International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

# Sheet Metal Forming Analysis with An Emphasis on Spring Back Deformation

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**ABSTRACT**

**Stress analysis plays important role in structural design and manufacturing. Proper stress estimation helps to prevent objects from failing during working. Spring back is mainly due to nonlinear plasticity with friction and heat loss in the material. Bauschigner effect is the main cause of this spring back phenomenon. In the present work, an analysis is carried out to find the spring back on the metal forming process is. Initially a geometrical model in plane strain approach is built using ANSYS mixed approach. The geometry is split to form mappable areas to quad meshing. Later contact elements are defined between the punch and the sheet metal and second contact pair between sheet metal and die surface. The analysis is done using Newton raphson iterative method to find the cone angle effect on spring back phenomenon. The results shows with the reduction in the cone angle all these parameters are increasing. Increasing plastic strain and residual stress are the potential sources for crack formation and propagation and eventual failure of the members.**

## 1. INTRODUCTION

Bending of sheet metal is one of the widely used in industrial process, especially in automobile and aircraft industries, sheet metal bending is one of the most widely applied sheet metal forming operation. Bending is such a shaping process used commonly in various sheet metal industrial products. The sheet parts in these products and in the others are shaped using bending dies. According to the shape of the product, the bending is divided into the following: Air bending .U-bending, V-bending, Roll bending, Edge bending.The accuracy and success of the bending process depends upon the operating parameters as well as, material properties, clearance, radius of the die and punch, friction condition etc.In past, sheet metal bending processes are dependent on the designer's experience and involve trials and errors to obtain the desired result. Many analytical models are proposed to study spring back in bending by using simple beam or plate bending and these models use a simplified assumption.

**The nature of the bending process.**

**V-Bending**: A V-bending operation is commonly performed by compressing the metal strip between a matching V- shaped punch and die. In most of the air bending, or free bending, a sheet is commonly supported by two shoulders of a stationary die. The required bending angle can be determined from the die opening and punch displacement as shown in Figure 1. Shows the springback was quantify based on the deviation of bend and usually refer as springback ratio. Figure1.1 defines the springback measurement for the V-bending method. The advantages of the V-bending die are the economical set-up time and fabrication of a wide range of part size and complex shape It has the advantage over other bending processes, for example, there is no need to change the dies to obtain different bending angles. The basic advantages of the V-die bending process are as follows:

A simple tool design, an economical setup time, and an enormous range of sizes and complex shapes that can be fabricated for the part but in contrast result in less accuracy.

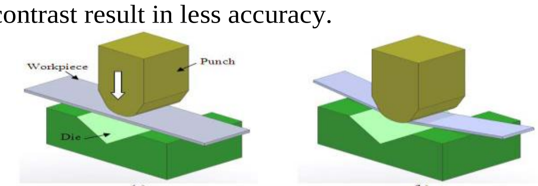


Fig. 1: V-bending process setup, (a) initial stage and (b) final stage

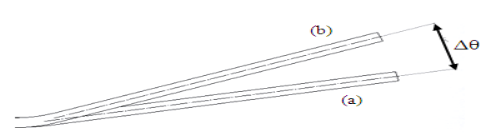


Fig.1. 1: Definition of the springback for v-bending, ( a) loading, (b) unloading

B. GRIZELJ et. al [1] In this paper St1403 Sheet Metal Plate is used to determine the effect of spring back and spring forward. Investigated two FEM simulations with different tool geometries were performed. During calibration sheet metal plate is in contact with both punch and die, and force causes large plastic deformation. It is commonly known that with large plastic deformation in the bended area – the amount of spring back is reduced.

ZHANG and LIN [2] developed an analytical model to study the springback in sheet metal stamps with a rigid punch and an deformable die. They discussed the dependence of springback on the main stamping parameters in detail. The study reveals that reduction of the springback ratio mainly due to interface action offered by the punches. The deformation of punch material during stamping alters the deformation mechanism of the sheet and makes springback ratio negative.

S. Thipprakmas and S. Rojananan [3] investigated spring-back and spring-forward effects with FEM method. When sheet metal plate is bended, outer „fibers" are under tension, and inner "fibers" are under compression. The neutral line divides tension and compression areas. When sheet metal plate is released of loads –fibers under tension tries to contract, and fibers under compression tries to extend, thus sheet metal plate opens until remaining stresses are in equilibrium. This is the effect of spring-back. According to the phenomenon of spring-forward yet needs to be investigated.

