

Design and Manufacturing of U-Bending Tool to Overcome Spring Back Effect by Ironing Impact

Manjunathan.R^{1*}, Mohanraj.R¹, Moshay.M¹, Natchimuthu.N¹, Suresh.S²

¹Final year UG student, Department of Mechanical Engineering, Jayalakshmi Institute of Technology, Thoppur, Tamilnadu, India

²Asst.Professor, Department of Mechanical Engineering, Jayalakshmi Institute of Technology, Thoppur, Tamilnadu, India

ABSTRACT: In sheet metal bending, the most sensitive feature is the elastic recovery during unloading of die, called springback effect that influenced by various factors, leads to change the bend angle and bend curvature and affects the geometric changes of the final product. Main factors that influence the springback effect are sheet thickness, material properties and tool geometry. Accurate prediction and controlling of springback is essential in the design of tools for sheet metal bending. In this work the attempt was made to overcome the springback effect by change the design of tools (Punch and Die). The concept has been introduced on the design of U- bending process tools and applied to produce the product from the 2mm thickness Mild Steel sheet. The corner setting of punch and die and punch relief angle are the major portions which are concentrated to apply the ironing impact in order to overcome the springback effect.

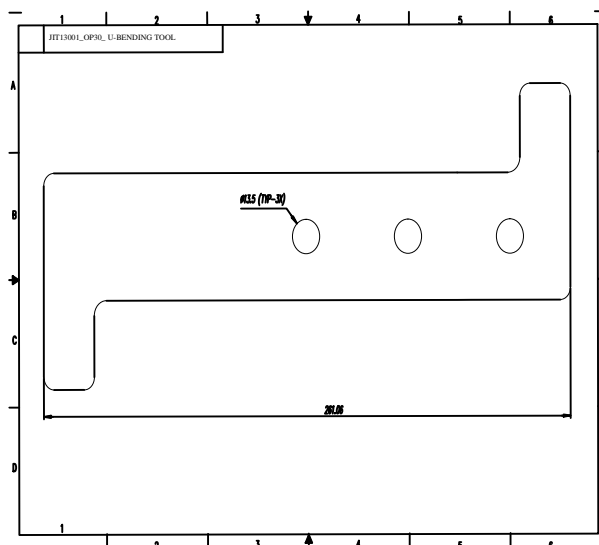
KEYWORDS: Sheet metal bending, Springback effect, U-bending die, Ironing impact, Relief angle.

I.INTRODUCTION

Bending, forming and drawing dies are used to perform non-cutting operation. When these operation perform, the cross-section will not change. At the same time, these operations are carried out within the ultimate stress but beyond the elastic stress. These are very familiar processes used in the manufacturing of panel's electronic components, drums, components of automobile vehicle panels etc. The major problem in bending process is the spring back or spring-go. The spring back is a complex phenomenon and it depends on process parameters and material parameters. Many of the research has been done to investigate the parameters affecting spring back and to reduce spring back.

The spring back is dependent on the parameters such as ratio of die radius to sheet thickness, sheet thickness, blank holder force, coefficient of friction. Sheet thickness the spring back increases with increase in sheet thickness.

Many researchers have tried to compensate the springback by various means. Sudhir Kumar et al. [1] carried out the spring back increases with increase in punch radius. The spring back decreases with increase the temperature. Ultimate tensile stress increase with increase tempering temperature. Percentage of elongation increase with temperature. Gawade Sharad, V. M. Nandedkar [2] examined the ratio of die radius to sheet thickness ratio it is seen that the spring back is minimum up to certain value of R/t ratio and it increases with increase in R/t ratio. For the sheet thickness the spring back increases with increase in sheet thickness. Liu et al. [3] adopted the variable blank holding force in order to reduce springback. Cho et al. [4] carried out numerical studies on the effects of some parameters such as punch and die corner radii, punch-die clearance, and coefficient of friction on spring-back in U-die bending process.



