Springback Analysis of Wipe Bending Process by Ansys

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Abstract- **Sheet metal stamped components find extensive use in engineering industry, in particular, in automobile like passenger cars, two wheelers, domestic white goods like washing machines, air conditioning equipment and electrical control equipment like switch gears and switches. The annual turnover in this sheet metal stamping industry itself extends to several thousands of lakhs of rupees. This is assuming importance because the process supplies near net shapes without the need of further machining. But in these sheet metal forming processes particularly in bending , defects such as rupture, wrinkling, galling and Springback in formed parts might occur, whether during or after the process. The Springback phenomenon is the most complex and challenging issue in industry.**

This work presents a study of spring back in wipe bending metal forming process. Spring back is one of the most sensitive features of the sheet metal forming, which occurs due to elastic recovery during unloading. The main purpose of this work is spring back prediction of sheet metal copper alloy and investigation into the causes of the spring back, such as process parameter, geometry of tools etc. In this work the prediction model of spring back in wipe bending process was developed using finite element method code ANSYS APDL 14.0 and an over bend approach is applied to compensate the spring back and the obtained spring back for different process parameters are validated by analytical method.

Index terms – **Ansys, Springback, Wipe Bending Process**

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I.   INTRODUCTION

A large variety of metallic parts of automobiles, aircrafts, building products and domestic appliances are produced by deformation processing. This comprises manufacturing methods that are used to create the primary shape of products by plastically deforming the material. Well-known examples are forging, rolling, extrusion, sheet metal forming and hydro forming. Sheet metal forming is a special class of deformation processes in which blanks, with the thickness being much smaller than the other dimensions, are formed into the desired shape. [9]Sheet metal forming is one of the most widely used manufacturing processes for the fabrication of a wide range of products in many industries. The reason behind sheet metal forming gaining a lot of attention in modern technology is due to the ease with which metal may be formed into useful shapes by plastic deformation processes in which the volume and mass of the metal are conserved and metal is displaced from one location to another. [7]

Sheet metal forming operations consists of simple bending, ironing, wheeling, press brake forming, stretch forming, roll forming, rubber-pad forming, stamping, flanging, spinning, embossing, bulging, hyper plastic forming, peen forming, explosive forming, magnetic-pulse forming and deep drawing of complex parts [6]Indeed, the sheet metal products have become current also due to low price, accuracy of dimensions, durability and favorable physical properties. In today's industry, where the costs play a very important role, the sheet metal products have replaced many products made by forming process. They have replaced also many complex composed products. [7]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. In many industries, e.g. automotive industries, Springback plays an important role in tooling and process designs. To effectively predict Springback for a potential application in determining optimal tooling shapes and process parameters, understanding the mechanics of Springback, a mainly elastic recovery process, is essential. [14]In the bending technology it is difficult to achieve accurate and repeatable angle of a bend. This problem is caused by elastic Springback, which is considerable in processes of sheet metal forming [1-4]. Springback in processes of sheet metal forming causes troubles in assembling processes, because Springback entails anomaly of required shape of the part. Economical aspect of problems associated with Springback is in the USA solely in the sphere of automotive industry estimated on the 50 million

dollar per year [5]. Springback is defined as a dimensional change of a shape after releasing a tool due to elastic effects [6]. In the past, handy tables or graphs were the traditional ways used for prediction of Springback. For this purpose, today are frequently used FE codes, which provide numerical simulations of sheet metal forming processes. [2]
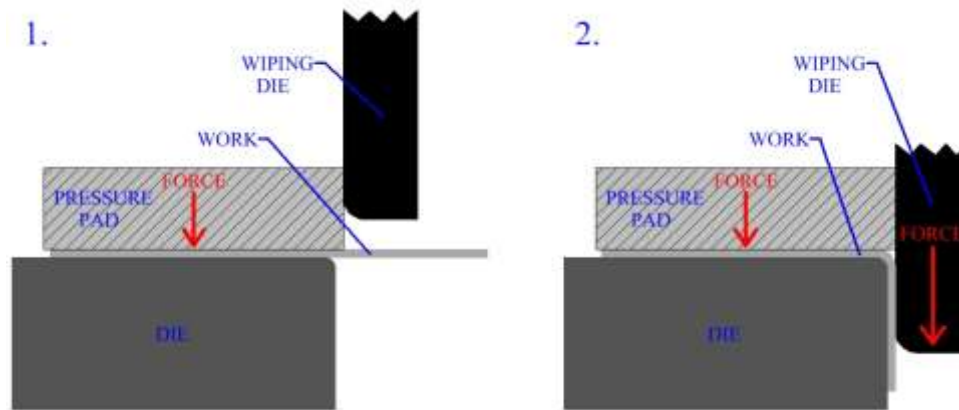
WIPE BENDING PROCESS

Figure.1 Sheet metal bent using wiping dies

A wiping die is as shown in fig. Here the work piece is clamped to a die block by a spring-loaded or fluid-cylinder pressure pad, and the punch wipes the extended materials over one edge of the die. A bend radius is provided on the edge of the die block. A radius or chamfer is often provided on the leading edge of the punch to prevent the wiping action from being too severe. [11]

PRINCIPLE OF SPRINGBACK

The elastic strains remaining in the bend region after bending load or pressure is removed will leads to a slight decrease in the bend angle. This decrease in bend angle is known as spring back, as shown in below figure.