W. L. Xu et al [4] investigated sensitive factors in FEM springback simulations. They concluded that FEM analysis is very complicated because of various input parameters such as material constitutive law, strain hardening curve, FEM element type, contact model, friction law, material and geometrical nonlinearities.

W. Frącz and F. Stachowitz [5] compared conventional pure bending theory with FEM simulations and experimental results and concluded that in the history most of the analytical approaches were based on the simple beam and plate bending theories.

W. M. Chan et al. [6] investigated the effect of spring-back with FEM analysis and concluded that the spring-back reduces with increased punch angle and punch radius. They also determined that with larger deformation zone (especially in closed V-die) the effect of spring-back is also reduced

ZHANG et al. [7] presented an analytical model to predict the springback in 'V' bending considering combined hardening coefficient, blank holder force, sheet thickness etc.

Tekiner et al [8] carried out an experimental study on the determination of springback on bent products. The amount of springback of several sheet metals with different bending angles was obtained on 'V' bending dies.

Ogawa et al. [9] considered the accurate prediction of spring-back in a V-bending process without friction, using the finite-element method with element meshes of different sizes and comparing the results to those of experiments.

## 2. METHODS AND METHODOLOGY

### A. *Finite Element Method:*

In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements. The material properties and the governing relations are considered over these elements and expressed in terms of unknown values at element corner. An assembly process, duly considering the loading and constraints, results in a set of equations, solution of these equations gives us the approximate behavior of the continuum. The analysis which uses FEM is known as FEA. A general purpose FEA program consists of three modules; a pre-processor, a solver, and a post processor. Commercial FEA programs can handle very large number of nodes and nodal degrees of freedom provided a powerful hardware is made available. User's manual, theoretical manual, and verification problems manual, document a commercial FEA program.

### B. *Non Linear Analysis:*

In a nonlinear analysis, an initial condition at the start of each increment is the state of the model at the end of the previous one. This dependency provides a convenient method for following complex loading histories, such as a manufacturing process. At each increment, the solver iterates for equilibrium using a numerical technique such as the Newton Raphson method. Due to the iterative nature of the calculations, non linear FEA is computationally expensive, but reflects the real life conditions more accurately than linear analyses.

### C. *Newton Raphson method:*

Newton raphson method is the widely used technique to arrive at the solution for the non linear problems. Concept of time: we have discussed that the loads in a non linear analysis are applied in an incremental manner. Hence while simulating such behavior we specify the load as a function of time. The time is just used to define the pattern in which the load should be increased for the model. The time specified here is completely a pseudo time and cannot be mistaken with the real time is used to apply time varying loads in a transient analysis.

## 3. MATERIAL SPECIFICATIONS:

Material Specifications:
Material: Mild Steel, Young's modulus=200Gpa
Density =7800kg/m$^3$, Yield stress=250Mpa
Plastic Modulus=3000Mpa.

### A. Model Specifications

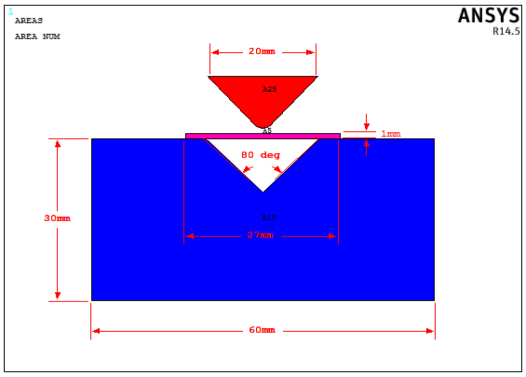


Fig 3.1: Geometrical dimensions of the Forming process

The figure shows geometrical parameters of the spring back system. The dimensional details are given in the problem. 80 $^{0}$ included angle is considered for the die. The primary objective is to analyze the effect of cone angle on spring back phenomenon. ANSYS mixed approach is used to built the geometry. Thickness of the sheet metal is considered as one mm. The mixed up approach considers point, line and area approach for complicated object (Punch and die) and direct rectangle creation for the sheet metal.

