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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

EXPERIMENTAL INVESTIGATION OF DRAWBEAD EFFECT ON SPRINGBACK İN PROFILEE OF DOUBLE CIRCULAR, RECTANGULAR AND TRIANGULAR BENDING SHEET METAL FORMING PROCESSES

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Abstract

Springback is considered as one of the most common problems in metal forming processes, which poses an inaccuracy of product angle during assembling of parts. The estimation of the springback is difficult to predict for formed parts since it depends on many factors such as the mechanical properties, the sheet thickness, and the die angle. In this work, an experimental investigation of drawbead for different material thicknesses and the use of different lubricants such as grease, oil and wax have been studied and analyzed. Samples of aluminum specimens with 120 mm length, 30 mm width and thickness of 0.5, 0.7 and 0.8 mm were selected in this study. Design and manufacturing of double bending die with profile of Circular, Rectangular, and Triangular have been applied firstly without drawbead and then with drawbead. The results showed that in a given profile configuration, the springback reduced with existing the drawbead.

Keywords: Springback; Drawbead; Sheet metal Forming; Bending process; Bending die.

BÜKME SAC ŞEKİLLENDİRME PROSESLERİNDE ÇİFT DAİRESEL, DİKDÖRTGEN VE ÜÇGEN PROFİLDEKİ ÇEKME ÇUBUKLARININ GERİ YAYLANMA ÜZERİNDEKİ ETKİSİNİN DENEYSEL OLARAK İNCELENMESİ

Özet

Geri yaylanma, parçaların montajı sırasında ürün açısının yanlışlığını ortaya koyan metal şekillendirme işlemlerinde en yaygın sorunlardan biri olarak kabul edilir. Geri esnemenin kestirimi, mekanik özellikler, sac kalınlığı ve kalıp açısı gibi birçok faktöre bağlı olduğu için oluşan parçalar için tahmin edilmesi zordur. Bu çalışmada, farklı malzeme kalınlıkları için çekme kafasının deneysel bir araştırması ve gres, yağ ve balmumu gibi farklı yağlayıcıların kullanımı incelenmiş ve analiz edilmiştir. Çalışmada 120 mm uzunluk, 30 mm genişlik ve 0.5, 0.7 ve 0.8 mm kalınlıktaki alüminyum numuneleri seçilmiştir. Dairesel, Dikdörtgen ve Üçgen profilli çift bükme kalıbının tasarımı ve imalatı önce çekme çubuğu olmadan, sonra da çekme çubuğu ile uygulanmıştır. Sonuçlar, belirli bir profil konfigürasyonunda geri çekme yayının mevcut yayla azaldığını göstermiştir.

Anahtar Kelimeler: Geri yaylanma; Çekme boncuğu; Sac şekillendirme; Bükme işlemi; Bükme kalıbı.

