DETERMINATION OF THE OPTIMAL SPRING- BACK PARAMETERS USING TAGUCHI METHOD

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ABSTRACT
Bending process is the one important process in the sheet metal forming in many industries, there are many parameters having a large effect on it. Spring- back is considered one of the most important indications to specify the quality of product parts. The objective of the present study is to find the optimum bending parameters to get lowest spring back on aluminum- silicon (Al- Si) alloy by applying the Taguchi method. The basic parameters which were taken into consideration in this work are: punch speed, hold time and the orientation of material in order. Experiments have been conducted by using L9 orthogonal array with three levels for each parameter. The bending process were done on Instron device ,the optimum combination of process parameters has been found through analysis of main effect of spring back value (α_s) and Signal-to-Noise S/N ratio, and the significant parameter was identified depending on ANOVA analyses. In the present work to determine the level of importance of spring back parameters, the results show that the significant factor is the orientation of metal followed punch speed and hold time, and the obtained results from the experiments are acceptable for the ranges of forming conditions that have been selected in this case study.

KEY WORD:- Bending , Spring Back , Optimization, Taguchi, ANOVA

ايجاد العوامل المثلى المؤثرة على الرجوعية باستخدام طريقة تاكوجي

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الملخص
تعتبر عملية الحني من العمليات التصنعية المهمة في تشكيل الصفائح حيث تتاثر بالعدجيد من العوامل. تعتبر الرجوعية من اهم الؤشرات لتهديد جودة ودقة المنتج. يهدف البحث الحالي الى ايجاد المتغيرات المثلى التي تحقق اقل ما يمكن من الرجوعية عند اجراء عملية الحني لاجزاء مصنعة من سبيكة الالمنيوم سليكون– بتطبيق طريقة تاكوجي . والمتغيرات التي تؤثر على الرجوعية التي اخذت بنظر الاعتبار هي سرعة التشكيل ، زمن التوقف واتجاهية المعدن.

اجريت التجارب باستخدام المصفوفة القياسية بواقع ثلاث مستويات من القيم لكل متغير. اجريتعملية الحني على جهاز الانسترون واوجدت من هذه الدراسة المتغيرات المثالية من خلال تحليل معدل قيم الرجوعية ونسبة (S/N)

وكذلك بالاعتماد على تحليل التباين لتحديد درجة اهمية العوامل المؤثرة على الرجوعية ، وجد ان لاتجاهية المعدن تاثيراً كبيرا على العملية يليه سرعة التشكيل ثم زمن التوقف وان النتائج المستحصلة من اجراء التجارب ظروف التشكيل التي تم اختيارها. مقبولة لمديات

INTRODUCTION

Bending process are used in various industry branches such as automobile, aerospace, petroleum industries, power systems, Spring-back is an unavoidable phenomenon, which accompany the bending process of work parts determined an undesirable change both of bending angle , bending radius, type of material , hold time and the orientation of material . The tools used in bending operations are designed so that they take into consideration the elastic recovery. In order to realize this compensation of elastic recovery measure it is necessary to know the value of the spring-back angle as for back as in the stage of designing the tools. [**ZENG, 2002**] [**Yanagimoto, 2005**] Various efforts were made to analyses the spring-back phenomenon analytically, experimentally, and numerically for different shapes, and process and material parameters illustrated in the following research [**Marciniak, 2002**] [**Dasisva ,2006**], [**Gnatowski, 2008**]and [**Yanagimoto, 2006**],W.M. Chan and A. Nilsson they showed that the spring-back was very much affected by punch speed and die angle [**Nilsson.A, 1997**][**Chan, 2004**].

In bending operation the quality of final form of the part is an important requirement for many bending process? Thus, the choice of optimized spring-back parameters is very important for controlling the required product quality [**Chirita, 2009**] therefore, the present work aims to use a statistical experimental design method named "Taguchi method" is the method that is presented for this purpose, and it is an effective approach to optimize the setting of the parameters that usually effect on spring-back in bending process sharing with analysis of variance (ANOVA) and confirmation experiment to verify the objective.