### B. Symmetric Representation Of The Geometry

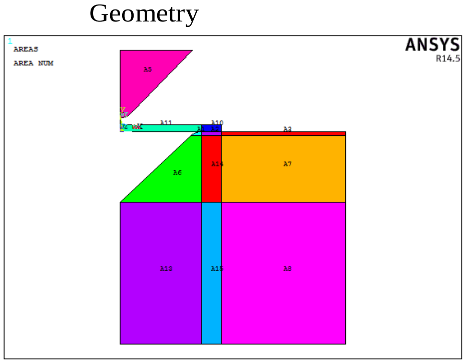


Fig.3.2:

Fig 3.2: Symmetric Representation of the forming process

The figure shows symmetric representation of the geometry. Since the problem is having symmetry, the geometry is built for half geometry. The geometry is split to ease map mesh of the structure. Map mesh is required for graphical plots to show variation in stress and contact pressure along with plastic strain. With free mesh, the elements are in disorder with shape and size, so free mesh can't be used for graphical presentation. So work plane option is extensively used to cut the geometry to regular shapes to built meshable areas. Also it helps for better convergence which is the most difficult part of convergence.

### C. Mesh Specifications

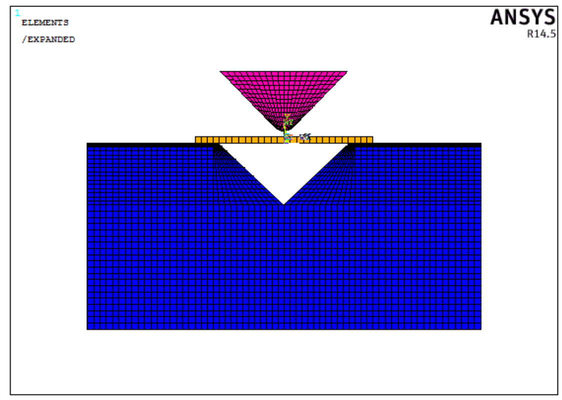


Fig 3.3: Map Meshed Geometry

The members are map mesh with the appropriate material properties. Steel properties are given for sheet metal and rigid material properties are given for die and punch members. Since the sheet metal is the point of interest, the body is meshed with deformable material properties. Plane182 element with plane strain option is used for meshing. Plane182 element has the properties of large deformation effects which is the essential requirement of the forming materials. A finer mesh is considered at the corner regions for better convergence. 1580 elements and 1693 nodes are used for meshing half symmetric geometry.

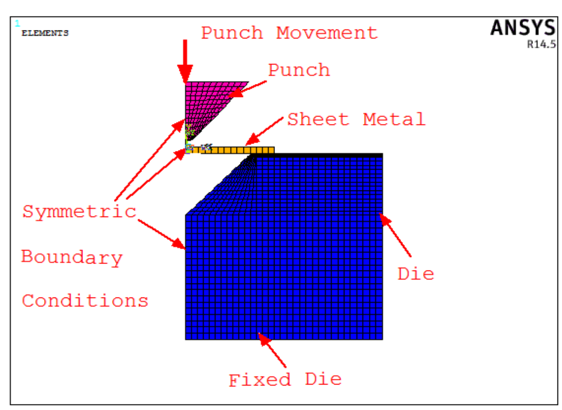


Fig 3.4: Applied Boundary Conditions on the problem

The figure 3.4 shows applied boundary conditions on the problem. Here the bottom die is fixed in all directions. Punch is given the displacement load.

Symmetrical boundary conditions (Ux=0) is applied at the center of the problem. Punch is applied with moving boundary conditions specifying Ux =0(X-axis constrained). Sheet metal is given elasto -plastic material properties with strain hardening effect. The members are shown with different colors to identify the parts. A fine mesh can be observed at the corner and fillet region.

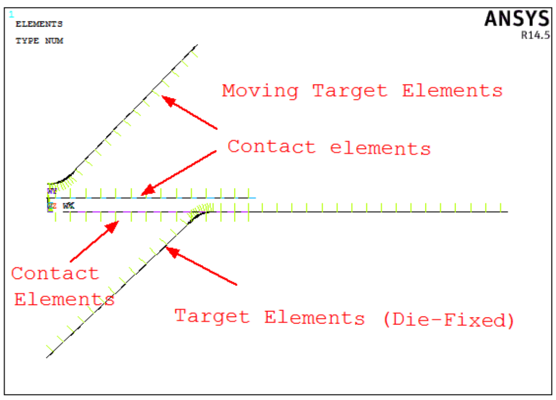


Fig 3.5: Contact pairs.