The Springback phenomenon will vary according to the material type, thickness and hardness. A larger bend radius will also cause grater spring back. For forming process the material will be stressed beyond elastic limit so that the permanent deformation takes place. The material status enters the plastic deformation region. Hence the sheet metal can be formed. Figure 2 shows the principle of spring back. [14]
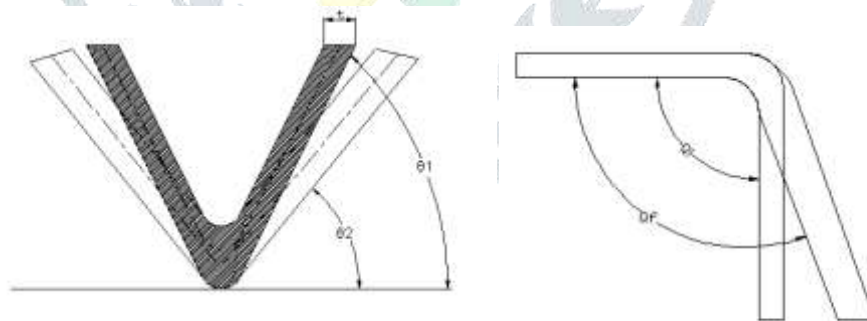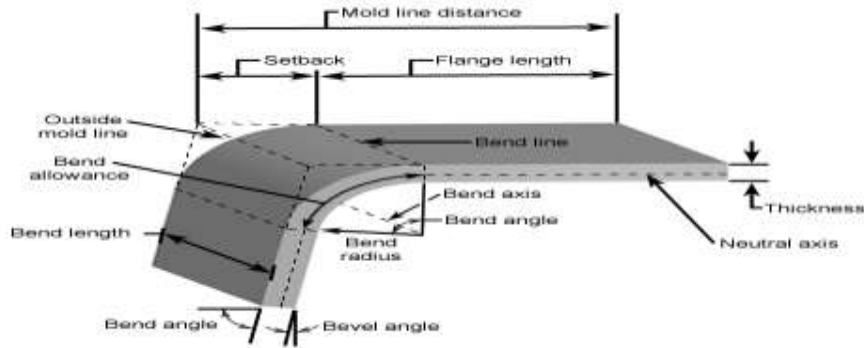

Figure.2- principle of springback

Fig.3. shows bend Specification of wipe bending process. [7]

The wipe-bending process plays a major role in sheet metal forming industry. In the bending process, after release of the load by withdrawal of the punch, the metal tries to return to its original shape because of the elastic stresses. This phenomenon is so-called ''Springback''. Springback is an important parameter in tooling design and obtaining the desired geometry of the part; hence Springback prediction is a considerable issue in sheet metal forming.

Many factors could affect Springback in the process, such as material variation in mechanical properties, sheet thickness, tooling geometry or forming speed. [3] In this work investigation of the factors, which are the reasons to cause the Springback are studied and analyzed. And an optimum method to avoid the Springback will be presented.

PROBLEM STATEMENT

It is reported from the industry users that problems are encountered with such sheet metal stamped parts that
a) The parts are not as per the geometry they expected in spite of correct tools.
b) As the parts are bent to a required bend angle, after removal of load the desired bend angle is not achieved after removal of load.
c) Such of the parts that are subjected to varying loads during use are undesirably losing elasticity and are permanently getting into plastic deformation, leading to reduced component life.

It is now proposed in the work to investigate into the causes and possible suitable solutions to the problem. The following will be investigated.

OBJECTIVES

1. It is known that the sheet metal stamped components undergo elasto-plastic deformation during the stamping process. The strain in the component is large enough to cause yielding.
2. Because of the elastic portion of the strain, the component will 'spring back' by some amount.
3. One of the solutions for preventing geometric inaccuracy is to predict and correct the 'spring back' in the bending process.
4. The main objective is to study the causes for Springback and suggesting the method to compensate the Springback which we are studying in this work.

