# Study the Optimization Parameters for Spring Back Phenomena in U-Die Bending

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## ABSTRACT

The main objective of the research is to find the optimum parameters that reduce the springback by using the commercially [SPSS] program to analysis data and find the best parameters which given lowest springback in the U-die bending. A commercial aluminum alloy [AL-1050] sheet (0.9 mm) thickness that founded when punch speed increase the springback increase, when rolling direction angle is $90^{o}$ Lower springback, and when increase the dwell time decrease the springback, and the value of parameters predicted from [SPSS] have lower springback and obtain a goal dimension for the products. And predict the springback value by especial equations which given correlation coefficient 95.4% between the observed value of the dependent variable and the predicted value.

**Keywords:** Springback, SPSS Program, U-Die Bending, Aluminum (1050)

## دراسة المتغيرات المثلى لظاهرة الرجوعية في عملية الحنيU-die

### الخلاصة

الهدف الرئيسي لهذا البحث هو ايجاد العوامل المثلى التي تقلل الرجوعية باستخدام البرنامج (SPSS) لتحليل البيانات وايجاد افضل المتغيرات والتي ستعطي اقل رجوعية في قالب الحني باستخدام صفيحة من الالمنيوم وبسمك (٠.٩) ملم حيث وجد انه بزيادة سرعة البنج تزداد قيمة الرجوعية وباقل قيمة للرجوعية باتجاه درفلة ٩٠ وعند زيادة زمن الانتظار يقل مقدار قيمة الرجوعية وقيم المتغيرات المتوقعة في برنامج SPSS سيقلل من قيم الرجوعية وبالتالي سنحصل على الابعاد المرجوة من المنتج.يتم توقع قيم الرجوعية من خلال معادلة خاصة والتي اعطت معامل ترابط مقداره ٩٥.٤ % ما بين القيم المقاسة والقيم المتوقعة للمتغيرات المعتمدة.



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## INTRODUCTION

The major problem of the bending process is the occurrence of springback. This problem is the key factor which affects the quality of the bended part. Accurate estimation of springback in which industries is important. Demands in bend angles can be within a narrow range. Several bending operations done on sheet metal are, air bending, V-die bending, rubber die bending and U-bending.

Sheet metals that give different flow strengths in different directions in the plane of the sheet are defined as having planar anisotropy. Parallel, perpendicular and ($45^0$) degrees to the rolling direction represent the three vectors of the planar anisotropy. Anisotropy has a great effect on the bending limit with the relative differences in yield strength.

U-die bending is performed when two parallel bending axes are produced in the same operation. A backing pad is used to force the sheet contacting with the punch bottom. It requires about 30% of the bending force for the pad to press the sheet contacting the punch. [1] , the important research done in springback are:

**Firat**(2007) [2] , present a kinematic hardening plasticity model based on an additive back stress form described in order to improve the predicted sheet metal deformation response. The performance of the model in the forming analyses of sheet metals is investigated; U-die benchmark is performed using implicit FE analyses based on the kinematic hardening plasticity model.

**Lawanwong** and **Premanond**(2010) [3] , aim to reduce spring back value of sheet metal in U bending process. The corner setting technique has reduced the thickness in bending area to( 5, 10, 15 and 20) percent of the original sheet thickness. Electrolytic zinc coated carbon steel grade JIS; SECC, JIS; 440 and JIS; 590 having the thickness of 1 mm was employed as the workpiece material for all experiments. The result of three materials in conventional U - bending die shows larger springback than that of the corner setting technique. Moreover, the corner setting technique reduces spring back value in bending process but requires high bending force.

**Datsko and Hilsen(1984) [4]** studied the strain history during bending in U die an analysis of springback in pure bending shows that springback increases with increasing ratio of tool clearance to sheet thickness, a finding confirmed by the analysis of flange bending. They conclude that springback decreases as work hardening increases, but their conclusions are based on test in only three steels of different composition and of widely differing yield strength. With the introduction of high strength steel sheet to assist in the weight reduction of structures extensive experimental studies have been performed on the springback of these materials.

The effect the backing pad in the U-bending process has been studied. Different backing pad values are used to study their effect on distributions of stresses and strains in workpiece. This work presents optimization of process parameters for spring back phenomena in the aluminum sheet (0.9mm) such as punch speed, rolling direction angle, dwell time and a modelis made.