1. INTRODUCTION

Springback is considered as inaccuracy in the dimension of the formed solid parts and, this situation occurs as the elastic recovery of the part after unloading the part. Springback causes deviation from the designed target and results difficulty through the assembly of the formed part. Generally, the elastic recovery after unloading the part is called as a spring back phenomenon. This phenomenon is related to many factors. In most researches, the materials are exhibited to a high springback effect after unloading the part which has a lower elastic and high strength properties. In industries, springback considered as an influencing phenomenon in tooling and process designs. In the present work, the review of the literature springback and drawbead in stamping process is presented. Ekici and Tekeli (2004) studied the geometry of drawbead and with four stages and three radius values such as Stage 1: R_1=6, R_2=1, R_3=1, Stage 2: R_1=5, R_2=2, R_3=2, Stage 3: R_1=4, R_2=3, R_3=3 and Stage 4: R_1=3, R_2=4, R_3=4. The changing of these radii will result in an important deformation in forming redundancy and springback. Iwata and Iwata (2018) studied the springback using FEM method and described an effective approach by which to improve the accuracy of springback analysis. Springback analysis is performed using the forming results modified by the data mapping and morphology mapping. It has been showed that, in general, using FEM in the analysis to decrease discretization errors greatly increases the computation time. Xu et al. (2005) have discussed the three factors that affect the prediction accuracy of the springback which includes the material model. It was compared the prediction with measurements of several automotive aluminum and high strength panels. It was found that the prediction was close to the measurement in springback direction and magnitude and, geometrical modification effectiveness. They concluded that there are two steps to minimize springback effect. The first one is by process control method which is performed by excluding the essential causes of springback through the forming process. The second step is done by geometrical modification of the die surface and this is a physical direct way to minimize the springback effect. The second step is only applicable for part with small springback. Hanapi, et al. (2010) has developed an effective approach to understanding the malleability and preventing potential defects in the sheet metal of a particular automotive component in their research. The defect on springback is the main focus of interest in this study. The first stage is to illustrate experimentally that springback is proportionally related to the die radius of the tool geometry. The second stage is to utilize finite element analysis using a simulation tool to analyze further the springback effect. Burchitz (2008) has investigated the improvement of the numerical prediction of the springback phenomenon in sheet metal forming processes. Modeling guidelines and advanced numerical algorithms presented that it is better to satisfy the industrial requirements for an accurate simulation of springback. An experimental and numerical study was carried out to reach a better understanding of the sensitivity of springback to various physical and numerical parameters. Billade and Dahake (2018) have studied the forming process using finite element method to analyze the strain and thickness variations during the REINF-RR END UPR-LH/RH. This is done by the theoretical calculations and the required number of draws and press tonnages has been obtained by improving the design of a draw bead. The simulation result is validated with the actual component. For this situation, HYPERFORM programming is used for the simulation of the component which avoids manufacturing the tool for the tryout. Mehmet Firat et al. (2008) have presented an engineering methodology to develop the performance of drawbead by basic supplementing sheet thickness and effective plastic strain into the contact algorithm. The material work hardening is predicted using an analytical model under the plain-strain deformation situation. Siswanto et al. (2014) have adjusted the springback to enhance the accuracy of cold forming product. It is done by using two principles together to refine the accuracy of springback numerically. The first one is displacement adjustment (DA) and the second one is spring forward (SF) algorithm. Özdemir (2017) has studied the effect of punch radius and thickness of sheet metal on the spring-back angle. The thickness of sheet metal was 2, 3, 4 and 5 mm, and the punch radius are R2, R4, R6 and R8 mm. Air V-bending technique and AISI304 stainless steel sheet have been used for the study. The results showed that the quantity of spring-back is increased when the radius of punch is increased, but it decreased when the thickness of sheet metal increased and obtained on mathematical model from analyzing the relationship between bending parameters and test results. The effects of thickness such as 0.5, 0.7, 1 mm and punch tip radius such as 2, 3, 4, 5 mm on the spring-back have been studied by Bakhshi-Jooybari, et al. (2009). Both V - bending and U - bending dies design were applied to a CK67 steel sheet. A comparison has also been made between experimental and numerical simulations. In some cases, the results showed that with V - bending die the spring - go was clear, but no spring - go appeared in U - bending die. Furthermore, increasing the sheet thickness of V - bending and U - bending die resulted in reducing the spring back and spring - go angle. While increasing the radius of the punch tip, the angle of spring - go decreases and the angle of spring back increases. Thipprakmas, and Phanitwong (2011) have studied the effect of geometrical parameters on spring back and spring go in V-bending process and used the FEM simulation in association with the Taguchi and the ANOVA techniques to investigate the importance of the parameters. Aluminum (Al100-O) of 30 mm width was used as a workpiece material. Bending angles were 30°, 45°, 120° and 135°, the material thickness were 2, 3 and 4 mm and the punch radius were 2.5, 3.5 mm. Results showed that the material thickness has a major influence on the spring-back, in dissimilarity of spring go case and the bending angle and punch radius have a secondary influence and closely followed by the material thickness. Leu and Hsieh (2008) have presented an analytical model to explore the influence of coining force (in the bottoming stage) on the spring-back reduction in the V-die bending process. In this model, the amount of the spring-back reduction caused by the coining force related to geometrical parameters and material properties was proposed. Results have indicated that the spring - back decreases linearly as the normal anisotropy decreases, or increases in the ratio of thickness/punch radius, half - bent angle, width/thickness ratio and strain - hardening exponent. However, it has been noted that the friction coefficient shows little effect on the spring - back ratio. Abdullah (2017) has studied the effect of bending parameters. The dimensions of the workpiece were 50 mm width and 100 mm length, while the V-bending die was 90° angle. Bending process for Al-Alloy 1050 sheets has various parameters such as thicknesses were 0.5, 1, 1.5, 2 mm, hold time were 0.5, 10, 15 min and punch speed were 10, 20, 50, 100 mm/min. The results showed that the thickness of the sheet was the major influencing parameter which effects in spring back by 77.29%, then punch speed about 10.51% and hold time about 3.36%. Spring back angle recorded the lowest magnitude at thickness was 2 mm, punch speed was 100 mm/min and hold time was 15 min. The predicted results of Artificial Neural Network displayed a good accuracy with the magnitude of 99.35% of spring back compared with the measured value. Asgari et al. (2008) have investigated the advancement of a technique to factually consider framing and springback issues of Transformation Induced Plasticity (TRIP) through a modern contextual investigation. The structure of Experiments (DOE) approach was utilized to contemplate the affectability of forecasts to four user input parameters in certain and unequivocal sheet metal framing codes. Numerical results were contrasted with trial estimations of parts stepped in a modern creation line. The exactness of shaping strain expectations for TRIP steel was equivalent to ordinary steel, however, the springback expectations of TRIP steel were far less exact. The factual significance of chosen parameters for shaping and springback expectation is additionally talked about. Changes of up to ±10% in Young's modulus and coefficient of friction were seen as irrelevant in improving or weakening the factual connection of springback exactnesses.