The contact elements are created between punch and sheet metal. Similarly contact pair is created between bottom die and sheet metal. Targe169 and contac172 elements are defined in the two contact pairs. These elements can predict contact behavior of the structure. These elements will be created on the existing plane elements. The elements use eulerian algorithm to predict and find the stress conditions during movement. Initially the lines of contacts are selected and nodes are grouped to nodal components to create the contact pairs.

## 4. RESULTS

Analysis has been carried out after giving displacement to the punch elements. Here the area mesh of both punch and die are cleared to increase the speed of computation. This is possible after the contact pairs are created. So the punch target elements are given the required displacement load for bending process. The die target nodes are fixed in the position. Incremental procedure based on Newton Raphson method is applied to solve the problem in the nonlinear material and geometrical domain.



A. I. Spring Back (With cone Angle $80^0$) - Loading condition:

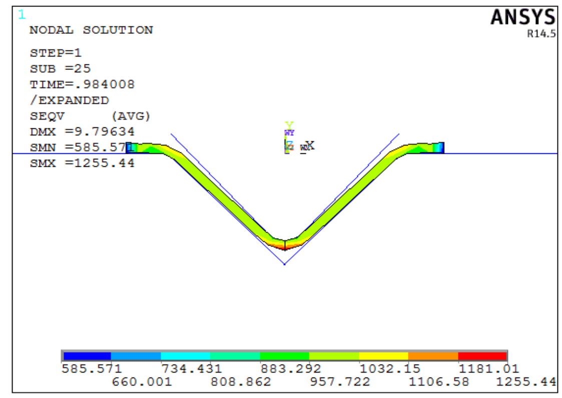


Fig. 4.1: Final Vonmises stress during loading.

The figure.4.1 shows final vonmises stress in the structure. Maximum stress is around 1255.44Mpa at the extreme corner of the sheet metal. This can be attributed higher deformation at the extreme corner. The strain is directly proportional to stress. Here strain is maximum due to plastic yielding of the sheet metal. Minimum stresses are developed at the end portions of sheet metal which are not displaced from the original configuration. Vonmises stress is the stress corresponding to the stored energy and also it is called as equivalent stress.

II. Contact pressure at the extreme bending process.

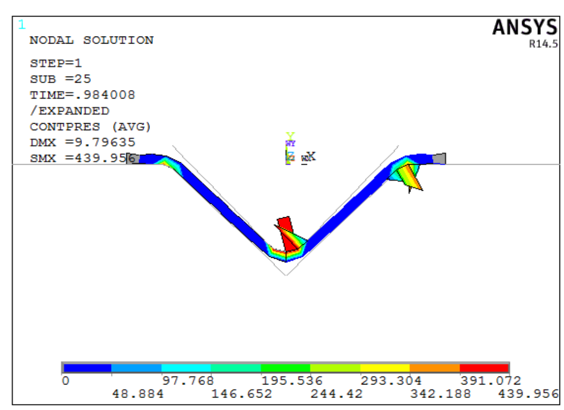


Fig 4.2: Contact pressure at the extreme bending process.

The figure 4.2 shows final contact pressure in the problem. Maximum contact pressure is around 439.956Mpa as shown in figure. Higher contact pressure generally shows higher load requirement along with improper die and punch shapes.

Always less contact pressure is desirable for better results.

III. Plastic Strain in the end of loading process

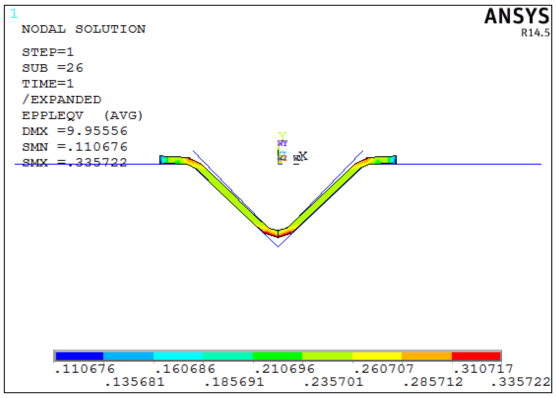


Fig 4.3: Plastic Strain in the end of loading process.

