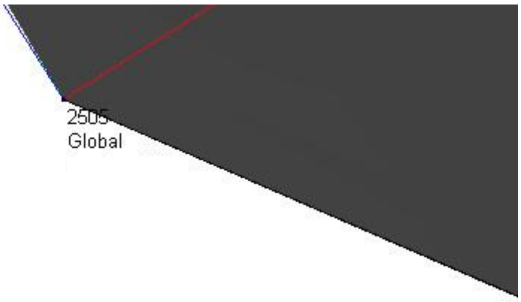

Fig.12: springback angle 0.134^0 for sheet thickness 3.5 mm

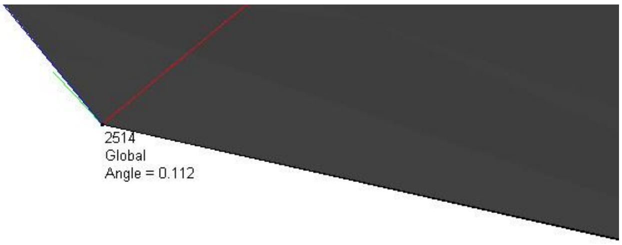

Fig.13: springback angle 0.112 for sheet thickness 3.4 mm

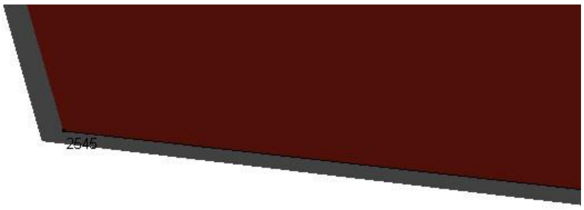

Fig.14: springback angle 1.125^0 for sheet thickness 2.5 mm

Fig.15: springback angle 1.051^0 for sheet thickness 2.8 mm

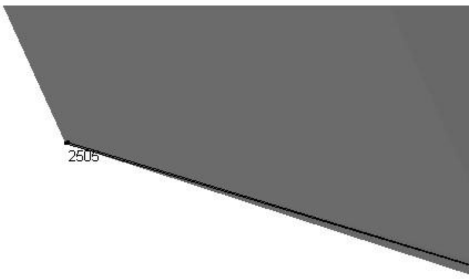

Fig.16: springback angle 0.161^0 for sheet thickness 3.8 mm

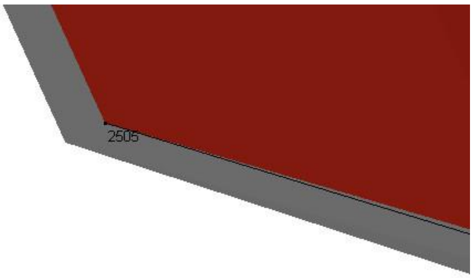

Fig.17: springback angle 0.188^0 for sheet thickness 4.0mm

Table 3 shows the data for amount of springback (in degree) with variation in sheet thickness. The table also shows the bending angle compensation required to obtain the desired shape of the V bend component. It shows that maximum amount of springback occurs at sheet thickness of 2.0 mm whereas minimum springback occurs at sheet thickness of 3.3 mm.

Table 3: Hyperform analyses data

Sn no.	Material thickness (mm)	Amount of Spring-back (^{0})	Bending angle after compensation (^{0})
1.	2.0	1.367	58.633
2	2.5	1.125	58.875
3.	2.8	1.051	58.949
4.	3.0	0.969	59.035
5.	3.2	0.048	59.96
6.	3.3	0.028	59.972
7.	3.4	0.112	59.888
8.	3.5	0.134	59.866
9.	3.8	0.161	59.839
10.	4.0	0.188	59.812

B. Conclusions

This study is an attempt to obtain the optimum sheet thickness (for CRDQ steel) for minimum springback angle. This is one of the several methods (discussed previously) to minimize the springback effect. This study also concludes that springback effect depends on the sheet thickness and efficient selection of sheet thickness plays an important role in reducing the springback effect.