The main objective of this study is the experimental investigation of drawbead effect on springback in profile of double circular, rectangular and triangular bending sheet metal forming process. Various parameters have been studied and analyzed which effect on the springback phenomena for three different thickness of aluminum metals such as 0.5, 0.7, 0.8 mm, and three types of lubricants grease such as grease, oil and wax have been used.

2. EXPERIMENTAL SETUP

Estimating springback value by performing a series of experiments has been the basis of this experimental investigation. To perform the experimental work, the design and manufacturing double bending dies with a profile of Circular, Rectangular and Triangular have been carried out, firstly without drawbead and then with drawbead. Rectangular aluminum sheet metal of 30 mm of width, and 0.5 ,0.7- and 0.8-mm thickness, and 120 mm of length for have been used.

Instron tensile test instrument (model WDW – 200 E) was used with the three dies adapter to execute the experimental work for the specimens under bending with the speed of 50 mm/min as shown in Figure 1.

Figure 1. Experimental setup for the bending process

The die and punches used in the three shapes of the profile are reversed profile and, these dies designed under standard specification. They consist of two parts, typically punch and die both are made from CK45 material as shown in Figures 2 and 3. It additionally gives the parameters such as hold time and die angle for three different thicknesses to study their effect on the springback. The punch-downs at some point of the loading stage to form the required angle, and then the force is holded for a selected duration. The test was performed for different times, and the effect of different hold time on the springback was investigated.

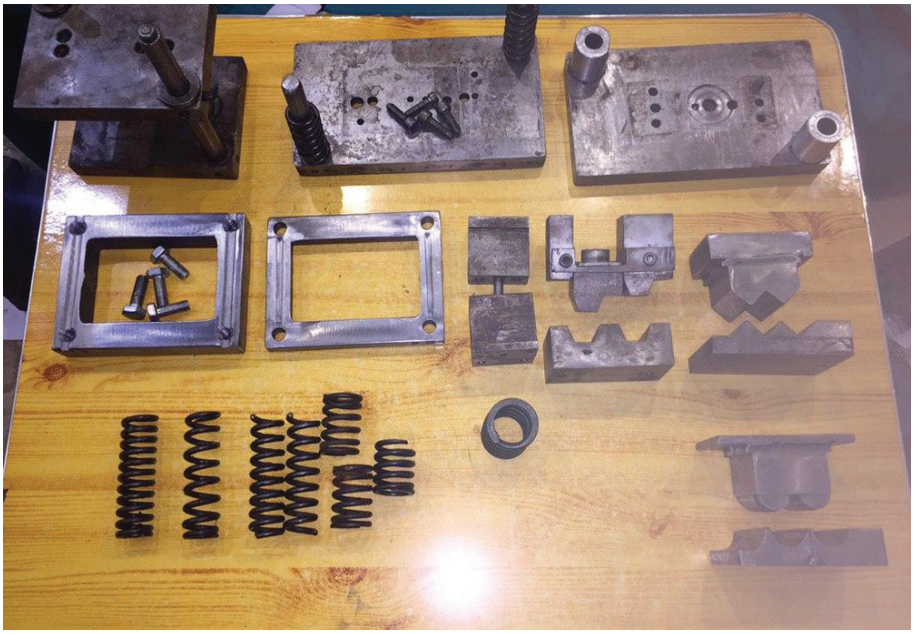
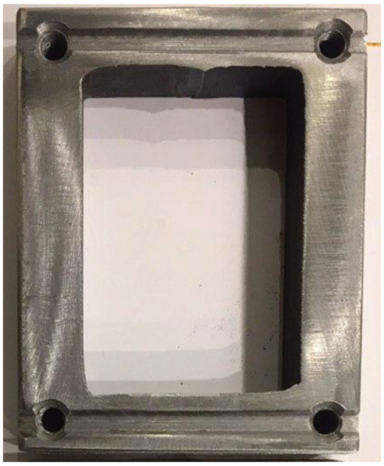
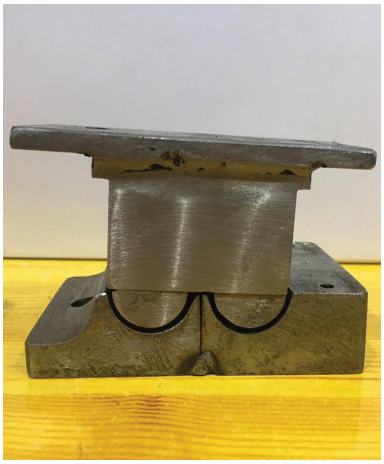