**Analytical Modeling** and **SPSS Statistics 17.0 software**

Because all materials have a finite modulus of elasticity, plastic deformation is followed by elastic recovery upon removal of the load; in bending, this recovery is known as *spring back.* As shown in Figure(1), the final bend angle after spring back is smaller and the final bend radius is larger than before. This phenomenon can easily be observed by bending a piece of wire or a short strip metal. Spring back occurs not only in sheets or plate, but also in bending bars, rods, and wire of any cross-section.[5][6]

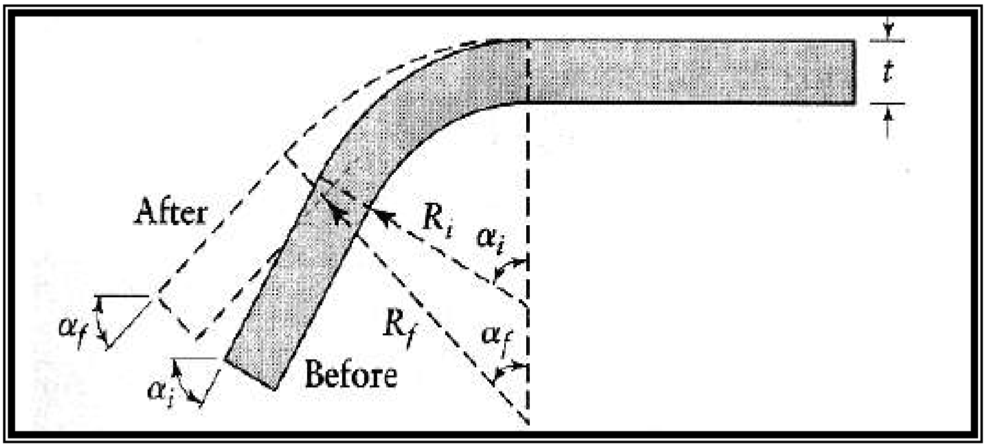



**Figure (1) Terminology for springback in bending [5].**

The quantity characterizing in springback mechanism is the springback factor Ks, which is defined as follows:

$$\text{Bend allowances} = \left(R_i + \frac{t}{2}\right)\alpha_i = \left(R_f + \frac{t}{2}\right)\alpha_f \quad \dots (1)$$

Because the bend allowance is the same as before and after bending, so the relationship obtained for pure bending, the Spring factor, Ks is defined as:

$$K_s = \frac{\alpha_f}{\alpha_i} = \frac{(2R_i/t)+1}{(2R_f/t)+1} \quad \dots (2)$$

Where $R_i$ , $R_f, \alpha_f$ and $\alpha_i$ are the initial bend radii , final bend radii, final bend angle and initial bend angle respectively**.** It can be noted from equation (2) that Ks depends only on the R/t ratio, where R is the minimum bend radius. A springback factor of Ks =1 indicates no springback, and Ks=0 indicates complete elastic recovery. The amount of elastic recovery depends on the stress level and the modulus of elasticity, *E,* of the material; hence, elastic recovery increases with the stress level and with decreasing elastic modulus. Based on this observation, an approximate formula has been developed to estimate spring back:[5]

$$\frac{R_i}{R_f} = 4\left(\frac{R_i Y}{Et}\right) - 3\left(\frac{R_i Y}{Et}\right) + 1 \quad \dots (3)$$

In this equation, *Y* is the uniaxial yield stress of the material.

SPSS is Windows based software that can be used to perform data entry and analysis to create tables and graphs. SPSS is capable of handling large amounts of data and can perform all of the analyses covered in the text and much more. It is commonly used in the Social Sciences and in the business world.[7] the SPSS software has comprehensive graphical user interface that gives user easy and interactive access to program functions and commands.

## MULTIPLE REGRESSION ANALYSIS

Since multiple regression is used to determine the correlation between a criterion variable and a combination of predictor variables, the statistical multiple regression method is applied. It can be used to analyze data from any of the major quantitative research designs such as causal-comparative, correctional, and experimental. This method is also able to handle interval, ordinal, or categorical data and provide estimates both of the magnitude and statistical significance of the relationships between variables. Therefore, multiple regression analysis will be useful to predict the criterion variable spring back predictor variables such as speed ratio, direction angle, or dwell time. [8]

### Multiple Regression Prediction Model

The proposed multiple regression model is a three-way interaction equation:

$$Y = \beta_1 + \beta_2 X_1 + \beta_3 X_2 + \beta_4 X_3 + \beta_5 X_1 X_2 + \beta_6 X_1 X_3 + \beta_7 X_2 X_3 + \beta_8 X_1^2 + \beta_9 X_2^2 + \beta_{10} X_3^2$$

where $Y$ : spring back (rad)

$X_1$ = punch Speed (mm/min)

$X_2$ = Rolling direction angle (rad)

$X_3$ = Dwell time (min)

In this model, the criterion variable is the spring back (rad) and spring back ratio and the predictor variables are speed ratio, rolling direction angle, and dwell time. Because these variables are controllable parameters, they can be used to predict the spring back in bending.

