Araştırma Makalesi
Bayburt Üniversitesi Fen Bilimleri Dergisi
Cilt 2, Sayı 2

Geliş Tarihi: 18.12.2019
Kabul Tarihi: 25.12.2019
dergipark.gov.tr/bufbd

Experimental Investigation of Springback of DC Series Steel Sheet in V-Bending Process

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Keywords:

Springback,
Sheet metal,
V-bending

Abstract

Sheet materials, which are commonly used in sectors such as automotive and whitewares, are usually formed by applying bending operations. The most important problem encountered in bending processes is springback. Springback problem arising from elastic behavior of the material complicates the assembly of manufactured part due to dimensional differences and causes financial loss. For this reason, it is required to properly estimate the springback behavior to provide the dimensional integrity and cost savings of the shaped parts as a result of the bending operations. In this study, the springback behavior of DC series sheet metals forming by V bending was experimentally investigated the different process parameter of material quality, thickness, rolling direction and die angle. The sheet metals have the quality of DC01, DC04 and DC05 and the thickness of 1, 1.5 and 2 mm. The V-bending dies have 60, 90 and 120^{o} angles. From the experimental studies, it is seen that the behavior of springback changes depending on the die and the process parameters.

1. INTRODUCTION

Sheet materials have been widely used in many fields such as automotive, aerospace, whitewares, machinery manufacturing, and construction area. Sheet materials are generally used after the application of various manufacturing processes such as deep drawing, bending, drilling, cutting, etc. The bending being one of these processes has different method such as V bending, U bending, edge bending and free bending. Bending of sheet metal is a common and vital process in manufacturing industry. Sheet metal bending is the plastic deformation of the work over an axis, creating a change in the part's geometry. Similar to other metal forming processes, bending changes the shape of the work piece, while the volume of material will remain the same. In some cases, bending may produce a small change in sheet thickness. The bending process is a process in which material is shaped around an axis without waste removal process by heating or without heating material.

Various failures might be encountered in bending process due to material properties and manufacturing. Measurement errors are one of these. Common error experienced in bending process is springback. By removing exerted force, the material tries to return the original state and partially elongates. Springback results from elasticity behavior of material is defined as the difference between bending angle of bended material and the true bending angle of material after it is processed. Springback is a processing problem consisted of many variables such as mechanical and chemical properties of sheet metal, processing factors, and dimensional parameter [1]. Springback brings about some troubles in installation of sheet metals and the installation of the material part has not been able to achieve properly. This means the disposal of the part to scrap, financial loses, and an increase in cost of product. Thus it is very significant to pre-estimate springback and its control in order to eliminate or to reduce problem experienced during installation, to ensure exact dimension in terms of decreasing cost of die and manufacturing low-cost parts. For obtaining intended angle after bending and shaping of sheet metal, springback should be compensated. Many methods are benefited to compensate the springback problem. There two fundamental methods, mainly numerical and experimental, in investigating bending and shaping sheet metal. The results provided by experimental methods forms true data.

In literature, some studies on springback behavior in V bending process have been taken into consideration. Zhang et al. investigated the amount of springback due to V-die bending process of three different materials mainly steel,

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brass, and copper by carrying out a series of experimental studies [2]. Esat et al. numerically and experimentally investigated springback of aluminum having different thicknesses using different angled die and concluded that the springback was decreased for the materials [3]. Yanagimoto et al. performed a serial of hot and mild shaping experiments of sheet metal on high strength sheet metals and analyzed the effects of working temperature on shaping [4]. Garcia-Romeu researched springback behavior due to free V bending by tensile tests of stainless steel and aluminum sheet metal [5]. Tekaslan et al. designed a V die in order to determine the amount of springback and determined how much sheet metal with thicknesses of 0.75 mm can elongate at different angles [6]. Bakhshi-Jooybari et al. examined the influence of springback test parameters (thickness, punch type radius, anisotropy, etc.) on V and U bending operations [7]. Osman et al. suggests a methodology for the prediction of springback ratio in V-die bending. They develop theoretical model for air bending using true strain and neutral fiber position that satisfy continuity of the radial stress [8]. Isiktas designed a V-bending die in order to determine the amount of springback of DKP and stainless sheet materials in different thickness and different die angles [1]. Kim and Lee analyzed the effects of remained austenite phase on springback of cold rolled TRIP steel sheet through a serial of V-bending tests [9]. Otu and Demirci studied the effect of pre-stress on springback bending AA5754 and Al1050, aluminum sheet materials, in V die with 60^o [10]. Ivanišević et al. focused on three different steel materials for the analyses of springback phenomenon in the V-bending operation and the stress state in the bending zone [11]. Aslan and Ibrahim evaluated and researched on the studies of springback problem in the V bending process [12]. Singh and Kumar looked into springback using effect of process parameters such as wall angle, tool diameter and step depth in the experiments conducted on AA 1200 H14 aluminum alloys [13]. The springback behaviors of high strength steel sheet materials in DP600, DP1000 and DP1400 qualities were investigated by Esener et al. [14].