Li et al. [5] also showed that the accuracy of spring-back simulation is directly affected by the material-hardening model. H.A.Al-Qureshi [6] predicted a theoretical method for the spring-back factor in bending with compressible dies from the basic properties of the sheet metal, the tool geometry and the frictional behaviour of the die. Kim, [7] examined the effect of temperature gradients on the final part quality (i.e., springback) in warm forming of lightweight materials was investigated. 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. Wagoner et al. [8] in addition, the increased availability of commercial programs for the simulation of forming processes like LS-DYNA, PAM-STAMP, AutoForm, DYNAform, Stampack, has greatly facilitated the numerical simulation of springback. Gan and Wagoner [9] suggested a die design scheme with a displacement adjustment method to compensate for springback. B.F.Rolfe et.al [10] have studied the effect of blank holder force die corner radius and clearance from the U bend tests. They found die radius and tool gap directly effect the final geometry of the channel. These two parameters are not independent in particular with the springback and side wall curl effects. The flange angle springback appears to decrease by increasing the blank holder force and die radii. The floor angle

springback is decreased by increasing the blank holder force. The floor angle springback is increased by increasing the combination of die radii and clearance. The error in the flange length is decreased when the blank holder force or the clearance is increased, and the error in the flange length is increased when the die radii is increased. The extended flange length shows decrease in error as the blank holder force or die radii is increased. In total they concluded that springback error decreases with the increase of blank holder force or increase of die corner radius and there is no consistency in the results given by clearance.

In this present work the concept of ironing impact has been introduced in tool design (corner setting, punch relief angle and ejection in punch) for U bending processes in order to reduce the effect of springback and scoring.

II. EXPERIMENTAL WORK

Product Design

The Figure 1 shows the design of the final product from the U bending. The material of the sheet was mild steel with 2mm thickness. The product consists of blanking, piercing and bending operations. One of the hole is

locating at the centre of product and another two holes in two legs at the certain distance from the base of the product made by laser cutting operation for the quality check of U-Bent. The product contains one long leg and one short leg for better analysis the spring back effect.

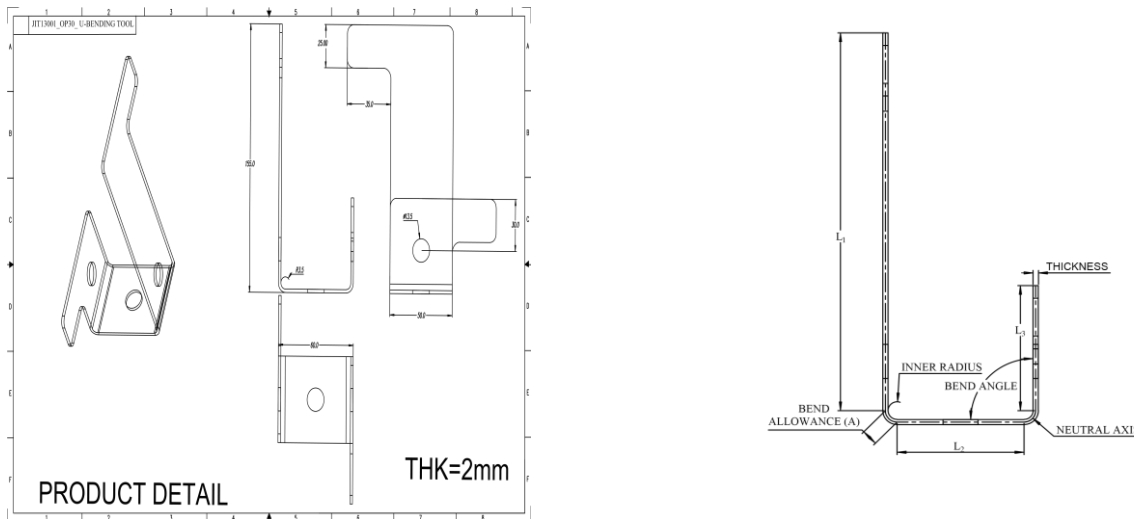


Fig. 1: (a) Before bending (b) After bending.