## EXPERIMENTAL WORK

Aluminum 1050 used as a work piece. It is known for its excellent corrosion resistance, high ductility and highly reflective finish, has good formability and has the ideal specification when bending or spinning is required with fair strength. [9]

In order to perform the experiments work, the specimens must fit the die and punch with a suitable clearance. a rectangular sheet of 60mm of width and 50 mm of length with (0.9) mm thickness used in experimental work .the die designed under standard specification, they consist of two parts, normally punch and die both are made from CK45, as shown in Figure (2) .

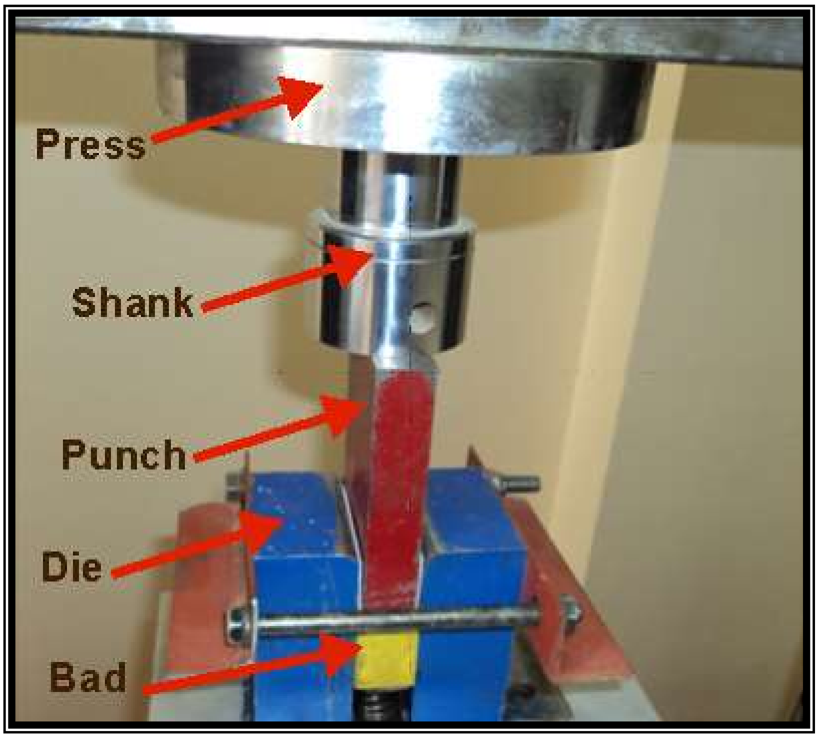



**Figure (2) The U-bending die.**

**Effective Parameters on Spring back**

Four parameters have used which affect on springback phenomenon, as follows:

**1- Punch speed**

Different speed was used in punching (2, 20 and 200 mm/min).

**2- Rolling direction.**

Sheet metals that exhibit different flow strengths in different directions in the plane of the sheet are defined as having planar anisotropy. Parallel and perpendicular rolling direction represent the three vectors of the planar anisotropy. A sample failed due to plastic deformation revealed equal-distanced depressions along the corner radius caused by the planar anisotropy of the sheet metal, which depends on its rolling direction (0,45,90).

**3- Dwell time**

Different dwell time shown (2, 60 and 300 sec)

