

Investigative Study on Bending and Spring Back of Electro Galvanized Steel

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Abstract: In manufacturing process, sheet metal forming occupies a special place as it produces parts of superior mechanical strength with minimum waste of material in short time. Bending is a common metal forming process making use of 'Theory of Plasticity'. In this process the sheet metal is shaped by straining the metal around a straight axis. Because all materials have a finite modulus of elasticity, plastic deformation is always followed by elastic recovery upon removal of the load, which is known as spring back. Bending is commonly used in automotive and other fabrication industries. Electro galvanizing is a process of electroplating in which zinc is coated over the outer surface of the steel. Today coated steels are widely used as corrosion resistant steel sheets with excellent economy, mainly in fields as automobile, aeronautics, fuel tank, smooth and shiny parts for aesthetic reasons, home appliances, building and structure, electrical application etc. This paper attempts to find the effect of different thickness of electro galvanizing during bending on spring back of galvanized sheets. Results have been compared for different bend angles and punch velocity. The effects of individual parameters and their interactions on the responses have also been analyzed. Further it is proposed to study the responses by using lubricants during the bending.

Keywords: electrogalvanizing, steel (CR4), bending force, spring back, air bending

1. INTRODUCTION

In manufacturing processes, sheet metal forming occupies a special place as it produces parts of superior mechanical strength, with minimum waste of material in short time. Precise manufacture, high material utilization and easy realization of automation are the key characteristics of sheet metal forming. Sheet metal products has a wide range of applications like aeronautics (panels, nose skins etc.), automotive (door panels, bonnet, gasoline tank etc.), electrical (switch boxes etc.), home appliances (kitchen wares, washing machines, refrigerator body) and building (sanitary products).

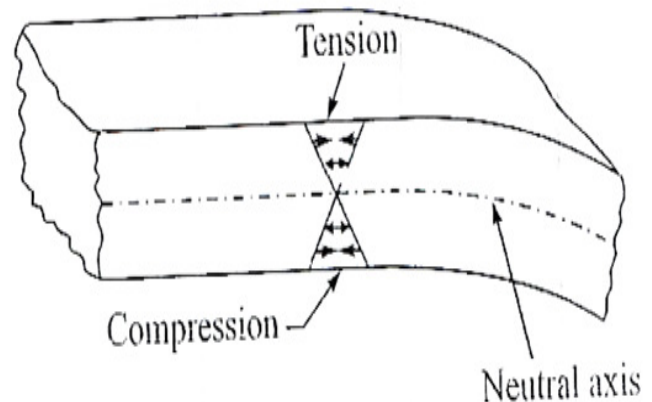


Fig. 1. Theory of bending [1]

Bending is a common metal forming process making use of Theory of Plasticity. In this process the sheet metal is shaped by straining the metal around a straight axis. During this operation internal side is compressed and external side is stretched. This process is used for forming parts such as flanges, curls, seams, and corrugations, it is also used to impart stiffness (by increasing the moment of inertia). Bending is commonly used in automotive and other fabrication industries.

2. BENDING PROCESS

There are three basic types of bending process which are air bending, V-die bending, wipe die bending. For the present study, air bending has been taken in consideration.

2.1 AIR BENDING

Also known as free bending and is a flexible bending process, where, different bend angle can be achieved using the same tool set. A problem in air bending is punch displacement, of the deformed part after unloading, caused by elastic recovery, also called spring back. As a result angles, often are not accurate enough to satisfy required dimensional tolerance. For desired bend it is sensitive to variation in sheet thickness. But one of the most critical problem is the dimensional change

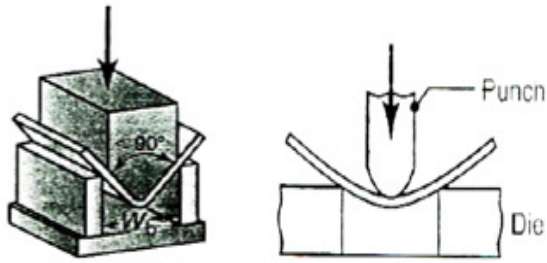


Fig. 2. Air bending [2]

2.2 BENDING FORCE

The bending force is also a function of the punch travel. It increases from zero to a maximum and may decrease as the bend is completed; it then increases sharply as the punch bottoms in case of die bending. In air bending (free bending), however, the force does not increase again after it begins to decrease. Bending force can be approximately calculated by the relation, [2]

$$F_{\max} = k \frac{UTS \cdot L \cdot T^2}{W}$$

2.3 SPRING BACK

Because all materials have a finite modulus of elasticity, plastic deformation is always followed by elastic recovery upon removal of the load. In bending, this recovery is known as spring back. As shown in Fig. 3 the final bend angle after spring back, α_f , is smaller than the angle to which it is bent, α_i , and the final bend radius, R_f , is larger than the radius to which it is bent, R_i . Spring back can be approximately calculated in the form of radii by the following relation [2]. Here T is sheet thickness, E is modulus of elasticity & Y is yield stress.