According to results mentioned above, it has been predicted changing die angle depending on the amount of springback in order to decrease springback. For this purpose, springback graphics obtained by experimental studies is very beneficial. However, these kind of graphics in literature have been available for limited materials. In this study, a serial of experimental studies to determine springback behavior of sheet materials were conducted out under different process parameters.

2. MATERIAL and METHOD

In the study, the effect on the springback behavior of different process parameters in V-die bending process was experimentally investigated. The V-die bending experiments were carried out depending on the different process parameters such as quality of sheet metal, sheet metal thickness, rolling direction and die angle. The bending process parameters were given in Table 1.

Table 1. Parameters used V-die bending process

Process parameter	*Parameters*
Material	*DC01, DC04, DC05*
Thickness (mm)	*1, 1.5, 2*
Rolling direction	*Parallel, Perpendicular to rolling direction*
Die angle (^{o})	*60, 90, 120*

DC01, DC04 and DC05 sheet steel qualities are suitable for bending, drawing and deep drawing and cold forming operations. These products are used in all applications requiring strength, durableness and forming in automotive, durable household appliances, kitchenware, radiator sectors. The mechanical properties of DC01, DC04 and DC05 sheet metals used in this study were given in Table 2, while their chemical compositions were given in Table 3.

Table 2. Mechanical properties of sheet materials

Material	*Maximum Tensile Stress (MPa)*	*Yield Stress (MPa)*	*Strain (%)*
DC01	*345*	*254*	*28*
DC04	*311*	*177*	*38*
DC05	*297*	*148*	*40*

Table 3. Chemical compositions of sheet materials

Material	*C*	*Mn*	*P*	*S*
DC05	*0.060*	*0.035*	*0.025*	*0.025*
DC04	*0.080*	*0.040*	*0.030*	*0.030*
DC01	*0.120*	*0.600*	*0.045*	*0.045*

The punches and dies used in V-die bending process were manufactured in the different dimensions from St37 steel material as shown in Figure 1. Samples of sheet experiment were cut to have size of 90x45 mm considering rolling direction. For each case, the bending experiments were performed three times. The bending process was continued until the distance between punch and die reached to the thickness of sheet material. The distance between punch and die should be the same as the thickness of sheet material to no effect springback behavior by crashing sheet material. As soon as the punch arrived the last point the load exerted on sheet was removed.

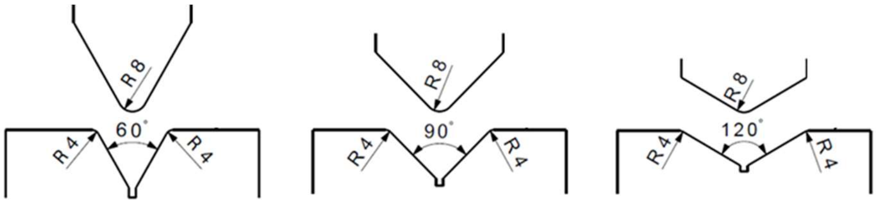

Figure 1. Dimensions of punch and die used

After the V-die bending experiments were carried out, the amount of springback in sheet metal was measured by determining how much deviation from die angle occurred. The bending angles of the samples were measured by using a digital goniometer.

3. RESULTS

The V-die bending process was applied at 60, 90 and 120^o die angles to the samples both parallel and to perpendicular the rolling direction (Figure 2).