The figure 4.3 shows plastic strain in the member during the end of loading process. Maximum plastic strain is 0.335722. Higher the plastic strain, possibility of cracking in the material is more. Also it can be predicted for crack generation in the sheet metal once it crosses the limiting strain value.

IV. Spring Back (With cone Angle $80^0$) – loading Condition:

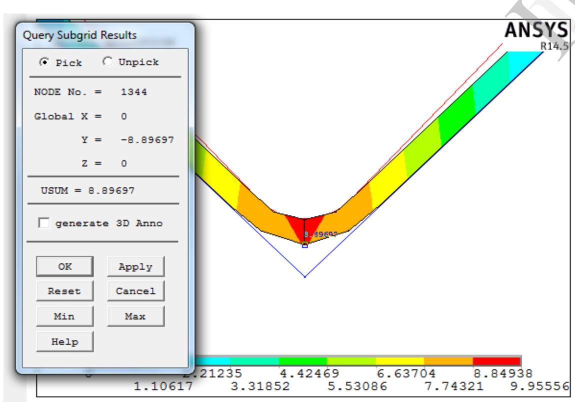


Fig 4.4: In the final movement of punch displacement.

The figure 4.4 shows final displacement in the structure during punch movement. Maximum displacement value is around 9.95556mm. Queried results shows maximum deformation of the extreme configuration is 8.89637mm. ANSYS query option helps in finding the displacement of various nodes. The red color shows maximum deformed position. Other colors show variation in the displacement along its path. ANSYS query option shows picked number is 1344. Maximum displacement is related to the punch displacement.

B. I. Spring Back (With cone Angle $80^0$) – unloading Condition:

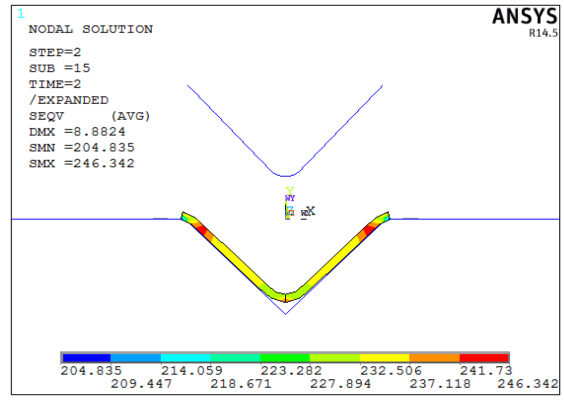


Fig 4.5: residual stress in the sheet metal after unloading.

The figure .4.5 shows residual stress retained in the structure after unloading process. Maximum residual stresses are observed at the corner fillet region and at the central region. Maximum stress value is around 246.342Mpa. Minimum residual stress observed is around 204.835Mpa.



II. Retained Plastic Strain in the member.

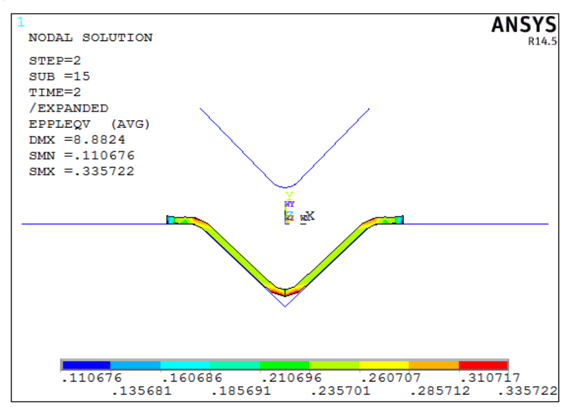


Fig 4.5: Retained Plastic Strain in the member

The figure 4.5 shows retainment of complete plastic strain in the structure. So this permanent strain is not recovered in the process. So this will cause residual stresses in the structures along with the source for cracking.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