$$\frac{R_i}{R_f} = 4 \left(\frac{R_i \cdot Y}{E \cdot T} \right)^3 - 3 \left(\frac{R_i \cdot Y}{E \cdot T} \right) - 1$$

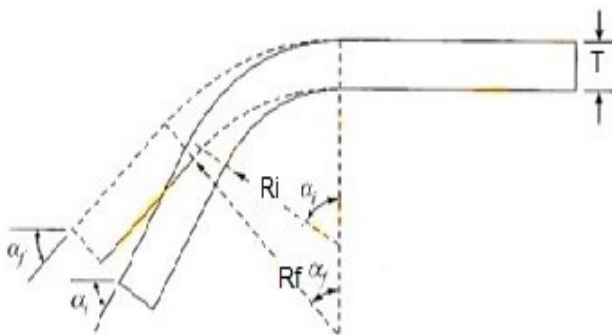


Fig. 3. Terminology of spring back [2]

2.4 GALVANIZING

Galvanizing is a process of depositing zinc over mother surface of steel. The zinc layer protects the steel by

sacrificing itself- called a sacrificial anode. When exposed to the atmosphere, the pure zinc reacts with oxygen (O_2) to form a very thin tenacious layer of zinc oxide (ZnO), with water it forms zinc hydroxide. These further reacts with carbon dioxide (CO_2) to form zinc carbonate ($ZnCO_3$), a usually dull gray, fairly strong material that stops further corrosion in many circumstances, protecting the steel below from the corrosive elements.

3. LITERATURE SURVEY

Schey, & Dalton [3] found that minor variation in surface finish modifies the friction significantly and the submicroscopic features of electrogalvanized sheet helped in retention of lubricants.

Shackelford [4] Since Zinc is anodic relative to steel, it provides galvanic protection losing slowly in the presence of corrosive elements. Even the coating is removed and steel is exposed in some area.

Hayashi & Nakagawa [5] said shape fixability is one of the main indices to access the sheet formability. Shape fixability is defined as the fixation degree of size and shape of formed part. During bending load is applied to bend the part in the expected shape. After bending when load is being removed, the total strain on the bend part is reduced due to elastic recovery. This causes a shape discrepancy referred as spring back. Spring back is a measure of shape fixability in bending de Vin [6],[7]; Kurtaran, [8]; Narayanasamy & Padamnabhan [9] Airbending is more flexible than its counterpart, closed die-bending. Different bend angles are achieved by changing the tooling in closed die bending process. In air bending, as the punch displacement decides the bend angles, the tool changes required to achieve different angles are reduced. Therefore airbending is used in automotive manufacturing and other fabrication industries.

Fei Hodgson [10] He identified the major parameter affecting the spring back behavior of cold rolled transformation induced plasticity (TRIP) steels in air bending process.

Garcia-Romeu et al. [11] Conducted experiments in air bending of aluminum and stainless steel sheets to obtain spring back values for different angles. The spring back values were presented graphically, and the effect of parameters were evaluated.

Narayanasamy and Padamnabhan [12]; [13] Presented experimental investigation on air bending process of interstitial free steel sheets to study important parameters affecting the spring back.

Vasudevan et al. ([14] conducted experiment on air bending to study the spring back behavior of electrogalvanized steel sheets to analyze the influence of various parameters such as coating thickness, orientation of the sheet, punch radius, die radius and punch velocity.

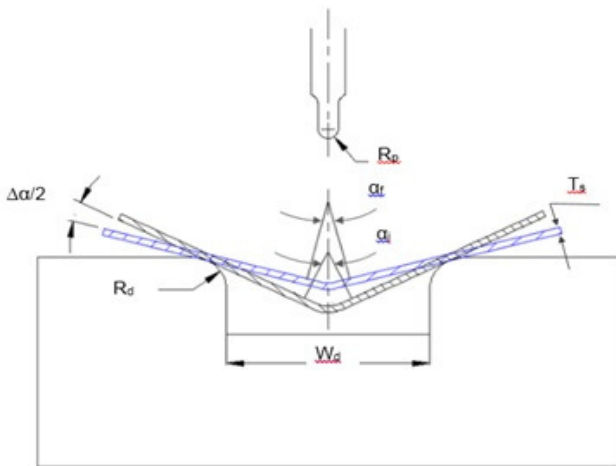
Element	% (w/w)
C%	0.081
Mn%	0.397
S%	0.026
P%	0.015
Al%	0.031
Fe%	99.45