II.   WIPE-BENDING PROCESS AND FE SIMULATION

The wipe-bending process is one of the mostly applied bending operations for flanging. In this study, the bending process was simulated using finite element (FE) software ANSYS (14.0). In the simulation modeling the tooling is defined geometrically by rigid surfaces. The sheet is represented by a deformable mesh. The tooling and sheet of the process and the geometry parameters are shown schematically. Following assumption/options are used during the analysis.

a. The sheet metal is in plane strain conditions along the flange width direction and in Plane stress conditions along the sheet thickness direction,
b. The sheet metal is homogeneous and isotropic,
c. The sheet metal follows the power hardening law and von Mises yield criterion,
d. Planes normal to the sheet surface remain planes during the deformation process,
e. The Bauschinger effect is neglected,
f. The middle layer of the sheet is considered to be bending-strain-free,
g. Volume conservation is assumed so that the volume variation due to elastic deformation is negligible, moment distributions along the straight and curved parts are linear,
h. Only elastic deformation occurs in the unloading stage.

In the process, first the sheet is clamped between die and blank holder, and then the punch moves downward to bend the sheet. After release of the load by withdrawal of the punch, the springback taken place and the change in the wall angle Ө, is defined to be a measure of distortion.

FINITE ELEMENT MODELING

FE simulation for L bending or wipe bending process of sheet metals was carried out by using a software package ANSYS 14. In order to elaborate the simulation model of the L-bending process of sheet metals, the following aspects have been taken into account. Establishing a set of parameters which have a significant influence on the springback in L bending process: dimensional parameters of the raw part (rectangular strip): thickness, length, width; geometry of the tools, elastic-plastic behavior of the material, elastic properties: E, ν.The FE model was created in ANSYS using plane183 element whose description is given below.

ELEMENT TYPE

PLANE183

PLANE183 is a higher order 2-D, 8-node or 6-node element. PLANE183 has quadratic pure displacement behavior and is well suited to modeling irregular meshes (such as those produced by various CAD/CAM systems).

The plane183 element is described by 8 nodes or 6 node which are having two degrees of freedom at each node i.e. Translations in the nodal x and y directions. This element can be used as a plane element (plane stress, plane strain and generalized plane strain) or as an axisymmetric element.

This element has plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. [12]
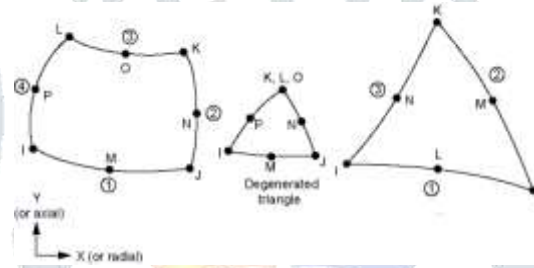

Figure.4- Plane 183 element

Table 1 - Summary of the Plane 183 element input

Element name	PLANE183
Nodes	I, J, K, L, M, N, O, P
Degrees of Freedom	UX, UY
Real Constants	None
Material properties	EX, EY, EZ, PRXY, PRYZ, PRXZ, ALPX , DENS, BETD
Special Features	Elasticity, Element Technology Auto selects, Hyper elasticity, Large Deflection, Large Strain, Linear Perturbation, Nonlinear Stabilization, and Plasticity with User Defined Material.

Since in the wipe bending process there exists contact between the die surfaces and sheet metal and also the punch surfaces to sheet metals surfaces hence it is necessary to provide the contact surfaces, if not the punch just passes through the sheet metal without bending. Hence other than the Plane 183 element, in the FE modeling TARGE169 and CONTA172 are used, these elements main function is to provide the contact between the respective surfaces in this process. [12]

TARGE169

TARGE169element is used as a 'Target' surface for different 2D models with the associated contact elements (CONTA171, CONTA172, and CONTA175). The contact elements always try to overlay themselves on the solid elements showing the boundary of a deformable object or body and are strongly in contact with the target surface, defined by TARGE169.

This target surface is separated or divided into set of segments which get paired with the respective contact surface through some real constant. We can apply any translational or rotational displacement, temperature, voltage, and magnetic potential on the target segment element. We can also apply forces and moments on target elements.
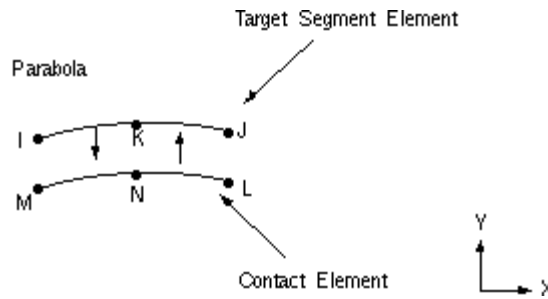
Figure.5- TARGE169 Element