III. Spring Back (With cone Angle $80^0$) – Unloading Condition:

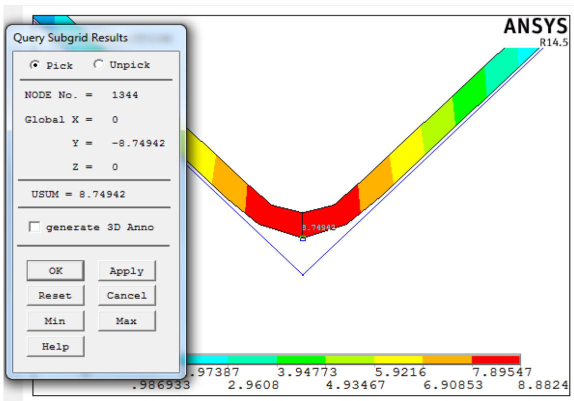


Fig4.6: Spring back after unloading:

The figure 4.6 shows final retained displacement in the sheet metal after the punch is removed. Maximum retained displacement for the structure is 8.8824mm. ANSYS queried results shows un-averaged value of 8.74942mm. This shows some spring back in the process. This shows some elastic recovery in the process. This elastic recovery is the cause of spring back in the structure.

Calculation for spring back:

Punch end Deformation: 8.89697mm
Retained Deformation: 8.74942mm
Spring back: 8.89697-8.74942=0.14755mm
Spring back effect =1.658%

Table 4.1: Numerical results for the Sheet Metal Bending Process

| Cone Angle(degrees) | Spring Back(mm) | Percentage of Spring Back | Vonmises Stress (Mpa) | Contact Pressure(Mpa) | Residual Stress (Mpa) | Plastic Strain |
|---|---|---|---|---|---|---|
| 80 | 0.14755 | 1.658 | 1255.00 | 439.90 | 246.3 | 0.3357 |
| 75 | 0.14768 | 1.660 | 1281.00 | 462.00 | 246.7 | 0.3364 |
| 70 | 0.14781 | 1.689 | 1281.24 | 464.24 | 247.06 | 0.3364 |
| 65 | 0.14914 | 1.705 | 1285.00 | 467.40 | 247.4 | 0.3376 |

The table 4.1 shows influence of cone angle on spring back phenomenon. It is observed that as the cone angle decreases, spring back and percentage spring back is increasing. So decrease in cone angle is not good for sheet metal forming process. The same thing is proven through graphical plots represented below.