Design Calculation

Bend Allowance

The bent allowance, the total length of the bend and bending force are calculated from the standard formulas that explained below. The figure 2 illustrate the allowance given to the base metal sheet.

$$\text{Bend allowance, } A = \frac{2\pi\theta}{360} (IR+KT)$$

Where, K = Constant
= 0.3 when $2T > IR$
= 0.5 when $2T \leq IR$

θ = Bend angle

IR = Internal radius of bend

T = Thickness of sheet metal

$L = L_1 + L_2 + L_3 + A$

Where, L = Length of flat blank required to make the bend

L_1 = Length of bend leg 1

L_2 = Length of bend leg 2

L_3 = Length of bend leg 3

A = Bend allowance = $A_1 + A_2$

$$A = \frac{2 \times \pi \times 90}{360} (3.5 + (0.33 \times 2))$$

$$A_1 = A_2 = 6.53\text{mm}$$

$$\begin{aligned} \text{Length of flat blank (L)} &= L_1 + L_2 + L_3 + A_1 + A_2 \\ &= 149.5 + 49 + 49.5 + 6.53 + 6.53 \\ &= 261.06\text{mm} \end{aligned}$$

Bending Force

The force required to bend a material is calculated by,

$$F_b = [(KLST^2) / W]$$

Where, K = Die opening factor

$$K = 0.67$$

L = Length of bent part in mm

S = Ultimate tensile strength in kg/mm^2 ($S=35\text{kg/mm}^2$)

T = Thickness of blank in mm

W = Span

$$W = RE + C + RP$$

Where, RE = Edge Radius in mm

RP = Punch radius in mm

$$\text{Span (W)} = RE + C + RP$$

$$= 5.5 + 2 + 3.5$$

$$= 11.0\text{mm}$$

$$\text{Length of bent part } L = 50 + 50 = 100\text{mm}$$

$$\text{Bending force } (F_b) = [(KLST^2) / W]$$

$$= [(0.67 \times 100 \times 35 \times 2^2) / 11]$$

$$= 852.7\text{kg} = 0.85 \text{ tones}$$

C = Die clearance in mm

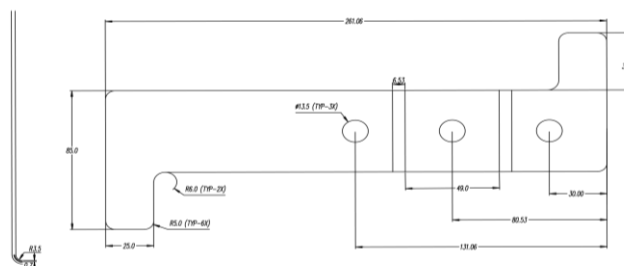
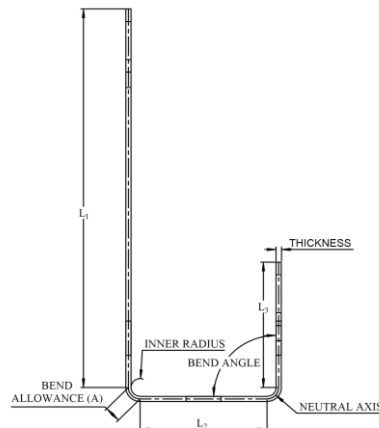


Fig 2: Bend allowance

Design of Die and Punch

In U-bending, the sheet deformation in die and punch corner region can be considered as sheet stretching.

The following assumptions are applied:

- 1) The bending force per unit width in each layer of sheet is considered to be uniform through thickness.

- 2) Straight lines perpendicular to the neutral surface remain straight during process.
- 3) The strain in the width direction is zero.
- 4) The transverse stress in each layer is neglected.
- 5) The adherence of the two layers is perfect, so there is no strain discontinuity in two layers interface.