CONTA172

CONTA172 represents contact and sliding between 2-D 'target' surfaces (TARGE169) and this CONTA172 element is used to represent the contact surface of a deformable body. The element is applicable to 2D structural and coupled field contact analyses. This element is positioned on the surfaces of 2D solid elements with midside nodes (PLANE35, PLANE77, PLANE53, PLANE121, PLANE183, SHELL209, PLANE223, PLANE230, or MATRIX50). [13]

This element has the same geometric characteristics as that of the solid element face or surface by which it is connected. (See Figure 6). The contacts between the two surfaces occur when element surface penetrates on one of the target segment element on a specified target segment. This element also allows separation of bonded contact to simulate interface delamination [13]

Figure.6- CONTA172 Element

In this study, finite element model with the variable geometry parameters and hardening characteristics are developed. The simulations are carried out in four groups based on the factors which are causing springback.

In the first group simulations, the geometry parameters that are going to be changed are die shoulder radius (Rd) and the remaining parameters are unchanged. And in the next groups of simulations, the geometry parameter that are going to be unchanged are punch nose radius (Rp), Die gap clearance (g) and sheet metal thickness (T).

Table2-Values of different process parameter on which FE model are prepared

1st group	2nd group	3rd group	4th group
Die radius (mm)	Punch radius (mm)	Sheet thickness (mm)	Die gap (mm)
0.2	0.2	0.3	0.3
0.5	0.4	0.4	0.4
0.8	0.6	0.5	0.5
1.1	0.8	0.6	0.6
1.4	1	0.7	0.7
	1.5 & 2		
Optimum 'Rd'	Optimum 'RP'	Optimum 'T'	Optimum 'g'

In first group the effect of the die shoulder radius is analyzed i.e. five set of FE models are prepared with different die shoulder radius and other parameters are unchanged as shown in below table.

Table 3- different die shoulder radius with unchanged parameters

Rd (mm)	RP (mm)	T (mm)	g (mm)
0.2	0.2	0.3	0.3
0.5	0.2	0.3	0.3
0.8	0.2	0.3	0.3
1.1	0.2	0.3	0.3
1.5	0.2	0.3	0.3
Changing parameter	The unchanged parameters		

After conducting the FE analysis, we will get an optimum die shoulder radius at which the springback angle (value) will be minimum that optimum radius is considered as constant (unchanged) during the analysis of other parameters.

Similarly in the second group five FE models with different punch nose radius were prepared and other parameters Rd, T and g are unchanged.

Table 4- Different punch nose radius

Rp (mm)	0.2	0.4	0.6	0.8	1	1.5	2
Rd (mm)	Unchanged (optimum value from above table after analysis)						
T & g (mm)	0.3						

Similarly the effect of sheet thickness (T) and die gap clearance (g) on the springback is analyzed with different sheet thickness and die gap g. and the results of these are shown in the next section.

Material Properties

The material used in this analysis is copper alloy, is assumed to be isotropic elastic–plastic following the Von-Misses yield criterion and isotropic hardening. The elastic properties are the modulus of elasticity, E =120GPa, Poisson's ratio, m = 0.33 and tensile yield stress, σyield = 260 MPa.The element used for the blank is 8 node plane183 linear plane–stress solid available in software element library.

The contact surfaces are modeled with using linear contact elements. In FE simulations, the friction is neglected. The sheet under the loading is analyzed by large displacement formulation. The number of increments for solution phase is dependent on the sheet thickness.

