International Journal of Advance Research and Innovation
Vol. 2(1), Jan-Mar 2014, pp. 196-200
Doi: 10.51976/ijari.211431

Article Info
Received: 01 Jan 2014 | Revised Submission: 20 Feb 2014 | Accepted: 28 Feb 2014 | Available Online: 15 Mar 2014

Experimental and Numerical Analysis of Negative Spring Back in Interstitial Free (IF) Steel

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ABSTRACT

One of the most sensitive features of sheet metal forming processes is the elastic recovery during unloading, called spring-back, which leads to some geometric changes in the product. This phenomenon will affect bend angle and bend curvature, and can be influenced by various factors. In this research, the effects of anisotropy i.e., the rolling direction of 0° , 45° & 90° of ultra low carbon steel Interstitial Free (IF) Steel in V- bending with a punch corner radii of 7.5mm, were studied by experiments and numerical simulations. Comparison between the experimental and the finite element simulation results are also presented and found to be in close agreement.

Keywords: *Spring Back; IF Steel; FEA.*

1.0 Introduction

The application of interstitial free (IF) or low carbon steel sheets for automotive use requires the control of spring-back because of their higher yield strength to elastic modulus ratio. After the press forming operations, the forming parts change their shapes to achieve the equilibrium with no external force.

Spring-back is thus an elastically driven process that adjusts internal stresses to attain zero moment and force at each sheet location [1].

Also, under certain conditions, it is possible for the final bend angle to be smaller than the original angle. Such bend angle is referred to as spring-go or spring-forward [2].

The amount of spring-back/ spring-go is influenced by various process parameters, such as tool shape and dimension, contact friction condition, material properties, sheet anisotropy, and sheet thickness [3].

Many research conducted recently have shown the importance of spring-back in sheet metal industry, and studied how this permanent physical variation can be avoided. It is known that different spring-backs are possible regarding die design and convenience of the material.

A combination of various materials and processes make it difficult to obtain the predicted spring-back.

Material parameters such as elasticity, yield stress, hardening property, and process parameters such as the load applied, thickness of sheet metal, die angle, punch radius and die gap affect spring-back in a complex way [4].

In the research conducted by Tan et al. [4], a simple method is proposed to prevent the spring-back. In this method, sheet metal is exposed to a set of loading and unloading process.

Each bending angle and the corresponding spring-back values are measured, and the output signal is computerized.

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Thus, the appropriate press depth of the punch, which corresponds to excessive bending, is determined.

The first objective of the research conducted by Shu and Hung [5] was to employ finite elements method to analyze the relation between coupled bending technique, springback and variables.

Later, in order to reduce spring-back and find optimum shaping parameters, they combined the finite elements analysis and optimization techniques.

The results obtained from the study were compared with the experimental data, and it was concluded that increasing die gap results in reduction of spring-back values.

Yuan [6] tried to lessen spring-back, in the material subjected to plastic deformation, through redistribution of elastic stresses inside the material after the release of the affecting load.

In this paper, experimental and numerical studies of the effects of sheet anisotropy on spring- back/spring-go in V-die for Interstitial Free (IF) steel sheet have been conducted.

The results of the experiments were also compared with those of the finite element analysis. In addition, the results obtained from the two bending processes were also

2.0 Methodology & Experimental Results

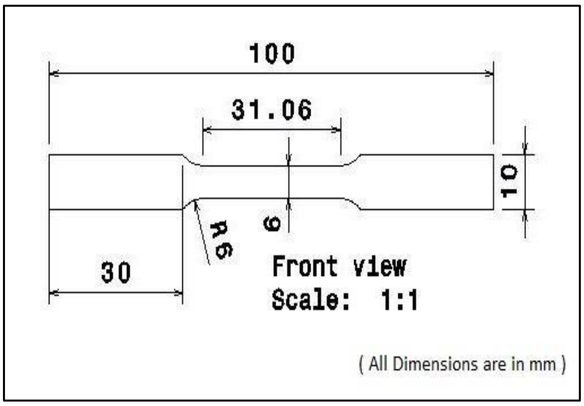
2.1 Mechanical properties of IF steel

The tension tests were carried out as per ASTM E 8M-04 (2004) on 10kN table top *UTM-Tinius Olsen* machine in metal forming laboratory at DTU Delhi.

The extra low carbon steel sheets of IF grade was tested for the tensile propertites. The Sheet thickness is 1.2 mm which is denoted by the symbol A1.

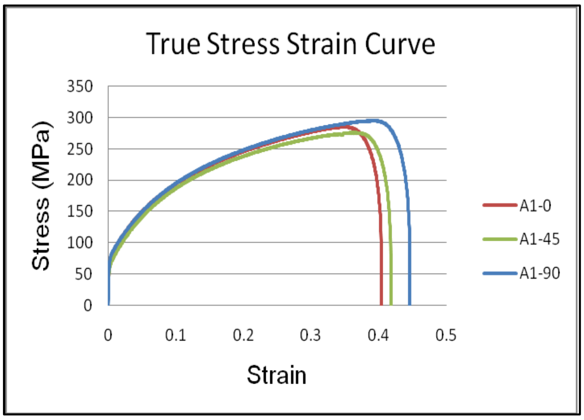
The Stress Strain curve is plotted for all the specimens.