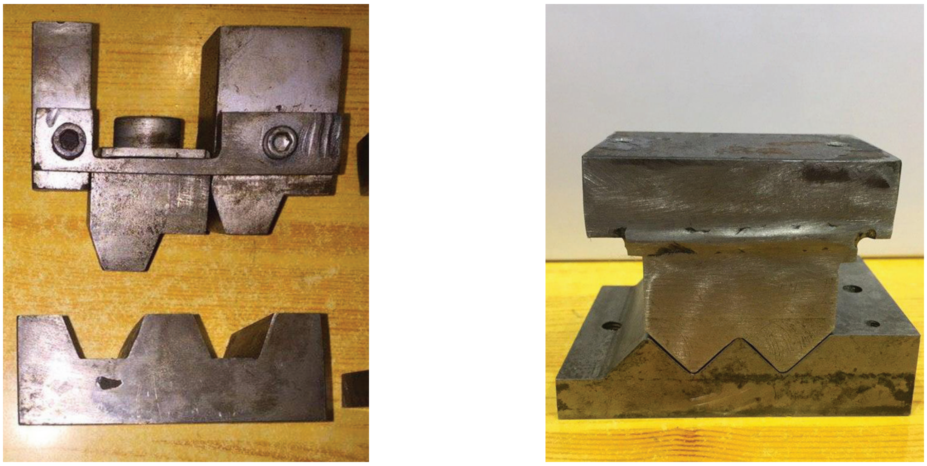
Figure 2. Three dies with double circular, rectangular, and triangular profile with and without drawbead with their accessories



a. Drawbead



b. Double circular



c. Double rectangular d. Double triangle

Figure 3. Three dies with double circular, rectangular, and triangular profile

3. RESULTS AND DISCUSSION

The results have been analyzed from the point of view that the effects of the thickness of the specimen on the springback bending process. During the bending of the specimen, both outside and the inside of the specimen is subjected to elastic stress. When the load reaches the yield point, then the specimen undergoes to plastic deformation and strain-hardening phenomenon. While unloading and removing the punch, the specimen had an elastic recovery. This phenomenon can be attributed to the difference in the residual strain value between the tension in the lower surface and the compression in the upper surface of the specimen.

The springback factor was determined using the required design angle and the final angle as shown in Figure 4 and according to the equations below:

$$K = \frac{\alpha_f}{\alpha_i} \quad (1)$$

$$\Delta\alpha = \alpha f - \alpha i \quad (2)$$

Where:

K : springback factor

α_f: final angle

α_i : initial angle

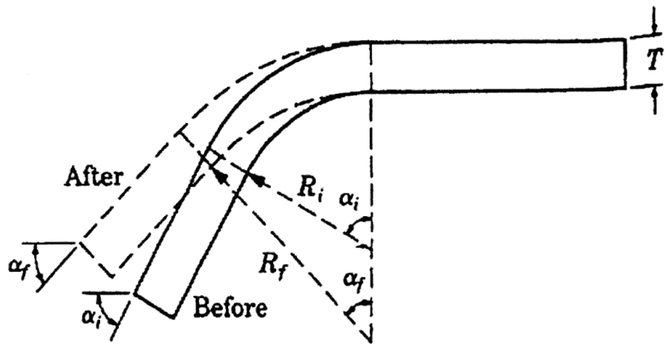


Figure 4. Springback phenomena

The experimental setup for the drawbead effect on springback in the profile of double circular, rectangular, and triangular bending sheet metal forming process have been carried out. Three different thicknesses of aluminum metals such as 0.5, 0.7, and 0.8 mm, and three types of lubricants such as grease, oil, and wax were considered. Tables 1 and 2 shows the experimental conditions and springback results with and without drawbead.