The wipe bending or L-bending process was assumed under the plane stress deformation because the width of the sheet metal is considered very less than the thickness. The material properties of Copper alloy obtained from the tension tests, as shown in Fig, were used for the finite elementsimulations [7].
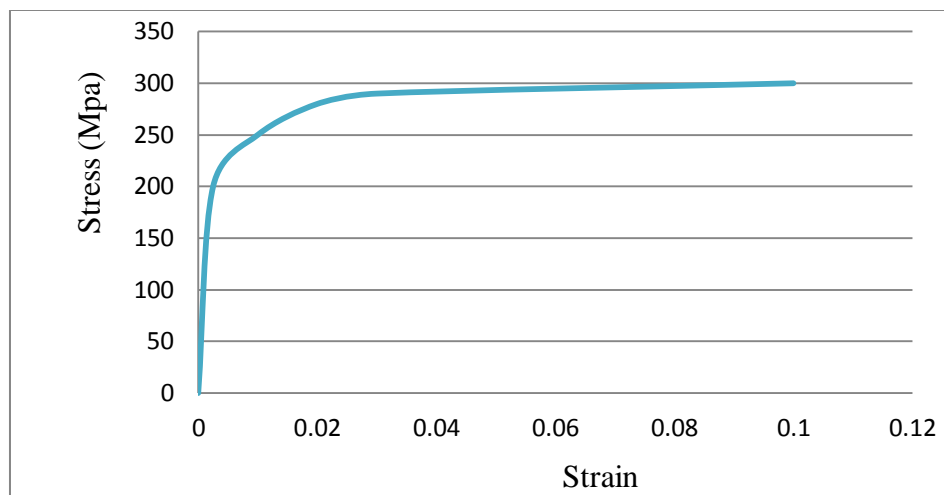
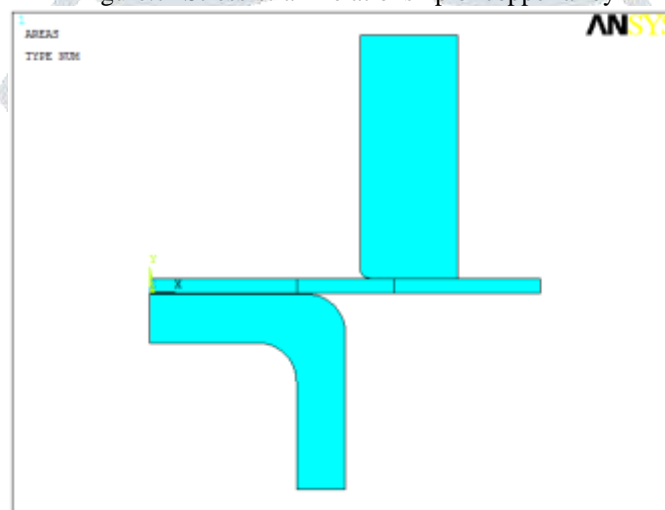Figure.7- Stress-strain relationship of copper alloy

Figure.8- FE Model

MESHING THE MODEL

Meshing is an integral part of the analysis process. The mesh influences the accuracy, convergence and speed of the solution. More importantly, the time it takes to create a mesh model is often a significant portion of the time it takes to get results from an ANSYS solution.The process for generating a mesh of nodes and elements consists of three general steps:

Set the element attributes.

Before we generate a mesh of nodes and elements, we must first define the appropriate element attributes. That is, we must consider the following:

The element type

Real constant set (usually comprising the element's geometric properties)

Material properties (such as Young's modulus, thermal conductivity, etc.)

And Element coordinate system.

Set mesh controls (optional).

Controlling Smart Sizing levels

Setting element size controls

Specifying element shape

Specifying meshing type (free or mapped)

Meshing solid model entities

Clearing meshes

Refining meshes

Meshing the model.

Once we have built our solid model, established element attributes, and set meshing controls, we are ready to generate the finite element mesh. In this analysis Free mesh is used for Die and punch material. Mapped meshing is used for sheet metal component.

BOUNDARY CONDITIONS AND CONSTRAINTS

Once the meshing of the finite element model is done. The next step is to apply the boundary conditions and constraints. In this analysis of wipe bending process, there are three components (Die, Punch and sheet metal) to which the BC's and constraints has to be applied.

a. The Die was constrained in All DOF (UX, UY) on which the sheet metal was bent.
b. The sheet metal and the punch were constrained along UX.
c. The sheet metal part which is resting on the die surface is also fixed with application of pressure pad or pressure (in this case pressure of 8-10 N/mm2 used).
d. Force in terms of displacement is applied with respect to time-load increments.
e. Contact and target were specified on the different surfaces of the Die, Punch and Sheet metal.
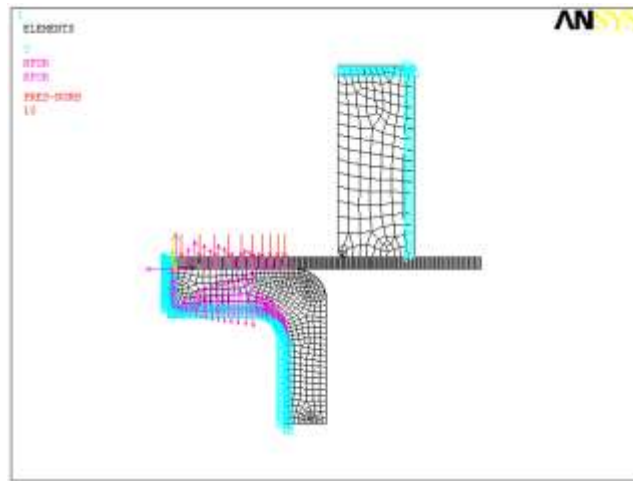

Figure.9– Finite element mesh of the model
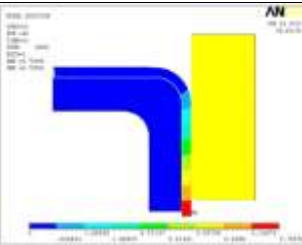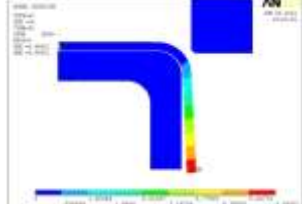
Figure.9– Boundary conditions and constraints

III.   RESULTS AND DISCUSSION

In the present study, the L-bending process of copper alloy, as shown in Fig. is studied. The effects of the process parameters on the springback occurring in the L-bending process were first examined. In addition, the deformation mechanics of the springback phenomenon also investigated in detail by the finite element analysis. An over bend approach is then proposed to reduce the springback in the L bending process.