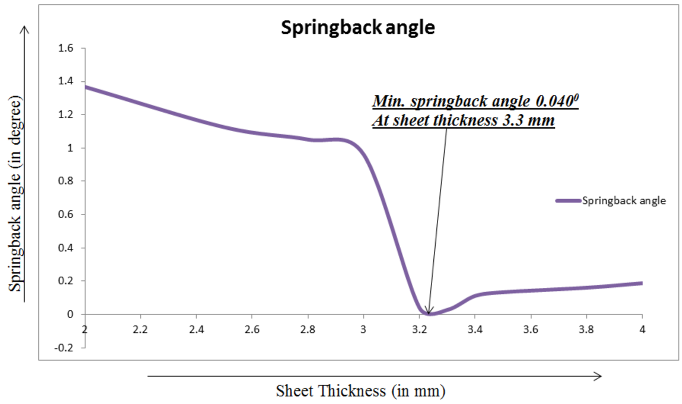

Fig.18: Graph between springback angle and sheet thickness

The results obtained, from the hyperform analysis, shows that when the bending angle and the punch radius are kept constant, there is variation in the amount of springback offered by the sheet.

i. Fig. 19 shows this variation of springback. As the sheet thickness is increased from 2.0 mm to 3.0 mm, springback angle starts to decrease gradually from 1.367^0 to 0.965^0.

ii. This gradual decrease in springback angle may be due to increase in plastic zone of the material (see Fig.1)

iii. Further increase in sheet thickness from 3.2 to 4.0 mm shows a steady increase in springback angle from 0.040^0 to 0.188^0.

iv. This steady increase in springback angle is due to increase in elastic zone along with plastic zone (see Fig.1)

v. It is also observed that when the sheet thickness was increased from 3.0 to 3.2 mm, there is a steep decrease in springback angle from 0.965^0 to 0.048^0. The decrease in angle is approximately 95%.

V. REFERENCES

[1] Panthi, S. K., N. Ramakrishnan, Meraj Ahmed, Shambhavi S. Singh, and M. D. Goel. "Finite element analysis of sheet metal bending process to predict the springback." Materials & Design 31, no. 2 (2010): 657-662.

[2] Panthi, S. K., N. Ramakrishnan, K. K. Pathak, and J. S. Chouhan. "An analysis of springback in sheet metal bending using finite element method (FEM)." Journal of Materials Processing Technology 186, no. 1 (2007): 120-124.

[3] Zhang, Dongjuan, Zhenshan Cui, Xueyu Ruan, and Yuqiang Li. "An analytical model for predicting springback and side wall curl of sheet after U-bending." Computational materials science 38, no. 4 (2007): 707-715.

[4] Chen, Peng, Muammer Koç, and Michael L. Wenner. "Experimental investigation of springback variation in forming of high strength steels." Journal of manufacturing science and engineering 130, no. 4 (2008): 041006.

[5] Thipprakmas, Sutasn. "Finite element analysis of punch height effect on V-bending angle." Materials & Design 31, no. 3 (2010): 1593-1598.

[6] Kazan, Recep, Mehmet Fırat, and Aysun Egrisogut Tiryaki. "Prediction of springback in wipe-bending process of sheet metal using neural network."Materials & design 30, no. 2 (2009): 418-423.

[7] Kim, Hong Seok, and Muammer Koç. "Numerical investigations on springback characteristics of aluminum sheet metal alloys in warm forming conditions." journal of materials processing technology 204, no. 1 (2008): 370-383.

[8] Tekaslan, Özgür, Nedim Gerger, and Ulvi Şeker. "Determination of spring-back of stainless steel sheet metal in “V” bending dies." Materials & Design29, no. 5 (2008): 1043-1050.

[9] Bakhshi-Jooybari, M., B. Rahmani, V. Daeezadeh, and A. Gorji. "The study of spring-back of CK67 steel sheet in V-die and U-die bending processes."Materials & Design 30, no. 7 (2009): 2410-2419.

[10] Parsa, M. H., and M. Ettehad. "Experimental and finite element study on the spring back of double curved aluminum/polypropylene/aluminum sandwich sheet." Materials & Design 31, no. 9 (2010): 4174-4183.

[11] Kim, Hyunok, Ninad Nargundkar, and Taylan Altan. "Prediction of bend allowance and springback in air bending." Journal of manufacturing science and engineering 129, no. 2 (2007): 342-351.

[12] Leu, Daw-Kwei, and Chung-Ming Hsieh. "The influence of coining force on spring-back reduction in V-die bending process." Journal of Materials Processing Technology 196, no. 1 (2008): 230-235.