Table 1. Experimental conditions and springback results without drawbead

No.	Symbol	Thickness t (mm)	Type of Lubricant	Type of Die	Drawbead	Final angle α_f (degree)	Spring-back angle Sb (degree)	K= α_f/α_i
1	A1	0.5	grease	Circular	û	24.8	0.8	1.033
2	A2		oil			24.8	0.8	1.033
3	A3		wax			24.8	0.8	1.033
4	A4		grease	Rectangular		70	3	1.044
5	A5		oil			70	3	1.044
6	A6		wax			70	3	1.044
7	A7		grease	Triangular		36	2	1.058
8	A8		oil			36	2	1.058
9	A9		wax			36	2	1.058
10	B1	0.7	grease	Circular		24.7	0.7	1.029
11	B2		oil			24.7	0.7	1.029
12	B3		wax			24.7	0.7	1.029
13	B4		grease	Rectangular		68	1	1.014
14	B5		oil			68	1	1.014
15	B6		wax			68	1	1.014
16	B7		grease	Triangular		35	1	1,028
17	B8		oil			35	1	1.028
18	B9		wax			35	1	1.028
19	C1	0.8	grease	Circular		24.7	0.7	1.029
20	C2		oil			24.7	0.7	1.029
21	C3		wax			24.7	0.7	1.029
22	C4		grease	Rectangular		68.6	1.6	1.023
23	C5		oil			68.6	1.6	1.023
24	C6		wax			68.6	1.6	1.023
25	C7		grease	Triangular		35	1	1.028
26	C8		oil			35	1	1.028
27	C9		wax			35	1	1.028

Table 2. Experimental conditions and springback results with drawbead

No.	Symbol	Thickness t (mm)	Type of Lubricant	Type of Die	Drawbead	Final angle α_f (degree)	Spring-back angle Sb (degree)	K= α_f/α_i
1	D1	0.5	grease	Circular	ü	24.2	0.2	1.008
2	D2		oil			24.2	0.2	1.008
3	D3		wax			24.2	0.2	1.008
4	D4		grease	Rectangular		67.5	0.5	1.007
5	D5		oil			67.5	0.5	1.007
6	D6		wax			67.5	0.5	1.007
7	D7		grease	Triangular		34.1	0.2	1.005
8	D8		oil			34.1	0.2	1.005
9	D9		wax			34.1	0.2	1.005
10	E1	0.7	grease	Circular		24.5	0.5	1.020
11	E2		oil			24.5	0.5	1.020
12	E3		wax			24.5	0.5	1.020
13	E4		grease	Rectangular		68	1	1.014
14	E5		oil			68	1	1.014
15	E6		wax			68	1	1.014
16	E7		grease	Triangular		34.3	0.3	1.008
17	E8		oil			34.3	0.3	1.008
18	E9		wax			34.3	0.3	1.008
19	F1	0.8	grease	Circular		24.5	0.5	1.020
20	F2		oil			24.5	0.5	1.020
21	F3		wax			24.5	0.5	1.020
22	F4		grease	Rectangular		68.5	1.5	1.022
23	F5		oil			68.5	1.5	1.022
24	F6		wax			68.5	1.5	1.022
25	F7		grease	Triangular		34.4	0.4	1.011
26	F8		oil			34.4	0.4	1.011
27	F9		wax			34.4	0.4	1.011

Table 3. A comparison of the springback angle value when there is a drawbead and without drawbead

Thickness	Type of die	Springback Angle (Degree)	
		Without drawbead	With Drawbead
0.5	Circular	0.8	0.2
	Rectangular	3	0.5
	Triangular	2	0.2
0.7	Circular	0.7	0.5
	Rectangular	1	1
	Triangular	1	0.3
0.8	Circular	0.7	0.5
	Rectangular	1.6	1.5
	Triangular	1	0.4

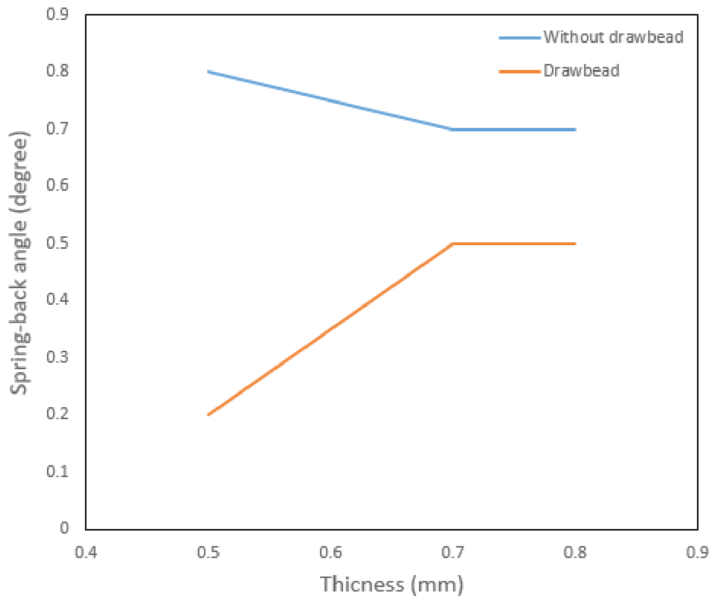


Figure 5. The Effect of thickness on spring-back angle for circular die

When using a circular die, it can be concluded from Fig. 5 that the value of the springback with drawbead is reduced for all thickness values. Meanwhile, the springback angle increases with increasing the thickness value with drawbead application. Without drawbead, minimum springback angle value has been obtained for 0.7 mm thickness.