The proposed approach was demonstrated to be very efficient by the finite element analysis and is validated by Theoretical calculation conducted in the present study.

Table 5- different positions of punch traveling

Different Positions of punch	Figure
Set up of L-bending process or wipe bending process	
Start of loading on the Blank material	
Punch moves down	

After L- bending	
Springback of the blank	

EFFECTS OF PROCESS PARAMETERS ON SPRINGBACK

In addition to the material properties, the springback is also affected by the process parameters, such as die corner radius, punch radius, blank-holder force, and friction condition in the L-bending process. In order to determine the predominant ones among these process parameters, the finite element analysis was performed using the Copper alloy sheet as specimen.
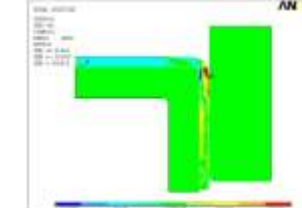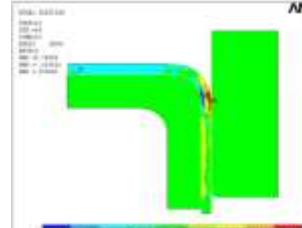
One process parameter was examined at a time, while the other process parameters were remained the same. The effect of the die corner radius on the springback has been discussed and shown in fig (9.5). The effect of punch radius on the springback is shown in fig (9.6). It is observed in Fig(9.6) that the springback increases as the punch radius increases for the punch radii smaller than 1.2 mm, and then the springback decreases as the punch radius further increases. It implies that there is an optimum punch radius in the L-bending process to reduce the springback.
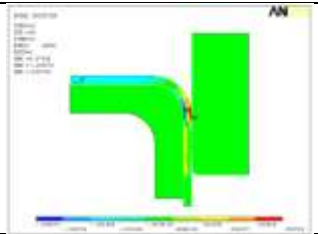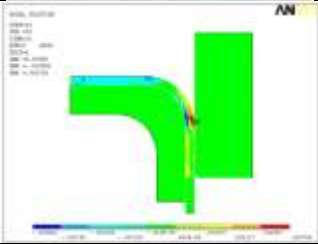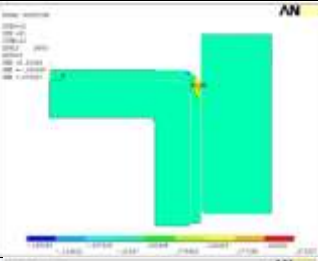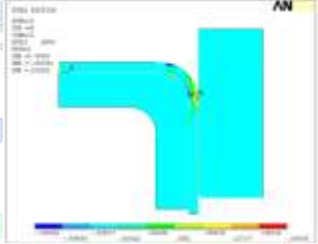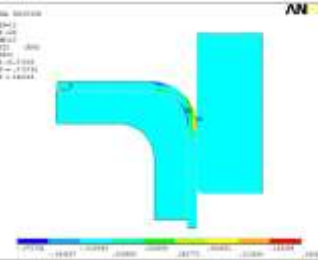
However, the optimum punch radius is quite small and the effect of the punch radius on springback is not so obvious, hence, it is not practical to reduce the springback by changing the punch radius. Figure (9.5) shows the effect of die gap on the springback. As seen in Figure(9.5), the die gap has a significant effect on springback, and the larger the die gap, the more significant is the springback. Since the sheet-metal is less constrained around the die corner when the die gap becomes large, resulting in larger positive springback.