**Experimental measure for spring back U-die**

**Table (1) Experimental measure for U-die.**

| punch Speed (mm/min) | Rolling Direction angle (degree) | Dwell time (sec) | Spring back (1) | Spring back (2) | Spring back (3) | Spring back (average) | Spring back factor $k_s = \frac{\alpha_2}{\alpha_1}$ |
|---|---|---|---|---|---|---|---|
| 2 | 0 | ٢ | 4 | 3.55 | 4.05 | ٤.٠٠ | 0.9574 |
| 20 | 0 | ٢ | 4.10 | 4.30 | 4.20 | ٤.٢٠ | 0.9554 |
| ٢٠٠ | 0 | ٢ | 4.30 | 4.25 | 4.35 | ٤.٣٠ | 0.9544 |
| 2 | 0 | ٦٠ | 3.50 | 3.55 | 3.45 | ٣.٥٠ | 0.9625 |
| 20 | 0 | ٦٠ | 3.55 | 4 | 4.05 | ٤.٠٠ | 0.9574 |
| ٢٠٠ | 0 | ٦٠ | 4.30 | 4.25 | 4.35 | ٤.٣٠ | 0.9544 |
| 2 | 0 | ٣٠٠ | 3.35 | 3.45 | 3.40 | ٣.٤٠ | 0.9635 |
| 20 | 0 | ٣٠٠ | 3.55 | 3.55 | 3.55 | ٣.٥٥ | 0.9620 |
| ٢٠٠ | 0 | ٣٠٠ | 4 | 4.05 | 3.55 | ٤.٠٠ | 0.9574 |
| 2 | 45 | ٢ | 4.25 | 4.20 | 4.15 | ٤.٢٠ | 0.9554 |
| 20 | 45 | ٢ | 4.30 | 4.35 | 4.25 | ٤.٣٠ | 0.9544 |
| ٢٠٠ | 45 | ٢ | 4.35 | 4.50 | 4.35 | ٤.٤٠ | 0.9533 |
| 2 | 45 | ٦٠ | ٤.٠٠ | ٤.٠٠ | ٤.٠٠ | ٤.٠٠ | 0.9574 |
| 20 | 45 | ٦٠ | 4.20 | 4.10 | 4.30 | ٤.٢٠ | 0.9554 |
| ٢٠٠ | 45 | ٦٠ | 4.25 | 4.35 | 4.30 | ٤.٣٠ | 0.9544 |
| 2 | 45 | ٣٠٠ | 3.40 | 3.40 | 3.40 | ٣.٤٠ | 0.9635 |
| 20 | 45 | ٣٠٠ | 3.50 | 3.55 | 3.45 | ٣.٥٠ | 0.9625 |
| ٢٠٠ | 45 | ٣٠٠ | 4.20 | 4.25 | 4.45 | ٤.٣٠ | 0.9544 |
| 2 | 90 | ٢ | 3.50 | 3.35 | 3.35 | ٣.٤٠ | 0.9635 |
| 20 | 90 | ٢ | ٤.٠٠ | ٤.٠٠ | ٤.٠٠ | ٤.٠٠ | 0.9574 |
| ٢٠٠ | 90 | ٢ | 4.20 | 4.20 | 4.20 | ٤.٢٠ | 0.9554 |
| 2 | 90 | ٦٠ | 3.35 | 3.35 | 3.20 | ٣.٣٠ | 0.9646 |
| 20 | 90 | ٦٠ | 3.55 | 3.55 | 3.40 | ٣.٥٠ | 0.9625 |
| ٢٠٠ | 90 | ٦٠ | 3.55 | 3.55 | 3.55 | ٣.٥٥ | 0.9620 |
| 2 | 90 | ٣٠٠ | 3 | 2.50 | 2.55 | ٢.٥٥ | 0.9724 |
| 20 | 90 | ٣٠٠ | 3.35 | 3.45 | 3.40 | ٣.٤٠ | 0.9635 |
| ٢٠٠ | 90 | ٣٠٠ | 3.45 | 3.45 | 4 | ٣.٥٠ | 0.9625 |

**Prediction for spring back**

The R Square pieces were 0.911 for U die. They show that 91.1% of the observed variability in spring back could be explained by the independent variables.

The Multiple R was 0.954 for U-die. This means that the correlation coefficient between the observed values is dependent variable and the predicted value based on the regression model is high. as shown in Table (٢) .

**Table (2) Model Summary for spring back (U- die)**

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
| 3 | 0.954 | 0.911 | 0.858 | 0 .00298179 |

**ANALYSIS OF VARIANCE) ANOVA**

A mathematical technique known as the sum of squares is used to quantitatively evaluate the deviation of the control factor effect response averages from the overall experimental mean response.

The value of F-ratio used to test the significance of factor effect. F were 33.019, 50.55and 17.053 for V die ,V air die and U die respectively, and the significance of F was 0 in the ANOVA Table as shown in the ANOVA tables (٣), The null hypothesis shows there is no linear relationship between spring back and the independent variables. Thus, the independent variables were rejected. At least one of the population of regression coefficients was not zero.

**Table (٣) ANOVA Table for spring back (U- die)**

| ANOVA | | | | | |
|---|---|---|---|---|---|
| Model | | Sum of Squares | df | F | Sig. |
| 3 | Regression | 0.001 | 9 | 17.053 | 0 |
| | Residual | 0 | 17 | | |
| | Total | 0.001 | 26 | | |

**Coefficients and the multiple regression equation**

In Tables (4) the coefficients for the independent variables are listed in column $\beta$ .

**Table (٤) Variables included in the multiple regression equation for spring back Coefficients[a].**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | $\beta$ | Std. Error | Beta | | |
| 3 | (Constant) | 6.769E-2 | 1.95E-3 | | 34.662 | 0 |
| | $X_1$ | 3.755E-4 | 9.8E-5 | 4.39 | 3.833 | 0.002 |
| | $X_2$ | 1.272E-2 | 3.58E-3 | 1.06 | 3.549 | 0.003 |
| | $X_3$ | -6.151E-3 | 1.85E-3 | -1.63 | -3.326 | 0.005 |
| | $X_1X_2$ | -2.118E-6 | 1.04E-5 | -2.87E-2 | -.204 | 0.841 |
| | $X_1X_3$ | 8.578E-6 | 3.3E-6 | 0.351 | 2.601 | 0.020 |
| | $X_2X_3$ | -1.372E-4 | 4.59E-4 | -4.55E-2 | -.299 | 0.769 |
| | $X_1^2$ | -1.675E-6 | 4.62E-7 | -4.13 | -3.623 | 0.003 |
| | $X_2^2$ | -1.055E-2 | 2.08E-3 | -1.45 | -5.064 | 0 |
| | $X_3^2$ | 6.672E-4 | 3.36E-4 | 0.949 | 1.987 | 0.066 |