Ironing Impact

The non-uniform distribution of stress in cross-section during forming process will change the part profile and cause springback when the loading is removed. In order to overcome the spring back effect the metal in the bending portion was squashed at an inner or outer corner radius of blank to relieve elastic stresses called as ironing impact. 10 to 15 % of sheet thickness was chosen for the ironing impact factor. Figure 3 illustrates the concept of ironing impact that shows the portion of bended sheet before and after applying the concept of ironing impact. In that figure the blue lines shows the sheet without ironing factor and the red line shows the sheet after applying the concept of ironing factor.

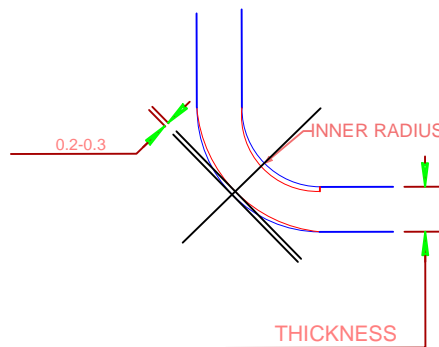


Fig. 3: Concept of Ironing Impact

The ironing impact concept was implemented by offsetting the bending corner radius in the punch and die. The curved portion of the die was offset by 0.2 mm outside in order to compress the sheet to make ironing of 0.2 mm outside. 10% of sheet thickness was chosen as ironing impact for this current study. Figure 4 shows of corner setting in die and the position of the sheet after bending.

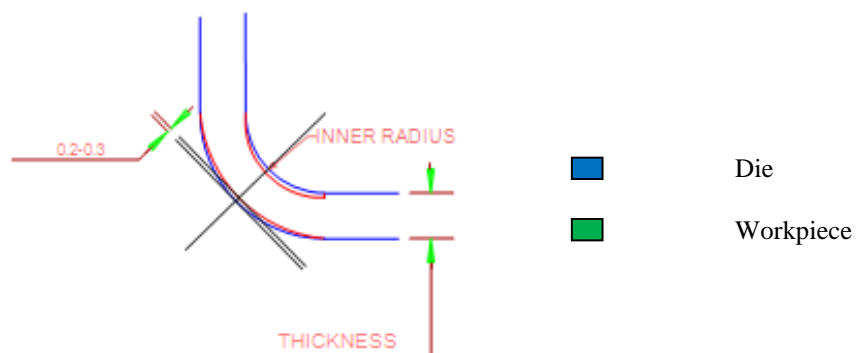


Fig. 4: Corner Setting in Die

The curved portion of the punch was offset by 0.2 mm outside in order to compress the sheet to make ironing of 0.2 mm inside. Same as die 10% of sheet thickness was chosen as ironing impact for this current study. Figure 5 shows of corner setting in punch and the position of the sheet after bending. The corner setting of both die and punch leads to change the elastic nature of the sheet bend and possible to reduce the spring back.

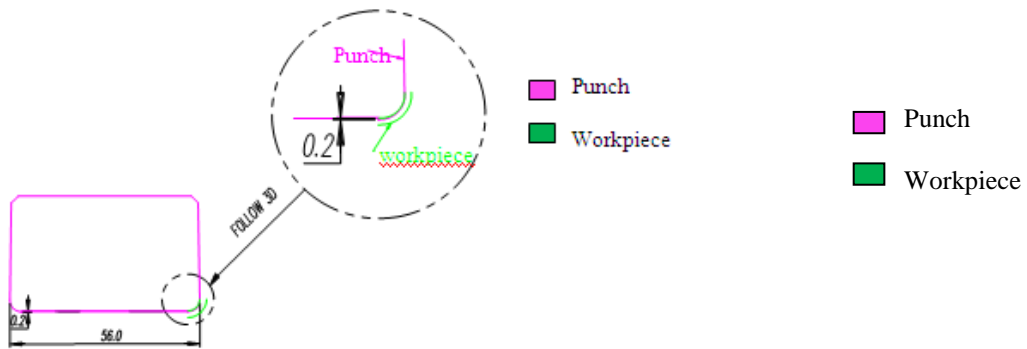


Fig. 5: Corner Setting in Punch

In addition the punch relief angle was maintained at $1^{\circ} - 3^{\circ}$ to avoid scoring/scratching on sheet during bending operation that shown in figure 6.