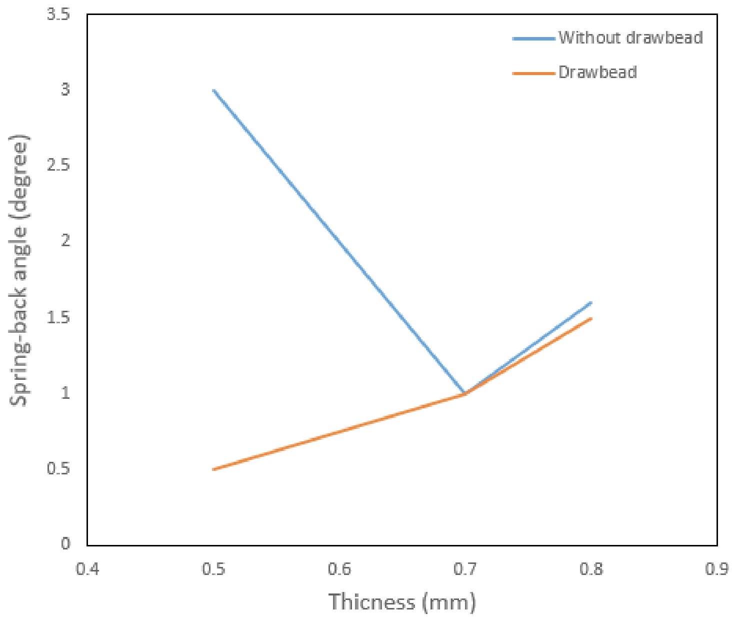


Figure 6. Effect of thickness on spring-back angle for rectangular die

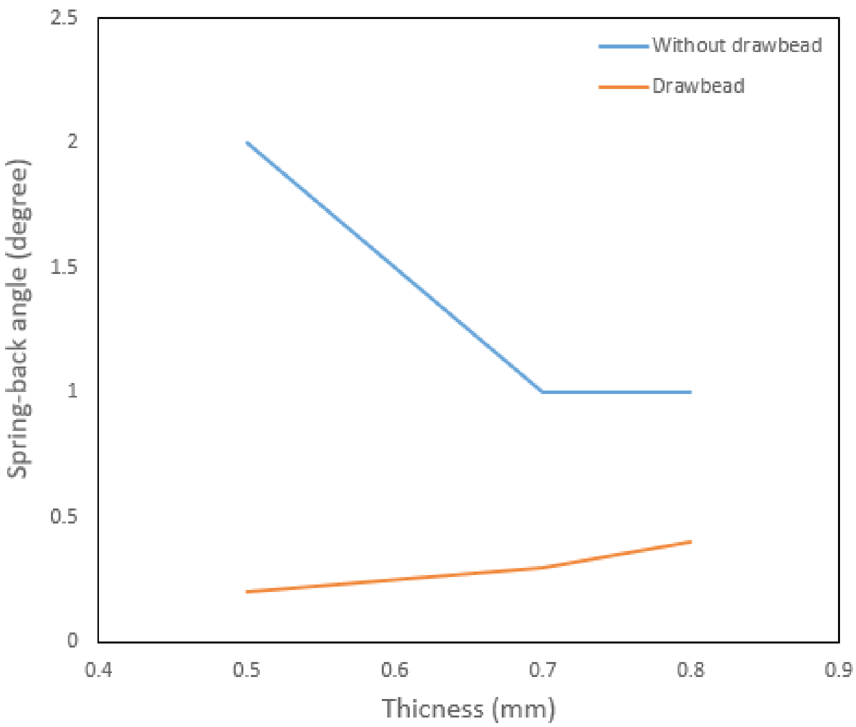


Figure 7. Effect of thickness on spring-back angle for triangular die

In Figure 6, when using a rectangular die, the value of springback decreases with the presence of drawbead in the thickness of 0.5 and 0.8 mm. The same springback value has been obtained for 0.7 mm thickness.

If the triangular die is used, it can be concluded from Figure 7 that the value of the springback decreases when there are drawbead for all thickness value in a high percentage, compared with when there is no drawbead.

Figures 8 to 10 show the K-factor variation with and without drawbead for circular, rectangular and triangular dies. It can be concluded that the minimum K-factor has been obtained as 1.005 for triangular dies with drawbead for 0.5 mm thickness.