C. Graphical Plots

I. Cone Angle to Spring back

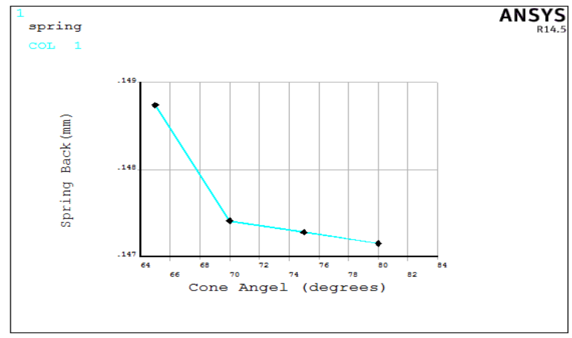


Fig 4.7: Cone Angle to Spring back

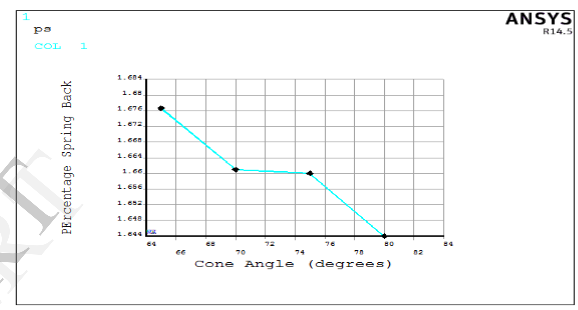


Fig 4.8: Cone angle to Percentage spring back

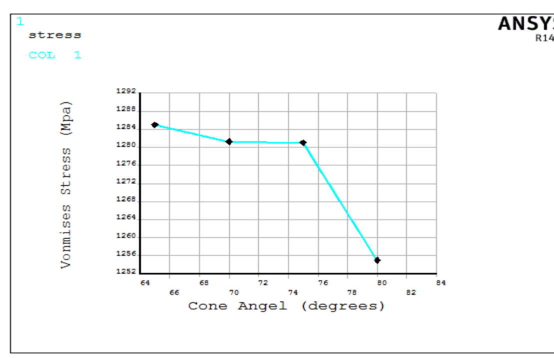


Fig 4.9: Cone angle to Residual stress graph

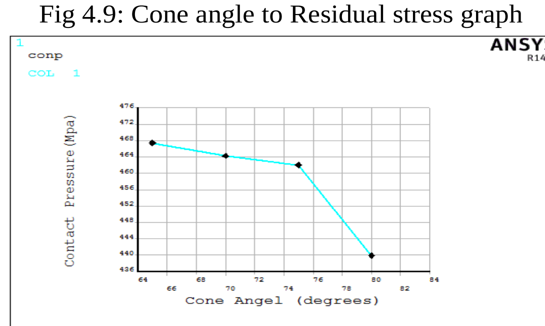


Fig 4.10: cone Angle to Contact Pressure Graph

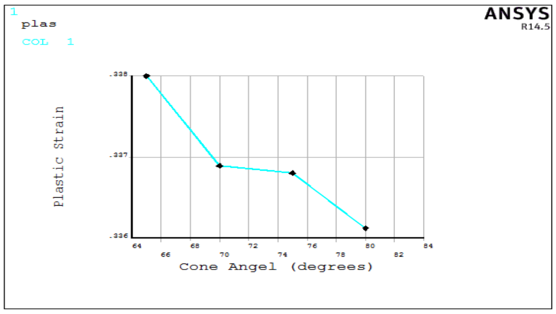


Fig 4.11: Cone angle to Plastic Strain graph.

## 5. Conclusions:

In the present work, the effect of cone angle on springback is analyzed using Finite element methods. The overall summary of results is as follows.

1. The results shows cone angle has effect on springback deformation. With the reduction in the cone angle , spring back, percentage of springback, vonmises stress, residual stress, contact pressure and plastic strains are increasing which is not a desirable parameter
2. Increasing residual stress and plastic strains are the sources for crack formation and propagation.
3. Increasing contact pressure requires stronger die and punch which will increase the process cost.

### *Referance:*

[1]BrankoGRIZELJ, Josip CUMIN1 and Dejan GRIZELJ.: Effect of Spring-Back and Spring-Forward in V-die Bending of St1403 Sheet Metal Plates; Strojarstvo 52 (2) 181-186 (2010)

[2] ZHANG L C, LIN Z.: An analytical solution to springback of sheet metals stamped by a rigid punch and deformable die . J Material Processing Technology, 1997, 63: 49−54.

[3] Thippraksmas , S.; Rojananan, S.: Investigation of spring-go phenomenon using finite elementmethod, Materials and design 29 (2008), pp 1526- 1532.

[4 ]Xu, W. L.; Ma, C. H.; Li, C. H.; Feng, W. J.: Sensitive factors in springback simulation for sheet metal forming, Journal of Materials Processing technology 151 (2004), pp 217-22

[5] FrAcz , W.; Stachowitz , F.: Springback phenomenon in sheet metal V-die air bending – experimental and numerical study, Manufacturing engineering (Výrobné inžinierstvo), Year 2008, Issue 2, pp 34-37.

[6] S Chan , W. M.; Chew , H. I.; Lee , H. P.; Cheok, B. T.: Finite element analysis of spring-back of V bending sheet metal forming process, Journal of materials processing technology 48 (2004), pp 15-24

[8]Tekiner Z. An experimental study of the examination of spring-back of sheet metals with several thicknesses and properties in bending dies. J Mater Process Technol 2004; 145:109–17

[7] Florica Mioara Groze1; Gheorghe Achimaş .; Springback prediction of the V- bending processs using finite element simulation; 7th International MultidisciplinaryConference
Baia Mare, Romania, May 17-18, 2007 ISSN-1224-3264

[8] Mohammad R. Barouzeh and Mahdi Mondali.; Springback Investigationat Warm V- bending Conditions by Numerical and Experimental Methods ; International Conference on Trends in Mechanical and Industrial Engineering (ICTMIE'2011) Bangkok Dec., 2011

[9] M.A. Osman, M. Shazly, A. El-Mokaddem, A.S. Wifi, Springback prediction in V-die bending: modelling and experimentation, Journal of Achievements in Materials and Manufacturing Engineering 38/2 (2010) 179-186.

.

[2] Pourboghratc, Kwansoo Chungd, Dong-Yol Yang.: Springback prediction for sheet metal forming processusing a 3D hybrid membrane/shell method; International Journal of Mechanical Sciences 44 (2002) 2133–2153.