Effect of Punch Radius and Sheet Thickness on Spring-back in V-die Bending

Kartik T and Rajesh R

Department of Production Engineering, PSG College of Technology, Coimbatore, India – 641 004.

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ABSTRACT

Background: Bending is a near net shape manufacturing process for sheet metal components. The work takes up the problem of spring-back encountered in V-die bending process. Spring back is the elastic recovery of plastically deformed sheet which affects dimensional accuracy of the final component. Objective: The objective of the work is to simulate V-die bending process to estimate spring-back and analyze the effect of punch radius and sheet thickness on spring-back. Results: The bending of sheet metal is simulated using Finite Element Method (FEM). The results suggest spring-back reduces as punch radius decreases and sheet thickness increases. Conclusion: Simulation of V-die bending is carried out using FEM based software to identify the defect and to understand effects of process parameters. The process variables have considerable significance in the spring-back of the final bend shape. Simulation helps predict spring-back which avoids the loss of time and money incurred during trial and error based experimentation.

KEYWORDS: Contact, Finite Element Method, Non-linearity, Plastic deformation, Spring-back.

INTRODUCTION

Bending process is one of the most common sheet metal forming process. The material in the inside of neutral axis is compressed and outside is stretched. Defects related to sheet metal bending are spring back and thinning. Due to their elastic property material tend to regain its original shape leading to spring back defect. Obtaining the desired size and design of die depends on the knowledge of the amount of this spring-back.

Fig. 1: Schematic representation of spring back, [6].
Spring back is the elastic recovery of plastically deformed sheet after unloading of punch which causes distortion of geometry and loss of dimensional accuracy. [6]

Traditionally spring-back is compensated by over bending the component to achieve the final angle desired. Spring-back is a defect which depends on number of process parameters like material property, tool geometry and press loading condition. Optimization of these variables will reduce spring-back.

Bakhshi et al. [1] simulated material models based on various anisotropic models and compared their results with experimental outcome to show the variation of spring-back in CK67 steel sheet. The work includes experimental and numerical studies of effects of significant parameters including sheet metal thickness, sheet metal anisotropy and punch tip radius on spring-back / spring-go in V-die bending. The plastic properties of rolled sheets differ through thickness direction, normal anisotropy, and vary with orientation in the plane of the sheet, planar anisotropy. Orientation of 0° to rolling direction gives better results. By increasing punch tip radius spring-go is converted into spring back is another finding of the work.

Chan et al. [2] have studied the effect of spring-back in Al 2024 T3 V-bending process with one end clamped and other end free. Different die punch parameters such as punch radius, punch angle and die-lip radius are varied. Valley spring back angle decreases as punch radius increase and increases as punch angle decreases and die-lip radius increases.

In the experimentation conducted by Dilipak et al. [3] effects of material properties and punch tip radius were studied in the bending of S235JR material. The effect of normalizing and tempering was also studied, which were applied to the materials. The process parameters considered were punch tip radius, material properties and punch holding time. Experimental results show tempering the material reduces spring-go and normalizing process increased spring-go compared to non-heat treated material.

O’zgur et al. [5] have studied spring back in stainless steel sheets. The process parameters considered are bending angle, sheet thickness and punch holding time. Major inference from the experimentation is increase in holding time decreases spring back.

Sutasn and Surasit [7] have researched extensively in spring go phenomenon. The process parameter considered is punch radius. The FEM simulation results clearly and theoretically clarified the spring-go phenomenon on the material flow analysis and stress distribution.

Sutasn Thippaprakmas [8] has conducted finite element method (FEM) based simulation to investigate the effects of punch height. FEM simulation results revealed the effects of punch height on the bending angle were clarified based on the material flow analysis and stress distribution. Punch heights to achieve required bending angle are found to be within a fixed limits.

Sutasn Thippaprakmas [9] has employed coin bead mechanism to minimize spring back in Aluminum A1100. Coining bead and punch shape are the two variables in the research. The results revealed that the mechanism of the coined-bead technique not only increases the compressive stress on the bending allowance zone, where the spring-back feature decreases, but increases the reversed bending zone on the leg of the workpiece, where the spring-go increases.

Vijay et al. [10] have employed localized compressive stresses on bend curvature to minimize spring back in High strength steel. The process parameters considered are sheet thickness and punch radius. It is confirmed by numerical simulation that as the sheet thickness increases the spring back decreases. It was determined that as punch corner radii increases spring-back effect increases.