Fig 1: Sample Size According to ASTM E8M-04 Tested in UTM



The typical stress strain curve obtained from the tests is shown in figure 2. Since the departure from the linear elastic region cannot be easily identified, the yield strength was obtained using the 0.2 % offset method. UTS was determined for the maximum load and original cross sectional area of specimen. compared.

Fig 2: True Stress Strain Curve for IF Steel



The strain hardening exponent (n) and the strength co efficient (K) values are calculated from the stress strain data in uniform elongation region of the stress strain curve. The plot of log (true stress) vs log (true strain) which is a straight line is plotted. The power law of strain hardening is given as :

$$\sigma = K \epsilon^{n} \qquad (1)$$

Where, σ and ∈ are the true stress and the true strain respectively.

Taking log on both sides

$$\text{Log}(\sigma) = \log(K) + n \log(\epsilon) \qquad (2)$$

This is an equation of straight line, the slope of which gives the value of "n" and "K" can be calculated taking the inverse log of the y intercept of the line (i.e log (K)).

The % elongation or the reduction in cross section area is used as a measure of ductility of material. % elongation values were calculated at the fracture. The elongation was measured by fitting together the fractured specimen.

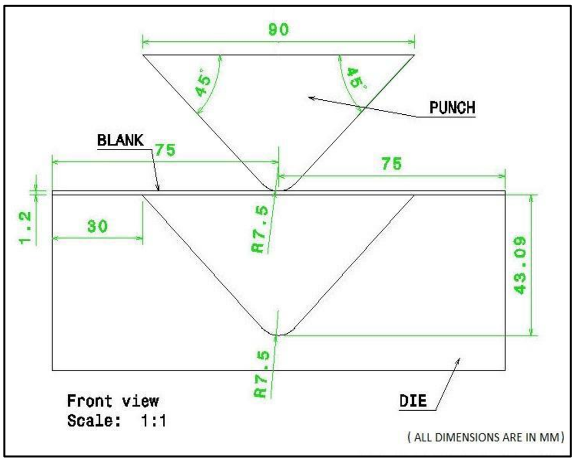
Table 1: Mechanical Properties of IF Steel for all the Samples in Different Rolling Direction

IF-steel	0.2%-offset yield σ_y (MPa)	$\sigma_{(UTS)}$ (MPa)	Strain hardening exponent 'n'	Strength coefficient 'K'(MPa)	% Elongation
Al-0	123.33	205.55	0.343	428.37	48.88
Al-45	124.351	209.787	0.336	432.25	51.52
Al-90	124.28	207.57	0.32	414.47	48.75

2.2 Experimental work for spring back or spring forward

In this experiment an offset was provided of the thickness of the blank i.e., 1.2 mm to allow the full displacement of punch and clearance of 0.5 mm was provided between the Die and lower surface of blank to prevent any type of excess punch holder force on blank to avoid the effect of sheet material on spring back, due to squeezing action of the bending section (profile). As soon as the punch reached the last point of depth, it was removed and the punch load was relieved instantly. Figure 3 shows the diagrammatic view of complete setup.

Fig 3: The Schematic Diagram of Complete Set-up

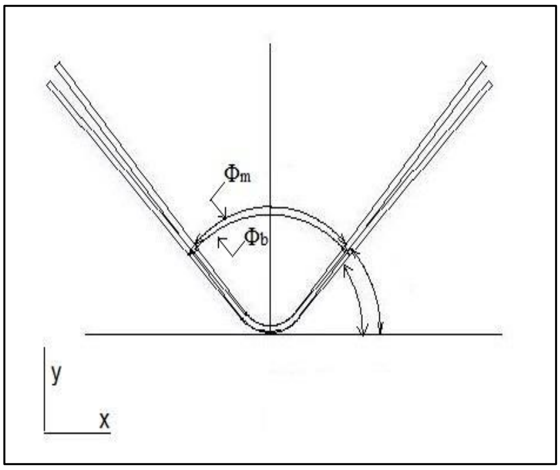


Here, Φb = Initial Bend Angle

Φm = Measured Angle after experiment

Now, let $$\frac{(180 - \Phi b)}{2} \qquad (3)$$

Fig 4: Diagram to Show Spring Forward



$$\theta m = \frac{(180 - \Phi m)}{2} \qquad (4)$$

Therefore, the spring back of the IF Steel can be calculated by subtracting equation (4) from equation (3) , we get

$$\delta = \theta b - \theta m \qquad (5)$$

Table 2: Spring Forward Data from Performed Experiment

IF-steel	Φ_{bE}	Φ_{mE}	θ_{bE}	θ_{mE}	$\delta_E = (\theta_{bE} - \theta_{mE})$ Springback(deg)
A1-0	90°	86.32°	45°	46.84°	-1.84°
A1-45	90°	86.58°	45°	46.71°	-1.71°
A1-90	90°	86.98°	45°	46.51°	-1.51°