THE EFFECT OF DIE RADIUS

In order to investigate the effect of die radius on the springback angle of the L bend or wipe bending process, the following strategy is employed. Five groups of FE simulation models each with the different die radius varying from 0.2 to 1.4 mm and for each trails other parameters are taken constant, i.e. sheet thickness is 0.3 mm, Punch radius is 0.2 mm and die gap of 0.3 mm.The FE simulation response of springback angle for the die shoulder radius is reported in Table 1. And also using these results from simulation, the graph of springback angle against die radius is plotted, as shown in table 6

Table 7- Effect of die radius on springback

Different Die Radius	Variations of Elastic Strain
Bending with Die radius 0.2mm	
a) Bending with Die Radius 0.8mm	

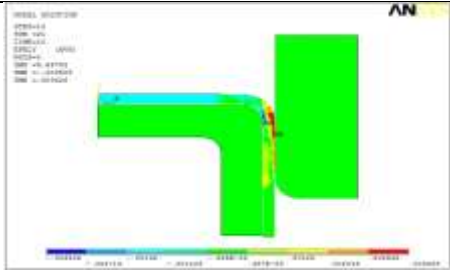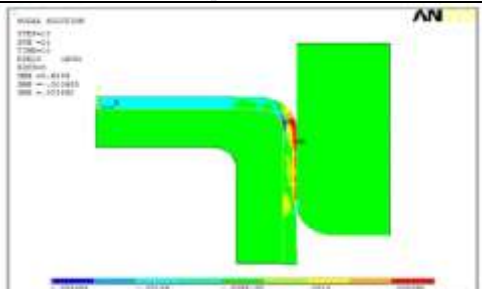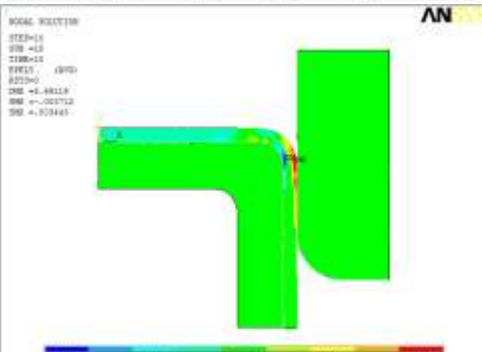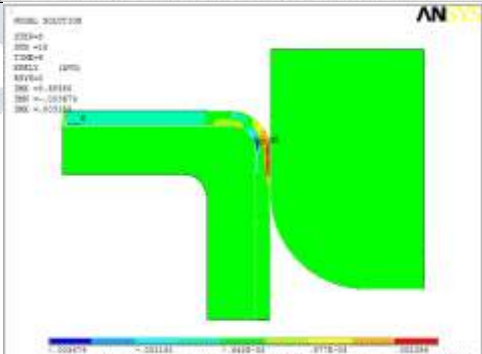| Different Die Radius	Variations of Plastic Strain
Bending with Die radius 1.1mm	
Bending with Die radius 1.4mm	
Bending with 0.2mm die radius	
Bending with 0.8mm die radius	
Bending with 1.1mm die radius	
Bending with 1.4mm die radius	

THE EFFECT OF PUNCH RADIUS

In order to investigate the effect of punch radius on the springback angle of wipe bending process, the following strategy is employed.

Five groups of FE simulation models each with the different Punch radius varying from 0.2 to 2 mm and for each trails other parameters are taken constant, i.e. sheet thickness is 0.3 mm, die gap of 0.3 mm and die radius can be taken in between 0.2 to 0.5 mm because from the earlier analysis it shown reasonably a lesser amount of springback than the other die shoulder radius elastic strain induced was minimum and plastic strain was maximum in tensile direction and reported less springback). In this the analysis shown

that the elastic strain for punch radius from 0.4mm to 0.8mm was increasing which led to greater springback and after sudden there was decrease in springback values due to decrease in elastic strain with respect to tensile surface.
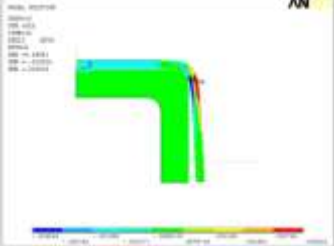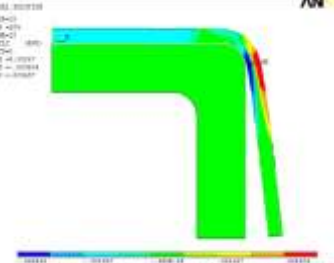
Table 8- Effect of punch radius on springback

Different Punch Radius	Variations of Elastic Strain
Elastic strain for punch radius 0.6mm	
Elastic strain for punch radius 0.8mm	
Elastic strain for punch radius 1.0mm	
Elastic strain for punch radius 1.0mm	