Table 2. Mechanical properties at room temperature of CR4

Orientation	Yield Stress (MPa)	Tensile Strength (MPa)	Young Modulus (GPa)	Hardness (HRB)
0°	210.6	349.8	207	50
90°	216.2	340.8	207	

TABLE 3: Overview of tool parameter used in experiment

Constant Parameters		
Name		Value
Work blank width	Ws (mm)	35
Work blank length	Ls (mm)	100
Work blank thickness	Ts (mm)	1
Die width	Wd (mm)	60
Punch radius	Rp (mm)	8
Die radius	Rd (mm)	5
Design Variables		
Name		Value
Punch travel	mm	5; 10; 15 ; 20 ;25
Rolling direction of sheet	(°)	0 ; 90
Galvanizing thickness	Tg (μm)	0 ; 4 ; 7 ; 10
Punch velocity	Vp (mm/sec)	0.4; 0.6 ;0.8


Fig. 4. Schematic diagram of experimental setup

4. EXPERIMENTAL

The steel sheet used in this experimental investigation is CR4, an aluminium killed grade of 1 mm thickness and chemical composition of the same is given above in Table 2. Steel sheet is electro-galvanized for different thickness of 4;

7; and 10 μ m. Various parameters used for the experimentation is given in Table 3. Rolling direction is considered (0°) and bending is done across the rolling direction. Across Rolling direction is considered (90°) and bending is done in rolling direction. Different punch velocity is used to see the effect of same on UTM. Different punch travel is used to see the effect of same at different angles. The longer edge of the bent sample was coated with black ink and impression of the profile were taken on a board supported, thick sheet of white paper, at the end of loading and after the unloading. The impression were scanned and converted into digitized images. The same were exported to AutoCAD and lines were drawn on the edges of the legs of image using CAD software. Required angles were measured. Spring back angle, $\Delta\alpha = \alpha_i - \alpha_f = 2 \cdot \Delta\alpha/2$.

5. RESULTS AND DISCUSSION

Experiments were conducted using different combination of rolling direction, galvanizing thickness, punch velocity, with constant die width; punch radius, die radius and work blank. Effect of various parameter on spring back was plotted at various punch travel on graph and illustrate

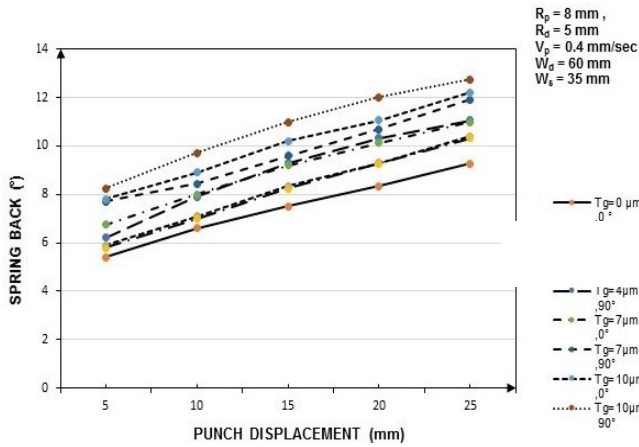


Fig. 5 Effect of rolling direction

5.1 EFFECT OF ROLLING DIRECTION

Fig.5 shows the spring back angles for un galvanized and galvanized both at 0° and 90° orientations. It is observed with the increase of punch travel, spring back is increasing in ungalvanized, galvanized, 0° orientation and 90° orientation. It is observed for both ungalvanized and galvanized, at 90° orientation the spring back is more as compared to 0°orientation. It is understood that the spring back angle isa function of yield strengthto modulus of elasticity ratio [12], [15]which is higher for90° orientation [14]

5.2 EFFECT OF GALVANIZING THICKNESS

Fig.6 shows effect of galvanizing thickness on spring back. It is observed with the increase of galvanizing thickness spring back is increasing at same punch travel. Zinc being softer it can be related with friction. Zinc presence changes the friction when it comes in contact with punch and die. Since zinc has lower shear strength then steel, it is softer and behaves as a solid lubricant [16].Therefore spring back angle is likely to increase[15].The increasing Coating thickness further reduces friction [17], [18] and so the spring back angle is found to increase with the increase of thickness[14]