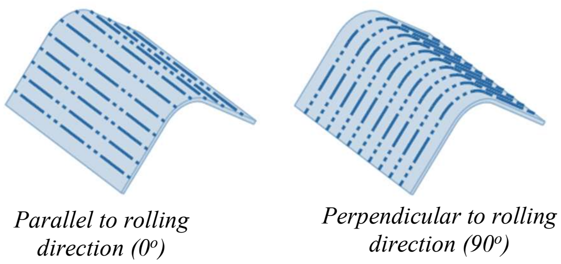

Figure 2. Illustration of rolling direction

The amount of springback in DC05 steel sheet metal was shown in Figure 3. The springback happen as positive at die angles of 60^o for all thicknesses and all rolling parameters, and the samples shown an opening out trend. At 90^o die angle, the springback behavior at sheet metal thicknesses of 1 and 1.5 mm realized in the direction of positive (+), while it was negative (-) at 2 mm thickness. At 120^o die angle, the springback behavior for all thickness of the material was negative, meaning that the DC05 sheet metal tended to close. The highest value of springback was observed in DC05 sheet metal with 1 mm thickness and 60^o die angle, while the lowest springback value was observed at 2 mm thickness and 120^o die angle.

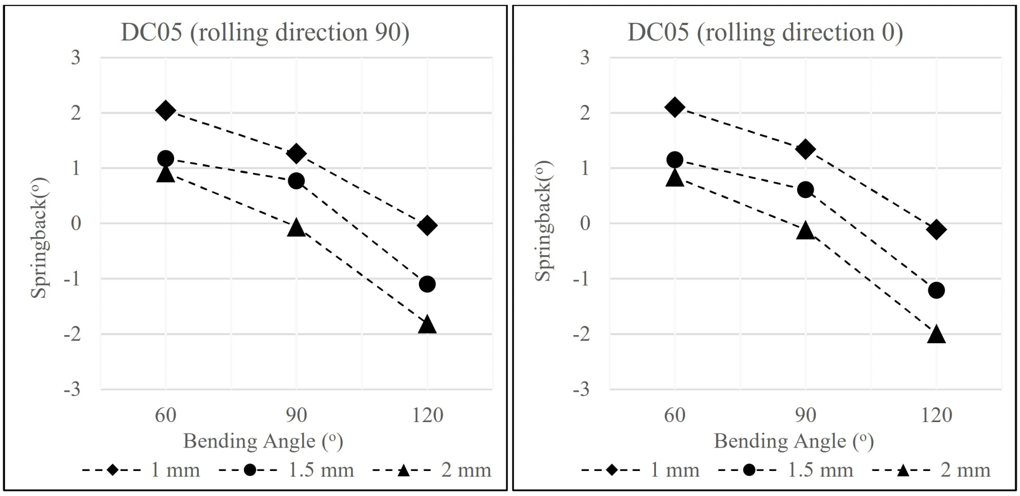

Figure 3. Springback behavior in DC05 sheet metal

The springback behavior in DC04 sheet metal is seem in Figure 4. From Figure 4, the springback values for all thickness and both roll directions at 60º and 90º die angles have been realized in the positive direction, indicating that the material tends to open. At the die angle of 120º and the sheet metal thickness of 1 mm, the springback occurred in the positive direction, while it occurred in the negative direction at the thickness of 1.5 and 2 mm. The springback behavior in the DC04 sheet metal with 1.5 mm thickness was the negative direction, it can be regarded as "0" because it is very close to zero.

