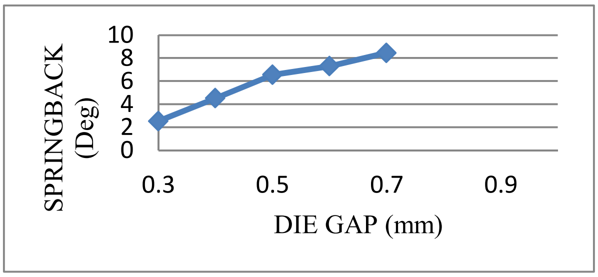


Figure 8: Effect of die gap on springback

Table 5: Effect of sheet thickness on springback

Thickness (mm)	Springback (Θ)
0.3	2.35
0.4	2.01
0.5	1.72
0.6	1.69
0.7	1.5

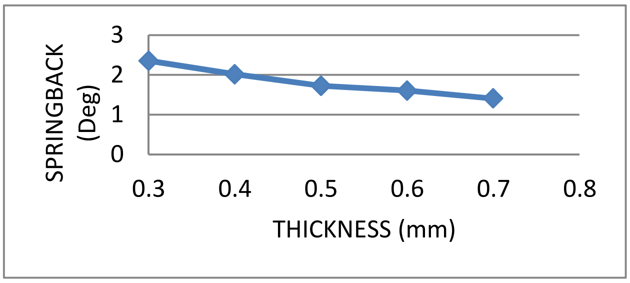


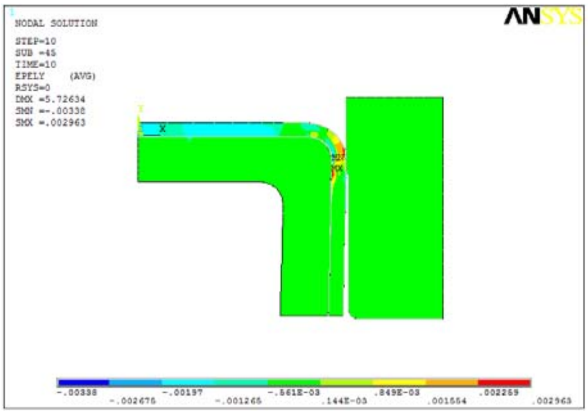
Figure 9: Effect of sheet thickness on springback

7. Over Bend Approach

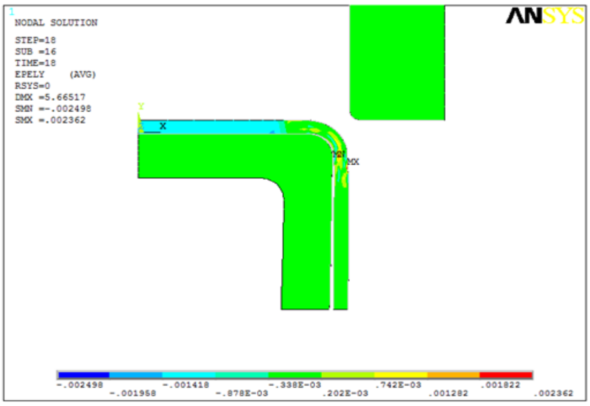
One of the common techniques used for compensating the springback is over bending the sheet metal with more angles then required. To apply this method, the amount of springback is calculated and the sheet metal is over bent to a smaller bend angle than required. Recovery of the sheet metal from the springback 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.

Table 6: Die undercut in deg. to minimize the springback

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



a) Over bend



b) Reauired 90 deg. Bend

Figure 10: an over bend approach

8. Analytical method

To validate the FE analysis a theoretical approach is applied.
Strain at the outer fiber = (change in length / original length) (1)

Change in length = $(2\pi Ro/4 - \pi/2\ Rn)$

Original length = $\pi/2\ Rn$

Where,
Ro = sheet metal bend radius (outer)
Rn = radius of neutral fiber or mean radius
Ri =sheet metal bend radius (inner)

Mean radius (Rn) = $(Ri + Ro)/2$

= $(0.5 + 0.8)/2$

Rn= **0**.65mm
Now from equation (1)

Total strain at the outer fiber = $(0.8 - 0.65)/(0.65)$
Ɛt=0.23

Now from the stress-strain curve for total strain of 0.23, the elastic strain reversible strain measured was of about 0.0045 and the remaining strain is plastic strain or irreversible strain.

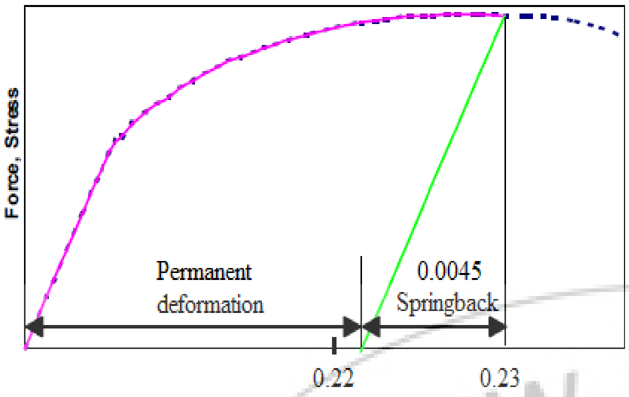


Figure 10: Showing Elastic strain from Stress-Strain curve

$$\varepsilon_t=\varepsilon_e+\varepsilon_p \quad (2)$$

$$\theta = (\delta_{elastic})/(T/2) \quad (3)$$

Where,
T=sheet metal thickness

$\delta_{elastic} = (\varepsilon_{elastic})*(\text{length of bent region})$ (4)