**Objective:**

The effects of process variables punch radius and sheet thickness on spring-back are analyzed using finite element analysis. The finite element based solution will be an approximation of the actual case and will reduce the cost associated with die and punch fabrication during fabrication.

**Simulation Model:**

Bending of sheet metal simulation using Finite Element Method includes three types of non-linearity – contact, material (plastic deformation) and geometry (large scale deformation). Based on number of non-linearity, complexity of the solution increases.

Figure 2 shows the details of process variables considered. The sheet material considered is steel and sample size is 80 mm x 30 mm. The sheet thicknesses considered are 0.5 mm and 1.0 mm. The punch radiiuses considered are 2 mm, 4 mm and 6 mm.
The components are modeled in Ansys (Finite Element based software). The element type considered is solid quadrilateral 8 node 183. The material properties are provided as per strain hardening plastic model [4].

The meshing is done by controlling the edges coming in contact. The number of elements is increased to achieve better result. Contacts are established based on the nodes available on the edges. Surface to surface contact is established between punch and top surface of sheet (non-frictional contact) and bottom surface of sheet and die (frictional contact). This ensures the punch when comes in contact will not penetrate the sheet, appropriate contact stiffness is provided as sheet thickness considered is very less.

The load is applied in two steps – loading punch to bottom of die (load step 1) and unloading the punch (load step 2). The loads are provided in terms of displacement. Load step 1 boundary conditions are:
1. Die fixed in all degrees of freedom
2. Punch load (displacement in negative y direction)
3. Sheet metal symmetry
4. Sheet metal centre nodes arrested for displacement along x axis.

For load step 2, punch is displaced in positive y direction and rest of the boundary conditions is same. Sheet metal centre nodes are arrested as these results in error during solution. Figure 4 shows constrain and load on the nodes.

Before solving the problem some changes have to be made to solution controls since this is a non-linear solution. The analysis option should be selected as large displacement. And number of sub-steps should be increased so that deformation in sheet metal can be controlled. Sub-steps divide the load into smaller values and avoid excessive loading leading to non-convergence of the solution.

**Results:**

The spring-back in the component is proportional to the x displacement of node in the extreme edges. The results for x-component displacement are analyzed at the end of each load step. The details of spring back are highlighted in table 1 and figure 5.
Table 1: Result table

<table>
<thead>
<tr>
<th>S no.</th>
<th>Punch radius (in mm)</th>
<th>Sheet thickness (in mm)</th>
<th>Spring back (in degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0</td>
<td>0.5</td>
<td>0° 58’</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>1.0</td>
<td>0° 41’</td>
</tr>
<tr>
<td>3</td>
<td>4.0</td>
<td>0.5</td>
<td>1° 59’</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>1.0</td>
<td>1° 4’</td>
</tr>
<tr>
<td>5</td>
<td>6.0</td>
<td>0.5</td>
<td>5° 59’</td>
</tr>
<tr>
<td>6</td>
<td>6.0</td>
<td>1.0</td>
<td>2° 19’</td>
</tr>
</tbody>
</table>

a. 0.5 mm thick sheet and 2 mm punch radius

b. 1.0 mm thick sheet and 2 mm punch radius

c. 0.5 mm thick sheet and 4 mm punch radius
In figure 5, the readings are x direction displacement. The minimum and maximum displacements are equal and in opposite sign as these show the edge travel from either side of the origin. The results are better understood in graph as shown in figure 6.

**Discussion:**

The spring-back values are clearly highlighted in graph, the sign values shows spring-back can still be reduced to zero by reducing punch radius in case of 0.5 mm sheet thickness. In the case of 1.0 mm sheet, negative spring-back (also known as spring-go) has occurred and spring back can be reduced to zero by iterations of punch radius in the range of 2.0 mm to 4.0 mm.
Fig. 6: Spring-back Vs Punch radius.

Conclusion:
Simulation of V-die bending is carried out using Finite Element Method based software to identify the defect and to understand effects of process parameters. This avoids trial and error in the fabrication of punch and die. The process variables have considerable significance in the spring-back of the final bend shape. The spring-back reduces with decrease of punch radius and increase of sheet thickness.

REFERENCES