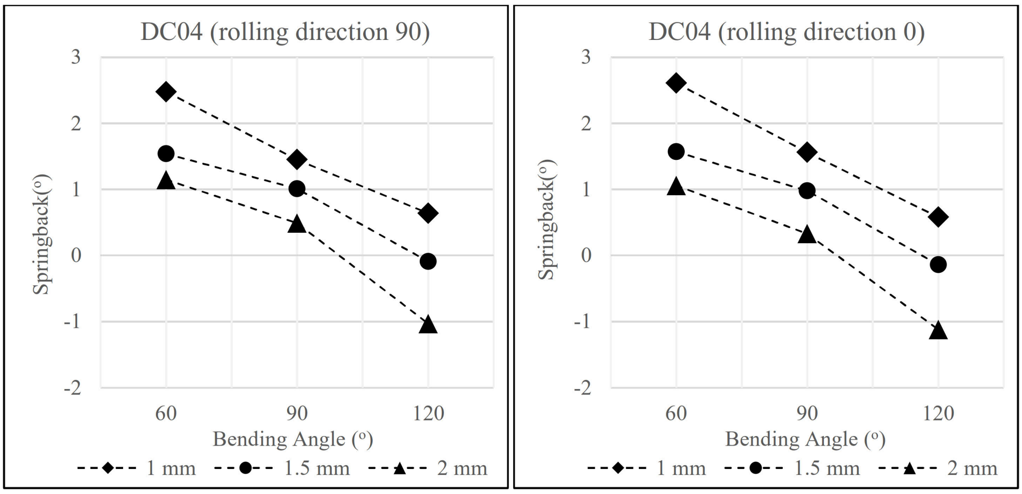

Figure 4. Springback behavior in DC04 sheet metal

The effect on the springback behavior of the different die angles in the V-die bending tests of DC01 sheet material is shown in Figure 5. The springback occurred in the positive direction for all die angles, sheet thicknesses and rolling directions and showed an opening out tendency. The springback values of the bending samples in the die angle of 60º were bigger than that of the bending samples at the die angles of 90º and 120º. The lowest springback value of DC01 sheet metal was obtained in the samples bended at 120º die angle. The highest springback value was obtained in the sample with 1 mm thicknesses, while the lowest springback value was obtained in the samples with 2 mm thicknesses.

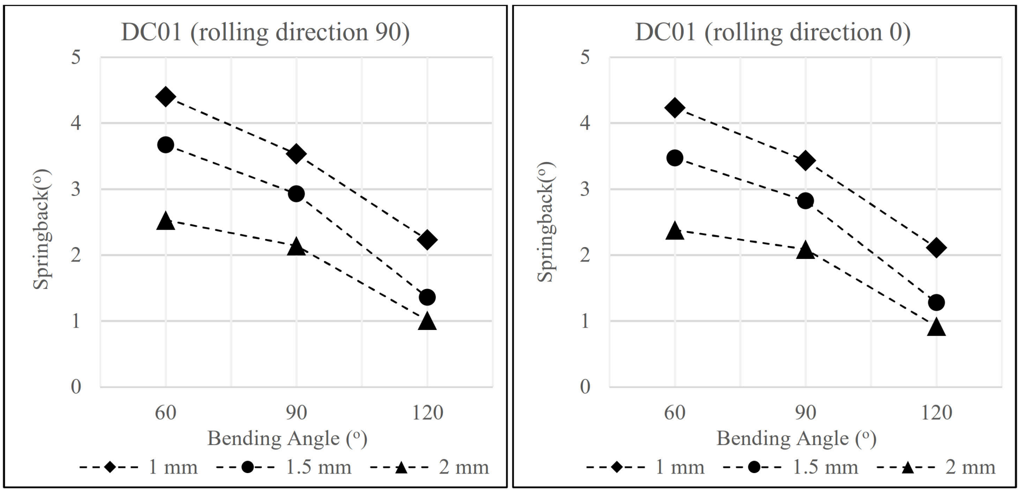

Figure 5. Springback behavior in DC01 sheet metal

When Figure 3, Figure 4 and Figure 5 were analyzed, it was seen that the amount of springback decreased with the increasing die angle [15]. While the highest springback value was obtained at the die angle of 60º, the lowest value was also obtained at the die angle of 120º. For example, the springback values in DC01 sheet material with 1 mm thickness at 60º, 90º and 120º die angles were measured as 4.4º, 3.53º and 2.23º, respectively. The reason of the decrease in springback with the increasing die angle can be explained by the decrease in elongation and deformation occurred on the outer face of sheet metal [15]. In Figure 6, the dark sections show the deformation regions and these regions were reduced from 60º to 120º.

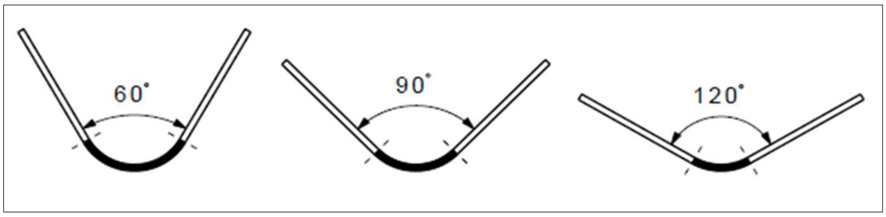

Figure 6. The deformation regions

It was clearly seen in from Figure 3 to Figure 5 that the amount of springback decreased, when the thickness of sheet metal was increased [16-18]. While the highest springback value was obtained in the sample with 1 mm thickness, the lowest springback value was obtained in the sample with 2 mm thickness. In the bending process of DC04 sheet metal chosen to be perpendicular to rolling direction, the springback values were measured as 2.48^o, 1.54^o and 1.15^o in samples having thicknesses of 1, 1.5, and 2 mm, respectively. Moreover, the results are in good agreement with the inverse proportionality between springback and thickness (K=R/t) [10]. The reason of the decrease in the springback with together the increasing sheet thickness can be stated as the decrease in the remained tensile occurred in the bending region [19]. Forming Limit Diagrams (FLD) are the most appropriate tools to characterize the formability of sheet metals. FLDs rises, the formability improves and the amount of springback decreases, when the thickness of sheet material is increased [20].