$\delta_{elastic}$ = change in length due to Elastic strain

$$\delta_{elastic} = (0.0045) * (\pi/2)Ro$$

$$\delta_{elastic} = (0.0045) * (\pi/2)0.8$$

$$\delta_{elastic} = 5.6556E - 3$$

Now from equation (3)

$$\theta = (5.6556E - 3)/(0.3/2)$$

$\theta = 0.037704$ Radians

$$\theta = (0.037704) * (180/\pi)$$

$$\theta = 2.16^{\circ}$$

9. 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.

10. Scope of Future Work

The method of Finite element analysis by ANSYS can also be extended to other materials with different mechanical properties. Behaviors of springback of different materials can be studied further and compared. For more accurate measurement of springback Bauschinger effect can be considered. In industries there is lot of requirement for the solutions to the cause of springback hence in further studies different solution techniques can be developed.

In this current work isotropic hardening law was considered for the material model, to predict the springback more accurately future ANALYSIS can be carried out by modeling the models with different hardening laws such as Kinematic hardening law, which also considers the Bauschinger effect.

References

[1] Abdulaziz alghtani, P.C. Brooks, D.C. Barton, V.V. Toropov 'springback analysis and optimization in sheet metal forming' 9th European LS-DYNA conference 2013.

[2] Jan slota, Miroslav jurcisin 'experimental and numerical prediction of springback in v-bending of anisotropic sheet metals for automotive industry'zeszyty naukowe politechniki rzeszowskiej, Mechanika z. 84 (3/12) 2012.

[3] Recep Kazan, Mehmet Fırat, Aysun Egrisogut Tiryaki 'Prediction of springback in wipe-bending process of sheet metal using neural network' Materials and Design 30 (2009) 418-423.

[4] Fuh-Kuo Chen, Shen-Fu Ko 'Deformation analysis of springback in L-bending of sheet metal' journal of achievements in materials and manufacturing engineering volume 18, issue 1-2, 2006.

[5] Z. Marciniak, J.L. Duncan, S.J. Hu 'Mechanics of Sheet Metal Forming' First published by Edward Arnold, London, 1992 Second edition published by Butterworth-Heinemann 2002 Copyright 2002 S.J. Hu, Z. Marciniak, J.L. Duncan All rights reserved.

[6] Florica mioara groze; gheorghe achimas lucian lazarescu , vasile adrian ceclan ' springback prediction of the v bending process using finite element simulation' 7th international multidisciplinary conference baia mare, romania, may 17-18, 2007 issn-1224-3264.

[7] Ivan sachy 'Handbook of die design second edition' Copyright © 2006, 1998 by Ivana Suchy., McGraw-Hill

[8] Filip Lindberg 'Sheet Metal Forming Simulations with FEM' Master's Thesis in Engineering Physics, 30 ECTS jan 2011.

[9] I.A. Burchitz 'improvement of springback prediction in sheet metal forming' ISBN 978-90-365-2656-2. Copyright 2008

[10] Jeong-Whan Yoona, Farhang Pourboghrat, Kwansoo Chung, Dong-Yol Yang Springback prediction for sheet

metal forming process using a 3D hybrid membrane/shell method' International Journal of Mechanical Sciences 44 (2002) 2133–2153.
[11] Yongde Zhang, Jixiong Jiang and Yi Liu 'Theoretical Analysis and Experimental Study of Springback Mechanism of Archwire Bending' Research Journal of Applied Sciences, Engineering and Technology 6(13): 2495-2501, 2013 ISSN: 2040-7459; e-ISSN: 2040-7467 © Maxwell Scientific Organization, 2013
[12] Cook, R. D., Malkus, D. S. and Plesha, M. E., Concepts and Applications of Finite ElementAnalysis, 4th Edition, John Wiley & Sons, New York, 2002, pp 530-587.
[13] Crisfield, M. A., Non-linear Finite Element Analysis of Solids and Structures, Volume 1: Essentials, John Wiley & Sons, Chichester, 1991, pp 77-80,131-132, 211-220.
[14] Gawade Sharad, Dr. V. M. Nandedkar, 'spring back in Sheet Metal Bending-A Review', IOSR Journal of Mechanical and Civil Engineering ISSN: 2278-1684, PP: 53-56
[15] I.Burchitz 'Springback: improvement of its predictability', Netherlands Institute for Metals Research.2005

Author Profile

Amul Biradar received the B.E. and pursuing M.Tech Degrees in Mechanical Engineering from HMS Institute of Technology and Mechanical machine design form KLS Gogte Institute of Technology in 2012 and 2014, respectively.

M.D Deshpande received the B.E. and M.Tech. degrees in Mechanical Engineering from MS Ramaiah Institute of Technology and Mechanical Machine dynamics from IIT Kharagpur in 1983 and 1991, respectively. He was head of the Department of mechanical Engineering and currently working as professor in KLS Gogte institute of Technology.