THE EFFECT OF DIE GAP AND SHEET METAL THICKNESS
In order to investigate the effect of die gap and sheet metal thickness on the springback the same strategy is used as earlier i.e. five different FE modules are prepared for different die gaps varying from 0.3 to 1 mm and die radius of 0.5mm, punch radius of 0.5mm is used as unchanged dimensions and the analysis for die gap shown that as the die gap increases there is increase in the springback angle because as die gap increase the punch will not be able to bend the sheet metal completely and analysis on sheet metal thickness varying from 0.3 to 1 mm reported that as increase in the sheet thickness there is decrease in the springback values.
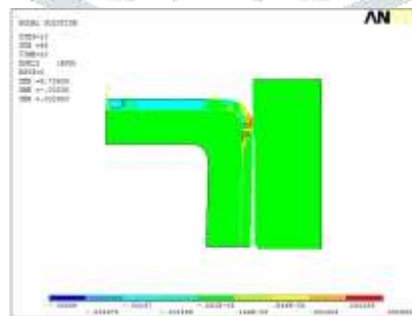
In the die gap trails the gap is provided equal to the thickness in order to avoid the reduction in the sheet metal thickness. And the results for both are reported under following tables. And also in sheet metal thickness trails the gap is provided same as the thickness of the metal.

Table 8- Effect of Die gap on springback

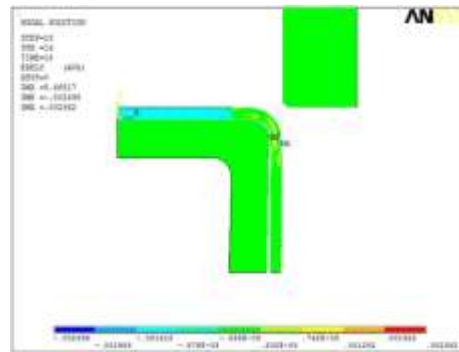| Different Die gap	Variations of Elastic Strain
Die gap 0.5mm	
Die gap 0.6.mm	

IV.   OVER BEND APPROACH

One of the common techniques used for compensating the springback is over bending the sheet metal with more angles then required. To apply this method, the amount of springback is calculated and the sheet metal is over bent to a smaller bend angle than required. Recovery of the sheet metal from the springback results in a calculated increase in bend angle. This increase due to the elastic strains makes the recovered bend angle exactly what was originally planned. For a case of 0.8mm die radius, for which we know the springback angle, which is used to show the effect of over bend for eliminating the springback i.e. to get the required 90° angle required for this work.But this solution is obtained by trial and error method as solved for a case shown below. And after analyses of springback compensation with an over bend method for a sample of 90° we can say that it is an effective and simple method to obtain the required angle of bend.

a)   Over bend

b) 90 deg. Bent obtained

Figure.10- an over-bend approach to compensate Springback

The over bend method successfully prevents the springback of the sheet metal as shown in above fig. which is proved in the FE simulations in this study. In order to investigate the effect of over bend to prevent springback, a previous analysis result i.e. for die radius of 0.8 mm the springback angle measured was 2.4°. Now to prevent this springback angle FE models are prepared with four different die undercuts that are 2.4°, 2°, 1.5° and 1° respectively. These trails are carried out to check the suitable amount of over bend to obtain L-bend or 90° bend, this over bend method is based on trial and error.

Table 10 Springback values determined with FE simulation for different undercut.

Die undercut in deg.	Springback (Θ)
2.4	-0.58
2	-0.5
1.5	-0.28
1	0.04 (optimum)

The above table shows the springback values for different die undercuts. As we see that the springback values are negative (negative springback) up to 1.5° undercut. And at 1° over bend the springback value is 0.04° which is almost close to 90° or perfectly L-bend is obtained. Hence from this FE simulation we get that the sheet metal has to be over bent by an angle of 1° in order to prevent springback value of 2.4°. On the same procedure for a springback of 2.8°, the sheet is over bent 1.4° and the springback values was 0.06° (89.94°). Hence in this it can be concluded that if the springback value of a metal is known then it can be prevented by over bending the specimen with trial and error approach.

V. CONCLUSION

From the investigation of Finite element analysis it shows that the die radius has a significant amount of effect on the springback. The results from analysis for die shoulder shown that the increase in die shoulder radius increases the springback hence to avoid the springback use of smaller die radius is recommended from this study. And also the punch nose radius has significant effect on the springback, up to certain punch nose radius though it doesn't have much effect as compared to the die radius on springback.

Apart from these two factors the die gap or clearance and sheet metal thickness also has a very appreciating amount of effect on springback, from this analysis it shown that an sufficient amount of die gap has to be maintained (same as thickness of the sheet metal) in order to compensate the springback and also to avoid some of the defects such as tearing. Closer or less clearance may lead to damaging which results in waste of material and cost. Springback is also affected by the thickness; however this parameter depends on the requirement for manufacturing.

An over bend approach is proposed to compensate the springback. After analyzing the different parameters responsible for the cause of springback, the springback is controlled for some extent but cannot be eliminated. Hence the over bend approach based on trial and error is chosen in this work by which the springback is almost eliminated. And for validation of this FE analysis a suitable theoretical computation is done. This shows good agreement with the results from analysis.

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