It was seen that springback results are almost same in the bending process parallel and perpendicular to the rolling direction under same conditions in the sheet metals used in experiments. Therefore, the results in the bending perpendicular to the rolling direction were only considered in the interpretations given below. For example, in the bending process in DC05 sheet metal with 1 mm thickness at 60^o die angle, the amount of springback was determined 1.17^o for the perpendicular case and 1.15^o for the parallel case.

In the bending perpendicular to the rolling direction at the sheet metal with 1 mm thickness, the effect of material quality on springback behavior was indicated in Figure 7.

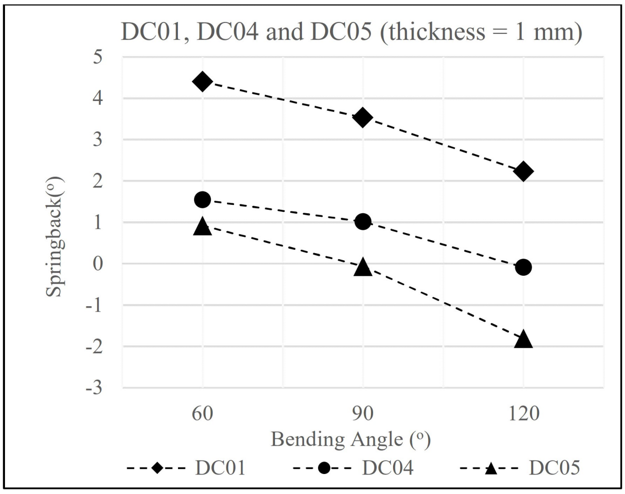

Figure 7. Springback behaviors in DC01, DC04 and DC05 sheet metals

The highest springback behavior was observed in DC01 steel sheet metal as shown in Figure 7, while the lowest springback behavior was observed in DC05 sheet material. The reason of this is that the yield strength of DC01 sheet metals is higher than that of DC05 sheet metals (Table 2). From Figure 7, it was seen that the higher yield strength materials exhibited the higher springback behavior and the lower yield strength materials exhibited the less springback behavior [1,6,21-23]. DC04 and DC05 sheet metals showed almost the same springback behavior due to their similar mechanical properties. Although DC01 sheet metal is also in the DC group, its springback value was higher than that of DC04 and DC05 sheet metals.

4. CONCLUSION

In this study, the springback behaviors of the sheet metals of DC01, DC4 and DC05 were determined depending on the process parameters in the V-die bending. The findings obtained from this study are as follow:

- ✓ The springback decreased with the increasing die angle. This case was explained by the decrease in the elongation and the deformation formed on outer surface.
- ✓ The springback behavior changed depending on the material quality. While the springback in the sheet metals with the low yield strength rarely occurred, it was generally occurred in the sheet metals with the high yield strength.
- ✓ The springback decreased with the increasing sheet thickness. Moreover, this case verified that the springback is inversely proportional to the thickness (K=R/t).
- ✓ The springback results was almost same in the bending process parallel and perpendicular to the rolling direction under same conditions in the sheet metals used in experiments
- ✓ Designers can compensate the springback problem in the V-die bending process by fixing dies in opposite direction as much as the springback value determined by experiments during the designing.

Note

This study was presented and reconstructed as an oral presentation at the 2nd International Conference on Advanced Engineering Technologies (ICADET 2017) held between 21-23 September 2017 in Bayburt-Turkey.

References

[1] Isiktas, A., "Examining the springback of DKP and stainless steel sheets with different thickness in the V-bending process carried out in different angles," Master's Thesis, Balıkesir University, Institute of Science, Balıkesir, 2011.

[2] Zhang, L.C., Lu, G. and Leong, S.C., "V-shaped sheet forming by deformable punches," Journal of Materials Processing Technology, vol. 63, pp.134-139, 1997.

[3] Esat, V., Darendeliler, H. and Gokler, M.I., "Finite element analysis of springback in bending of aluminium sheets," Materials and Design, vol. 23, pp.223-229, 2002.