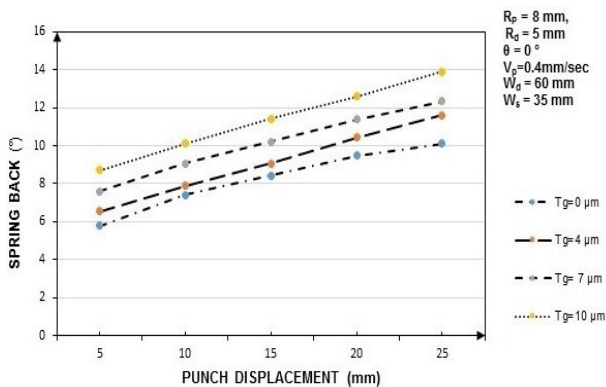


Fig. 6. Effect of galvanizing thickness

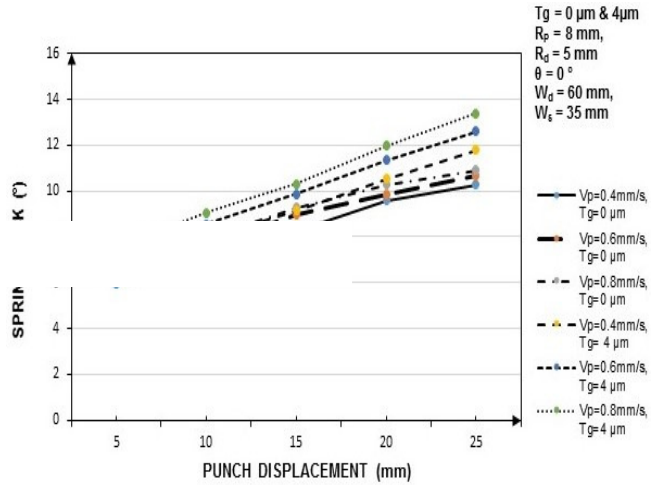


Fig. 7.Effect of punch velocity (Tg = 0 μm & 4 μm)

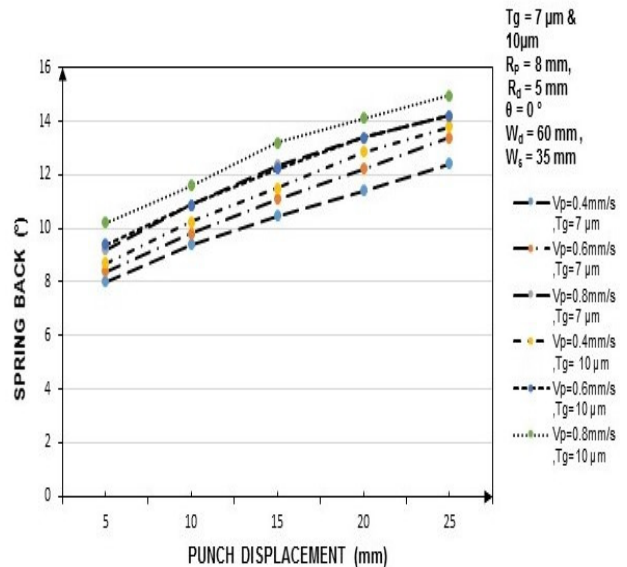


Fig. 8. Effect of punch velocity (Tg = 7 μm & 10 μm)

5.3 EFFECT OF PUNCH VELOCITY

Fig.7& Fig.8 shows effect of punch velocity on spring back. It is observed with the increase of punch velocity spring back is increased for each punch displacement in case of un galvanized as well galvanizedsheet of each galvanizing thickness The reason may be decrease of friction coefficient due to higher velocity[19]. Due to decrease of friction coefficient,spring back increases[20].It is observed the effect of punch velocity is more effective in case of galvanized sheet as compared to un galvanized sheet Fig.7

6. CONCLUSIONS

In this investigative study, effect of galvanizing thickness, punch velocity, rolling direction orientation and different bend angles by changing punch travel was studied in case of air bending. The main conclusion are as:

With the increase of punch travel(bend angle) spring back increases for galvanized as well as un-galvanized sheet.

In case of bending along rolling direction 90° orientation spring back is more for galvanized as well as un galvanized for each punch displacement (bend angles) as compare to bending across rolling direction 0° orientation.

Spring back is more in case of galvanized sheet as compare to un- galvanized sheet. Spring back increases with the increase of coating thickness.

With the increase of punch velocity spring back increases for both galvanized as well as un galvanized sheet. It increases with the increase of galvanizing thickness. But observed substantially higher in case of galvanized sheet as compared to un-galvanized sheet.

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