Using these coefficients, the multiple regression equation could be expressed as: U die equation (٤).

$$Y = 0.06769 + 3.755\times10^{-4}X_1 \_ 0.01272X_2 - 6.151\times10^{-3}X_3 - 2.118\times10^{-6}X_1X_2 + 8.578\times10^{-6}X_1X_3 - 1.372\times10^{-4}X_2X_3 - 1.675\times10^{-6}X_1^2 - 0.01055X_2^2 + 6.672\times10^{-4}X_3^2$$

Where $Y$ in equations is the predicted spring back for U die. $X_1$ is also apparent value Speed bunch (mm/min) , $X_2$ apparent value rolling direction angle(rad) and $X_3$ apparent value of dwell time (min).

This means that the statistical model could predict the spring back with 91.1% accuracy of the testing data set.

## DISCUSSIONS

### The effect of rolling direction angle on spring back

Springback is reported higher at higher strength, reflecting minimal spring observed for bend perpendicular to the rolling direction. In this study the rolling direction was found to be has a great significant, shown in Figures (٣) to (5) ,Therefore lower spring back found when rolling direction angle $90^o$,but changeability percentage differ of for different. dwell time

The Springback phenomena was higher when the deformation is opposite to the direction $[90^o]$, the direction of the rolling increase strain hardening and due to this case the Springback will be decrease.

### The effect of punch speed on spring back

Setting the punch speed to the maximum possible press value is desired to reach the highest production rate, but springback will be increase. in this work studying widely effect of punch speed on spring back phenomena ,and found in that optimization state to bending die process when decrease punch speed don't regard to other parameter. The other parameter found percentage for spring back to control it and getting optimization. Shown in Figures (٦) to (٨) ,and the results show that the Springback phenomena will increase, the punch speed increase because the speed increase the response of deformation will be decreased.

### Effect dwell time on spring back

Dwell time are linearly proportional to the springback behavior; this may be related to the creep characteristics of aluminum alloy (9).

In this study, chosen low time important in the industries, and to find the relationship between low time and the improvement of product. when the dwell time increased, the spring back decrease. As shown in figures (٩) to (١١).
These results were plotted in Figures (١٢) to (١٤).

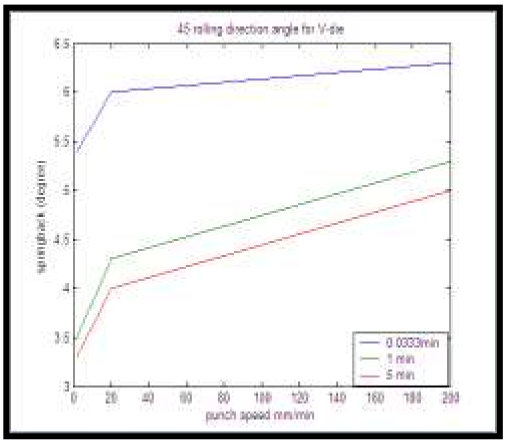



Figure (٣) Relationship between rolling direction angle with springback(1min)

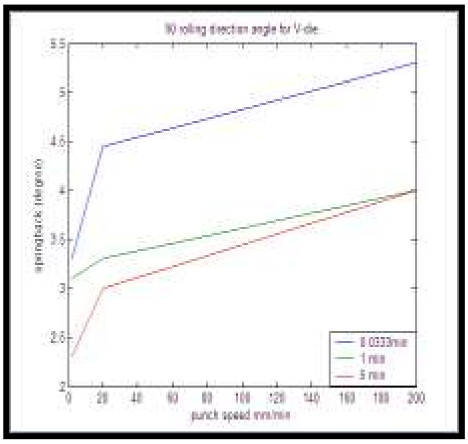



Figure (٤) Relationship between rolling direction angle with springback(0.033min)

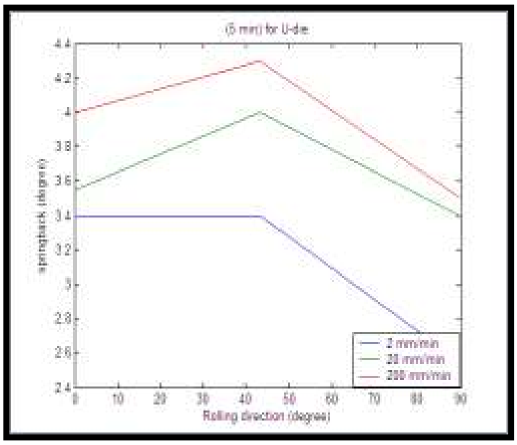



Figure (٥) Relationship between rolling direction angle with springback(5min)