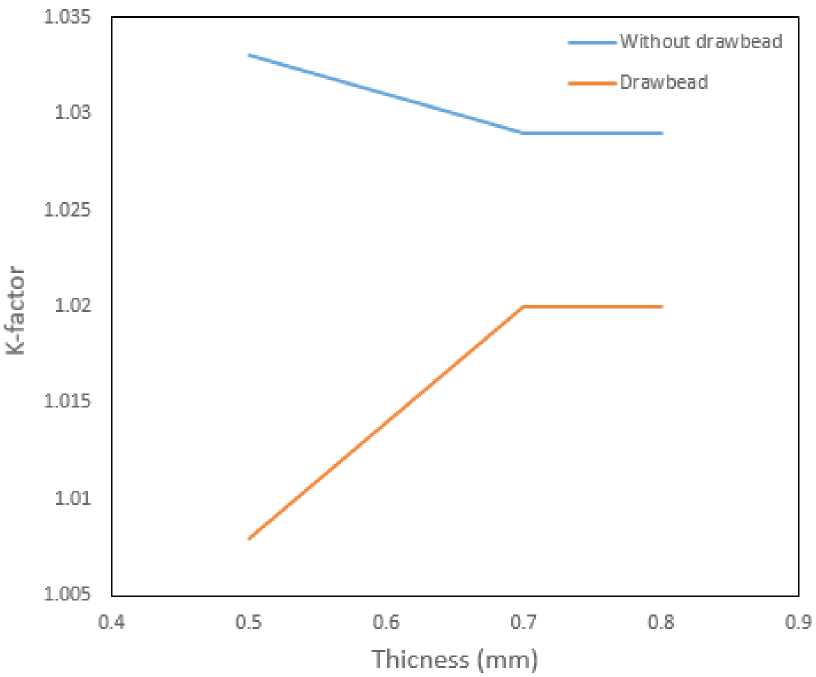


Figure 8. Effect of thickness on K-factor for circular die

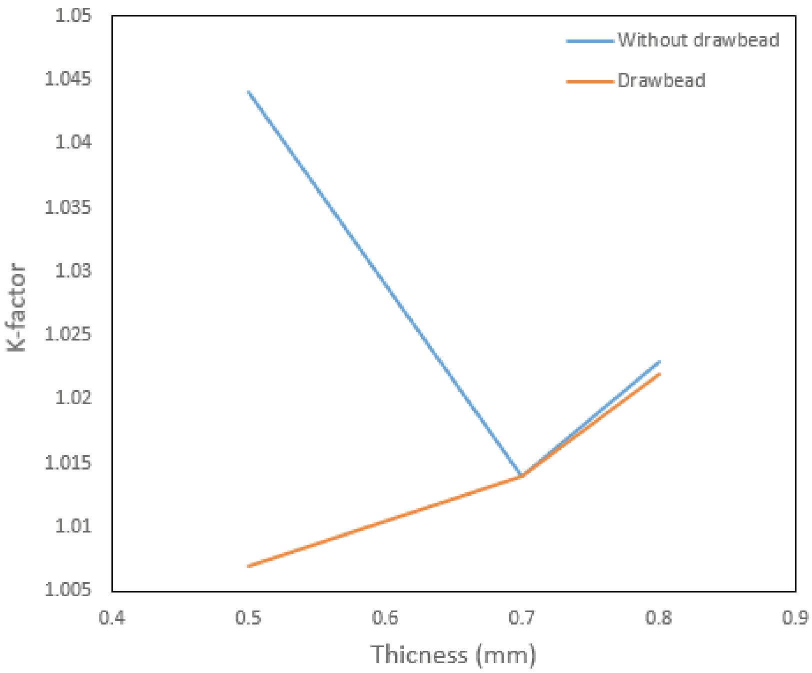


Figure 9. Effect of thickness on K-factor for rectangular die

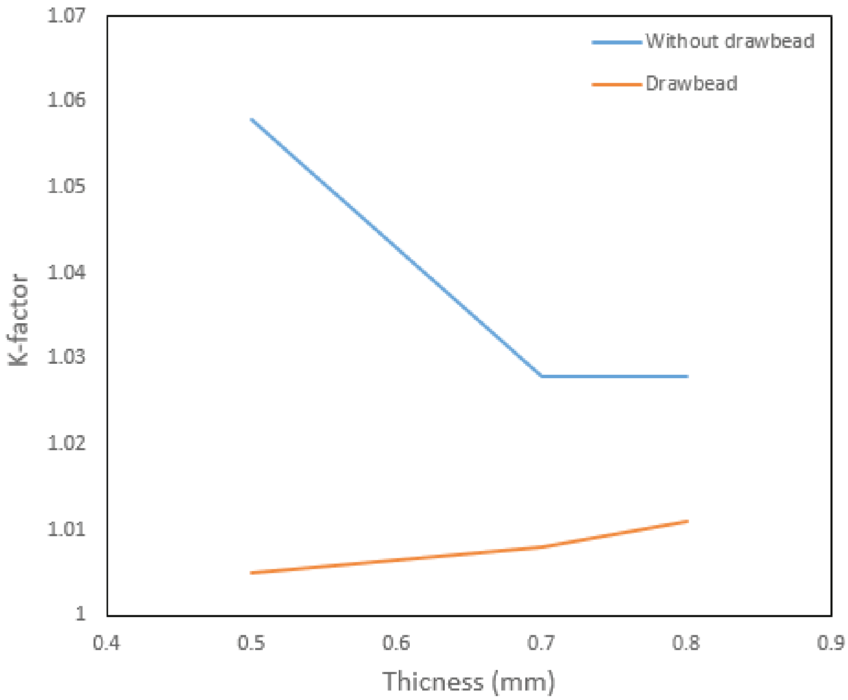


Figure 10. Effect of thickness on K-factor for triangular die

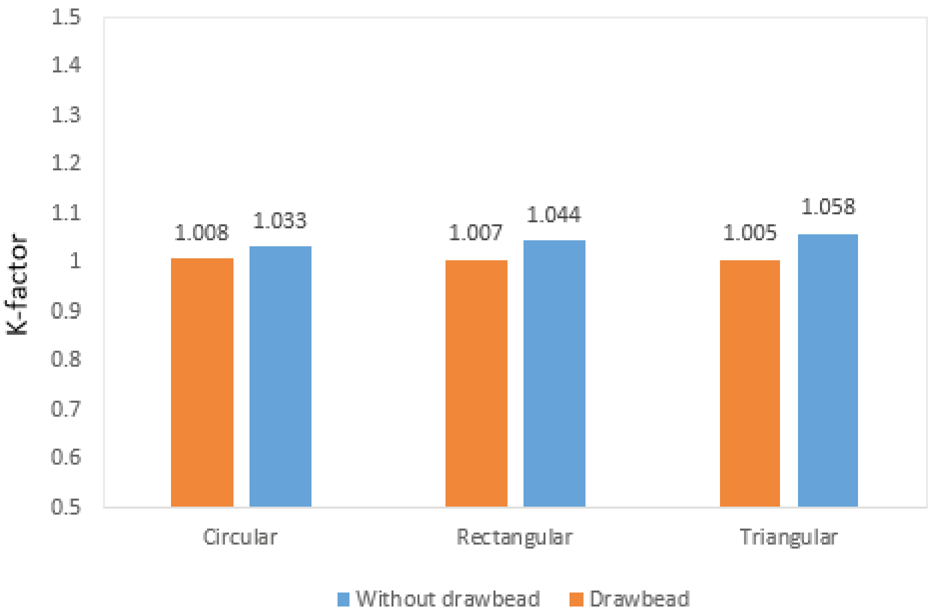


Figure 11. Effect of thickness 0.5 mm on K-factor for all types of dies with and without drawbead

It can be pointed out from Fig.11 that the smallest value of K-factor is obtained when using a triangular die with drawbead as the magnitude of 1.005 for the thickness of 0.5 mm while triangular die without drawbead has the highest K-factor of all as the magnitude of 1.058.

The results showed the drawbead led to a decrease in the percentage of spring-back angle in all types of dies for different thickness of specimens used in this work. Also, the spring-back angle percentage would be high when used small thickness 0.5 mm in different dies (Circular, Rectangular, Triangular). The lubricant used such as grease, oil, or wax haven't any effect on springback angle. Therefore, it is useful to decrease the friction, and this led to a decrease in the required force to form, and the process of ejection for sample may be easy.

4. CONCLUSIONS

In this work, the experimental investigation of drawbead effect on springback in a profile of double circular, rectangular and triangular bending of sheet metal forming process has been implemented. The research dealt with many influencing parameters that have an impact effect on metal springback during many sheet metal forming processes. From the above results and Table 1 and 2, the following conclusions can be offered regarding the effect of the sheet thickness on springback parameters:

1. The variation of sheet thickness leads to very important differences of springback parameters,

2. Increasing of the sheet thickness results in decreasing the springback effect, and the final geometry of the formed part is closer to the ideal part shape,

3. Variation of the springback phenomenon proportional with sheet thickness is detected for both zones of the part,

4. The results showed that in a given profile configuration, the springback reduced with the existing of the drawbead,

5. The type of lubricant does not effect on the springback.

6. Minimum K-factor value has been obtained for triangular dies with drawbead for 0.5 mm thickness.

The followings are some advices for the future studies:

1. The effect of bending speed and the holding time on the springback may be investigated.

2. The springback value for the superplastic alloys may be considered.

3. The springback values for smart materials may be investigated.

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