3.0 Experimental Results Validation with Fea

The numerical model developed in this study considers a finite displacement of punch of PCR 7.5 mm on the blank to provide bending to the blank which was placed on the die. During bending process no blank holder forces acts on blank and thus after complete bending it is in perfect V Shape of different angle with respect to bend angle. The clearance of 0.5 mm was provided between the Die and lower surface of blank to prevent any type of excess punch holder force on blank to avoid the effect of sheet material on spring back, due to squeezing action of the bending section (profile). As soon as the punch reached the last point of depth, it was removed and the punch load was relieved instantly. The Coefficient of friction between Blank and Punch is taken as 0.125 and coefficient of friction between Blank and Die is taken as 0.05. The Modulus of Elasticity is taken as 210 GPa and Poisson’s ratio is taken as 0.3. The subsequent pages of this chapter show the bending of sheet.

Fig: 5. Overlay Plot of the Specimen A1-0 of Both Spring Forward with Bend Angle

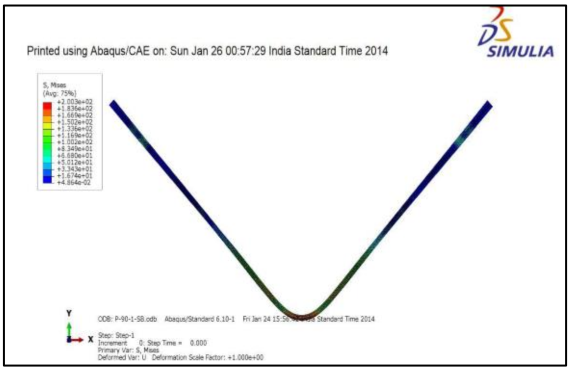


Fig 6: Overlay Plot of the Specimen A1-45 of Both Spring Forward and Bend Angle

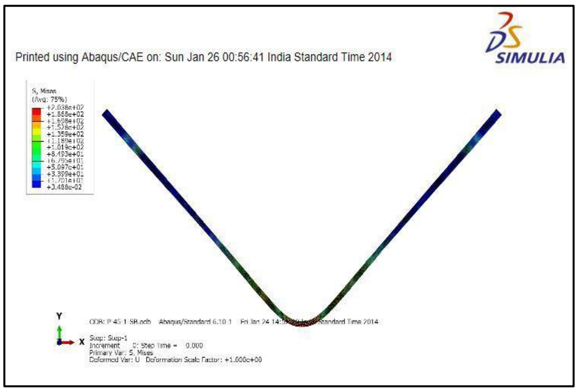
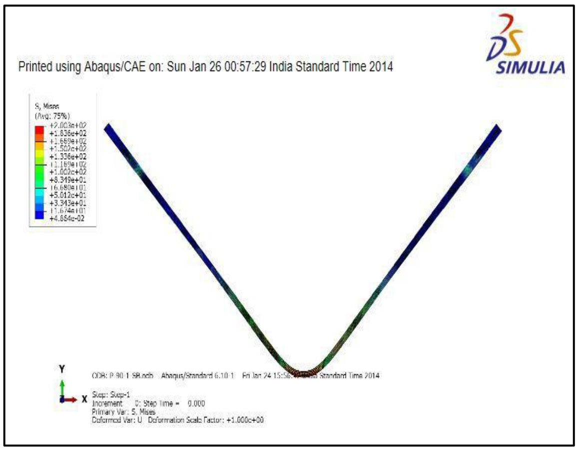


Fig 7: Overlay Plot of the Specimen A1-90 of Both Spring Forward and Bend Angle



Combined result of negative springback is formulated in Table 3 and comparison of negative springback obtained from experimental as well as from FEA is also shown.

Table 3: Spring Forward Data from FEA and its Comparison with Experimental Values

IF-steel	ΦbFEA	ΦmFEA	θbFEA	θmFEA	δFEA	δE
A1-0	90°	87.65°	45°	46.17°	-1.17°	-1.84°
A1-45	90°	88.10°	45°	45.95°	-0.95°	-1.71°
A1-90	90°	88.40°	45°	45.80°	-0.80°	-1.51°

4.0 Conclusion

The mechanical properties of IF Steel were experimentally studied. IF steel depicts soft and ductile behavior with 49% of elongation on an average. The material is highly anisotropic affecting the bend angles with respect to rolling direction. During bending of sheet specimens, spring-forward takes place instead of spring back. At very small R/t ratios, this may even result in negative springback [7].

The Spring Forward has been studied in V-bending force and its effect on the negative Spring Back has been analysed using Abaqus CAE. The numerical model confers to the theoretical concepts of Bending and the results obtained are in agreement.

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