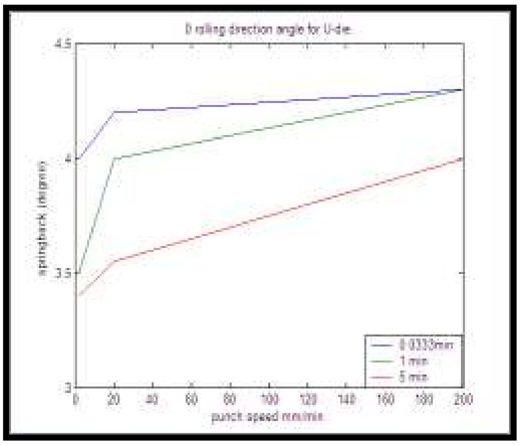



Figure (٦) Relationship between punch speed with springback (0°)

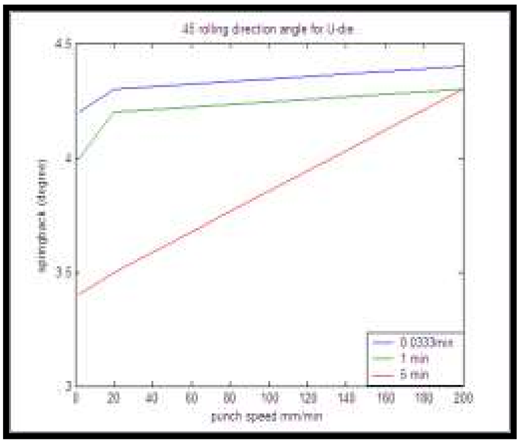



Figure (7) Relationship between punch speed with springback (45°)

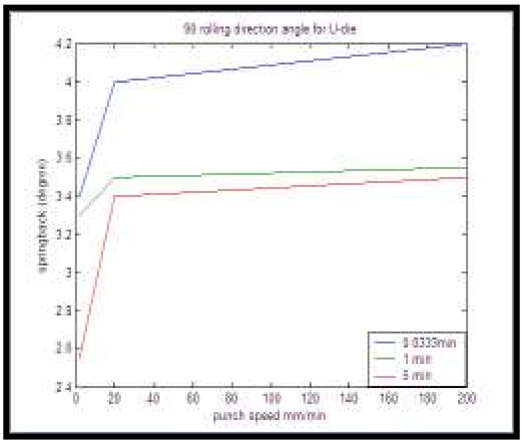
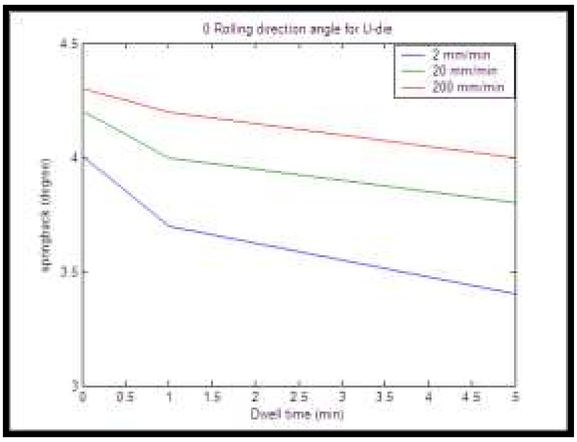



Figure (٨) Relationship between punch speed with spring back (90°)



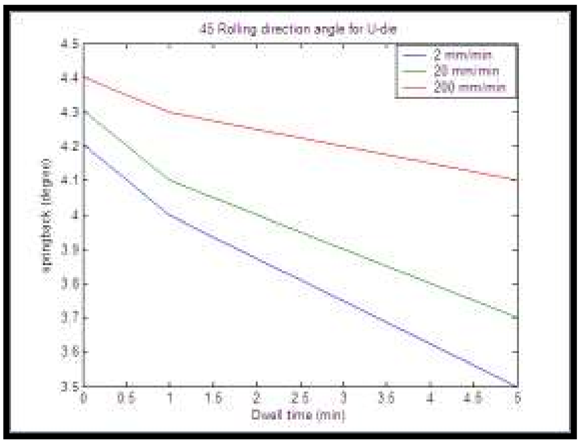




Figure (٩) Relationship between dwell between time with springback (0 $^o$ ) (45 $^o$ ) dwell