[4] Yanagimoto, J., Oyamada, K. and Nakagawa, T., "Springback of high-strength steel after hot and warm sheet formings," CIRP Annals-Manufacturing Technology, vol. 54, pp.213-216, 2005.

[5] Garcia-Romeu, M.L., Ciurana, J. and Ferrer, I., "Springback determination of sheet metals in an air bending process based on an experimental work," Journal of Materials Processing Technology, vol. 191, pp.174-177, 2007.

[6] Tekaslan, O., Seker. U. and Gerger, N., "Determining springback amount of steel sheet metal have 0.75 mm thickness in bending dies sheet materials," Journal of Engineering Sciences, Pamukkale University Engineering College, vol. 13, pp.15-22, 2007.

[7] Bakhshi-Jooybari M., Rahmani B., Daeezadeh V. and Gorji A., "The study of spring-back of CK67 steel sheet in V-die and U-die bending processes," Materials and Design, vol. 30, pp. 2410-2419, 2008.

[8] Osman M.A., Shazly M., El-Mokaddem A. and Wifi A.S., "Springback prediction in V-die bending: modelling and experimentation," Journal of Achievements in Materials and Manufacturing Engineering, vol. 38(2), pp. 179-186, 2010.

[9] Kim, S. and Lee, Y., "Effect of retained austenite phase on springback of cold-rolled TRIP steel sheets," Materials Science and Engineering A, 530, pp. 218-224, 2011.

[10] Otu, R. and Demirci H.I., "Determination of amount springback of AA5754 and Al1050 sheet materials by using different bending methods in 60° V-die bending," International Iron & Steel Symposium, Karabuk, Turkey, 02-04 April 2012.

[11] Ivanišević, A., Milutinović, M., Štrbac, B. and Skakun, P., "Stress State and Spring Back in V-Bending Operations," Journal for Technology of Plasticity, vol. 38, no.2, pp. 157-168, 2013.

[12] Aslan Y. and Karaağaç İ., "V Bükmede Geri Esneme Davranışları," Gazi Üniversitesi Fen Bilimleri Dergisi, Part: C, Tasarım ve Teknoloji, vol. 2, no. 3, pp. 255-263, 2014.

[13] Singh P. and Kumar N., "Experimental and Statistical Study on Springback Behavior in Incremental Sheet Metal Forming Process," International Journal of Innovative Research in Science, Engineering and Technology, vol. 4(9), pp. 8125-8130, 2015.

[14] Esener, E., Sönmez, E., Özsoy, M., and Firat, M. "Determining Springback Behavior of High-Strength Steels via Channel Forming Process," Acta Physica Polonica A, vol. 132, no.3–II, pp.1010-1012, 2017.

[15] Ozdemir A., “Sac metal ürünlerde geri esneme miktarının deneysel ve sonlu elemanlarla tespiti, yapay sinir ağlarıyla tahmini,” Master's Thesis, Gazi University, Institute of Science, Ankara, 2010.

[16] Fei, D. and Hodgson, P., “Experimental and numerical studies of springback in air v-bending process for cold rolled TRIP steels,” Nuclear Engineering and Design, vol. 236, pp. 1847-1851, 2006.

[17] Kilic, S., “İnvestigation of springback behaviour of DP600 steel,” Master's Thesis, Nigde University, Institute of Science, Niğde, 2009.

[18] Turan, S.E., “The investigation of effects of straight flanging and rotary die flanging operations on springback,” Master's Thesis, Istanbul Technical University, Institute of Science, Istanbul, 2009.

[19] Livatyalı, H., and Altan, T., “Prediction and elimination of springback in straight flanging using computer aided design methods Part 1. Experimental investigations,” Journal of Materials Processing Technology, vol. 117, pp. 262-268, 2001.

[20] Capan, L., Plastic Forming of Metals Metallere Plastik Şekil Verme, Çağlayan Publishing House Kitabevi, Istanbul, 2003.

[21] Tekiner, Z., “An Experimental Study on The Examination of Springback of Sheet Metals with Several Thicknesses and Properties in Bending Dies,” Journal of Materials Processing Technology, vol. 145, pp. 109-117, 2004.

[22] Chen, P. and Koç, M., “Simulation of Springback Variation in Forming of Advanced High Strength Steels,” Journal of Materials Processing Technology, vol. 190, pp. 189-198, 2007.

[23] Sahin, Ç.Ö., “The Observation of Springback Behaviour Resulting from V Die Bending of Sheet Metals,” Master's Thesis, Gazi University, Institute of Science and Technology, Ankara, 2013.