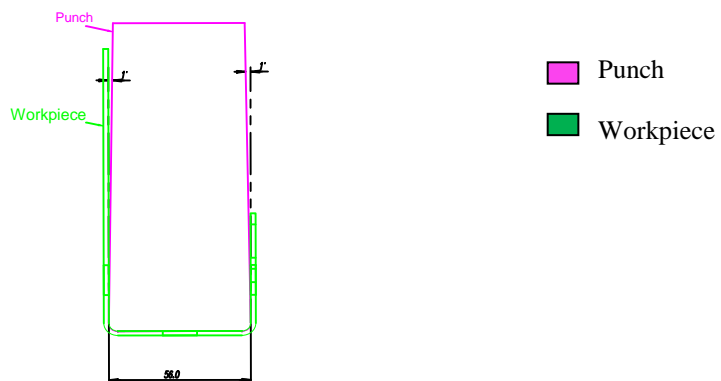


Fig. 6: Angle Relief in Punch

The figure 7 shows the complete die set used for U-bending operation.

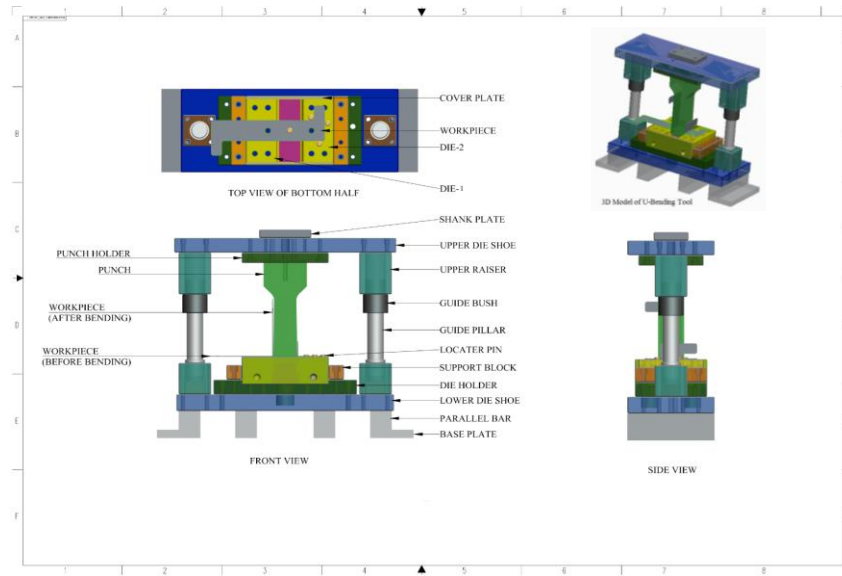


Fig. 7: Design of Die Set

The manufactured die set was installed on the pressing machine and the die opening after bend are shown in figure 8. The required product was made with implementing ironing factor and calculated bending force was shown in the figure 9.



Fig. 8: Setup on Pressing Machine



Fig. 9: The Final Product

III. CONCLUSION

The following conclusions were made from the present work:

1. The bending process was successfully done by implementing ironing factor on tool design.
2. The corner setting of die and punch significantly influence the effect of spring back of sheet after bending.
3. By chosen 10% of ironing factor, springback can be reduced significantly.
4. The scoring/scratching defects also was rectified by relief angle on punch.

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