Figure (١٠) Relationship time with springback

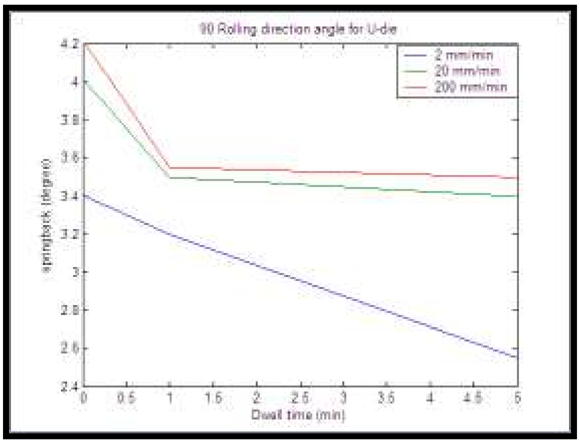



**Figure (11) Relationship between dwell time with springback (90 $^o$ ).**

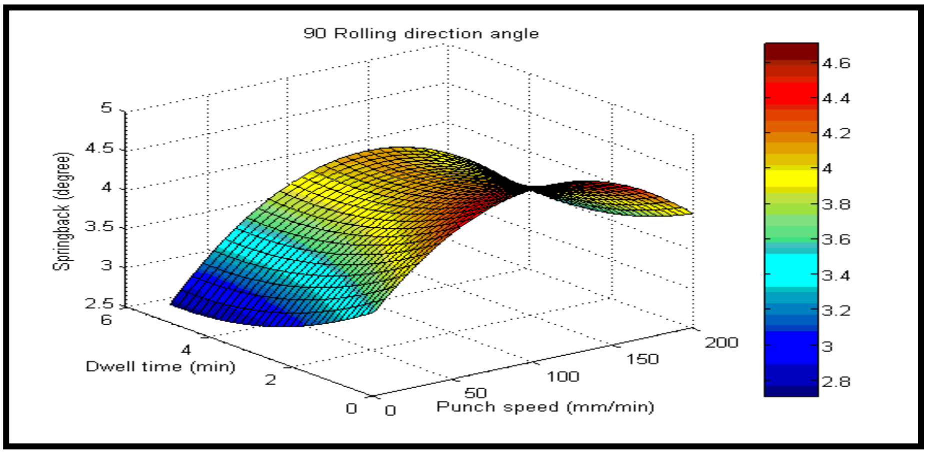



**Figure (١٢) Relationship between the punch speed and dwell time with spring back in 90 $^o$ direction angle rolling.**

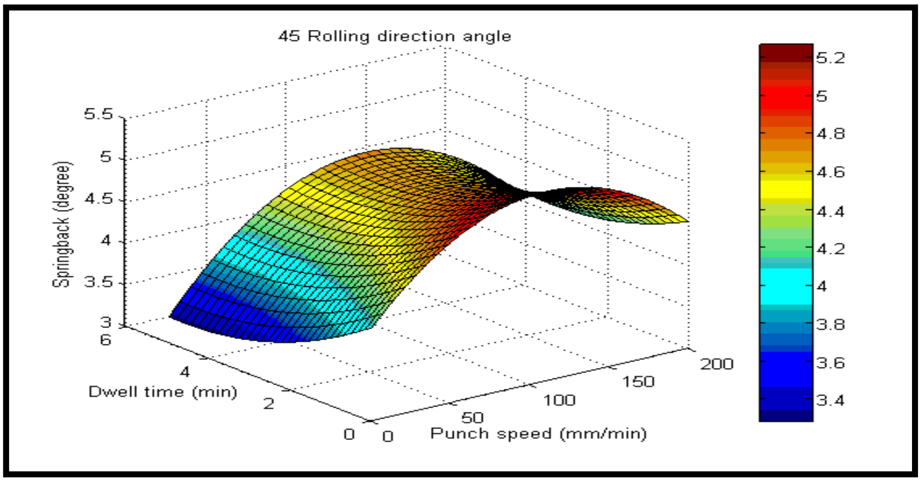



**Figure (١٣) Relationship between the punch speed and dwell time with spring back in 45$^o$ direction angle rolling .**

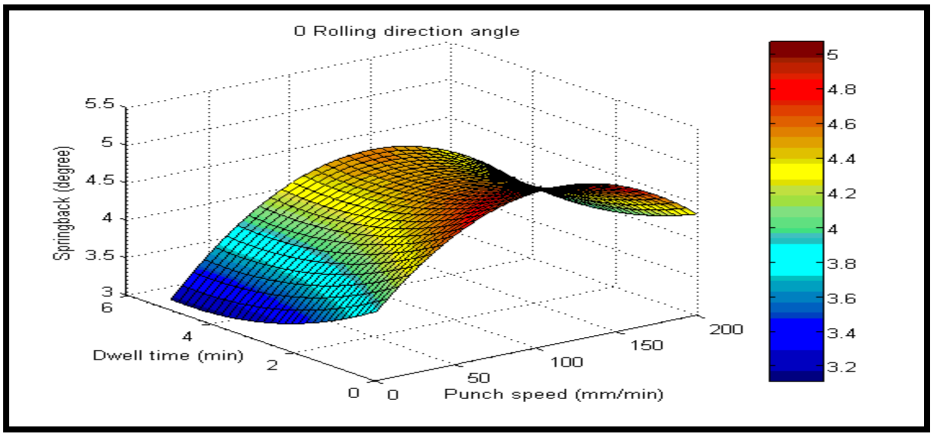



**Figure (١٤) Relationship between the punch speed and dwell time with spring back in 0$^o$ direction angle rolling.**

Tables (5) show the predicted values and measured values of the spring back of 27 data sets by using (SPSS).

**Table (5) Predict and Measured value of spring back.**

| No. | Punch | Direction | Dwell | Spring | Spring | residual |
|---|---|---|---|---|---|---|
| 1 | 2 | 0 | ٢ | ٤.٠٠ | 4.0339 | -0.0339 |
| 2 | 20 | 0 | ٢ | ٤.٢٠ | 4.1134 | 0.0866 |
| 3 | 200 | 0 | ٢ | ٤.٣٠ | 4.4309 | -0.1309 |
| 4 | 2 | 0 | ٦٠ | ٣.٥٠ | 3.4542 | 0.0458 |
| 5 | 20 | 0 | ٦٠ | ٤.٠٠ | 4.1088 | -0.1088 |
| 6 | 200 | 0 | ٦٠ | ٤.٣٠ | 4.2971 | 0.0029 |
| 7 | 2 | 0 | ٣٠٠ | ٣.٤٠ | 3.2677 | 0.1323 |
| 8 | 20 | 0 | ٣٠٠ | ٣.٥٥ | 3.5430 | 0.0070 |
| 9 | 200 | 0 | ٣٠٠ | ٤.٠٠ | 4.0090 | -0.0090 |
| 10 | 2 | 45 | ٢ | ٤.٢٠ | 4.1366 | 0.0634 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 20 | 45 | ٢ | ٤.٣٠ | 4.1737 | 0.1263 |
| 12 | 200 | 45 | ٢ | ٤.٤٠ | 4.5181 | -0.1181 |
| 13 | 2 | 45 | ٦٠ | ٤.٠٠ | 4.0567 | -.0567 |
| 14 | 20 | 45 | ٦٠ | ٤.٢٠ | 4.1232 | 0.0768 |
| 15 | 200 | 45 | ٦٠ | ٤.٣٠ | 4.3188 | -0.0188 |
| 16 | 2 | 45 | ٣٠٠ | ٣.٤٠ | 3.2928 | 0.1072 |
| 17 | 20 | 45 | ٣٠٠ | ٣.٥٠ | 3.5724 | -0.0724 |
| 18 | 200 | 45 | ٣٠٠ | ٤.٣٠ | 4.2450 | 0.0550 |
| 19 | 2 | 90 | ٢ | ٣.٤٠ | 3.3772 | 0.0228 |
| 20 | 20 | 90 | ٢ | ٤.٠٠ | 4.0544 | -.0544 |
| 21 | 200 | 90 | ٢ | ٤.٢٠ | 4.2407 | -0.407 |
| 22 | 2 | 90 | ٦٠ | ٣.٣٠ | 3.2567 | 0.0433 |
| 23 | 20 | 90 | ٦٠ | ٣.٥٠ | 3.5667 | -0.0667 |
| 24 | 200 | 90 | ٦٠ | ٣.٥٥ | 3.4590 | 0.0910 |
| 25 | 2 | 90 | ٣٠٠ | ٢.٥٥ | 2.5777 | -0.0777 |
| 26 | 20 | 90 | ٣٠٠ | ٣.٤٠ | 3.5737 | -0.1737 |
| 27 | 200 | 90 | ٣٠٠ | ٣.٥٠ | 3.4565 | 0.0435 |

## CONCLUSIONS

The present work has reached the following conclusions:

1. The Punch speed has a greater impact on spring back, when Punch speed increases, spring back increases.
2. The direction angle rolling has a greater impact on springback, when direction angle rolling is $90^o$ lower spring back result. and higher spring back result when direction angle rolling $45^o$ .
3. The dwell time has a greater impact on spring back, when dwell time increases, spring back decreases.
4. Spring back could be predicted effectively by Punch speed, direction angle rolling and dwell time, and their interactions in the multiple regression model.
5. The multiple regression model by using (SPSS) could predict the spring back with about 91% accuracy from training data for spring back.
6. Average Standard error for equation model of the estimate of springback is 0.0029.

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