1. TAGUCHI METHOD

One method presented in this study is an experimental design process called the Taguchi design method. Taguchi design, developed by Dr. Genichi Taguchi, is a set of methodologies by which the inherent variability of materials and manufacturing processes has been taken into account at the design stage. The application of this technique had become widespread in many US and European industries after the 1980s. The beauty of Taguchi design is that multiple factors can be considered at once. Moreover, it seeks nominal design points that are insensitive to variations in production and user environments to improve the yield in manufacturing and the reliability in performance of a product [**Ghani, 2004**]. Therefore, not only can controlled factors be considered, but also noise factors. Although similar to design of experiment (DOE), the Taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than a fractional factorial design. By using the Taguchi techniques, industries are able to greatly reduce product development cycle time for both design and production, therefore reducing costs and increasing profit. Moreover, Taguchi design allows looking into the variability caused by noise factors, which are usually ignored in the traditional DOE approach. [**Chen, 2001**][**Genichi Taguchi, 2001**].and also The Taguchi approach is a form of DOE with special application principles. For most experiments carried out in the industry, the difference between the DOE and Taguchi approach is in the method of application [**Thamizhmanii, 2007**]. Taguchi method is a technique for designing and performing experiments to investigate processes where the output depends on many factors (variables, inputs) without having tediously and uneconomically run of the process using all possible combinations of values. Thanks to systematically chosen certain combinations of variables it is possible to separate their individual effects [**Berginc, 2006**]. In Taguchi methodology, the desired design is finalized by

selecting the best performance under given conditions. The tool used in the Taguchi method is the orthogonal array (OA). OA is the matrix of numbers arranged in columns and rows [**WuY, 2000**]. The Taguchi method employs a generic signal-to-noise (S/N) ratio to quantify the present variation. These S/N ratios are meant to be used as measures of the effect of noise factors on performance characteristics. S/N ratios take into account both amount of variability in the response data and closeness of the average response to target. There are several S/N ratios available depending on type of characteristics: smaller is better, nominal is best (NB) and larger is better [**Thamizhmanii, 2007**].
Therefore, for the present study, "smaller is better" has been depended to find the optimum machining (optimum cutting parameters) which result in a best surface roughness. The signal-noise [S/N] ratio is calculated from applying eq. (1) and eq. (2) [**Syrcos, 2003**]

i) For the "smaller is better" quality characteristic, the equation is:

$$\frac{S}{N} = -10Log(1\ln\sum_{i=1}^{n} y_i^2 \qquad (1)$$

ii) the "larger is better" quality characteristic, the equation is:

$$\frac{S}{N} = -10Log(1/\text{n}\sum_{i=1}^{n}\frac{1}{y_i^2} \qquad (2)$$

Where: S/N is the signal-noise ratio; n the number of observations; and yi the observed data. To achieve the goal of this research "minimum surface roughness (α)", the smaller (α) value, results in better surface roughness or enhancement the finishing of machined parts. The eq. (1) will therefore be used for that, and yi will represent the surface roughness measurements that will be repeated three times for each experiment

2. EXPERIMENTAL WORKE

3.1 Material

V- Die experimental are conducted on (50* 100) mm (Al- Si) alloy sheets having thickness of (2 mm). The specimen are cut in three different directions of rolling, normal (0^0), perpendicular (90^0) and (45^0) to the rolling direction these sets will be used for the validation of the V- die bending with different speed (5,50,500)mm / min. and hold time (10, 20, 30) min The chemical composition for Aluminum silicon Alloy is given in **Table 1** and the mechanical properties obtained from un-axial tension tests are given in **Table 2**

3.2 V- Bending Experiment

A semi closed 90 V- die is designed and used to conduct bending process. The die assembly is installed on the comparison side of 100 KN testing machine (INSTRON MACHAIN) The V- die bending processes are conducted under constant force .The experimental setup for the V- die bending illustrated in **Figure 1**
Three experiments are conducted for each rolling directions, punch speed and hold time combination. The bend angles are measured three times on each parameter the resultant spring-back angle for each parameter is obtained by averaging the values of the spring back for t5he three experiments.

3.3 Experimental Design

In order to obtain the representative experimental data, necessary to determine the relative importance of parameters influencing the spring back, based on a minimum number of practical tests, a matrix

Taguchi L9 (3^3) is chosen. The number (9) indicates the number of experiments in different conditions. The number (3) represents the number of the studied parameters, and the number (3) indicates the number of experimentation levels. This kind of experiment is called factorial experiment (3^3) because every level of each factor (out of the three) is combined with all the three levels of the other three factors. The experiment using Taguchi method was considered. **Table 3 shows three factors and three levels used in the experiment**. If three levels were assigned to each of these factors and a factorial experimental design was employed using each of these values, number of permutations would be (3^3). The fractional factorial design reduced the number of experiments to nine. **The orthogonal array of L_9 type was used and is represented in Table 4.** This design requires nine experiments with three parameters at three levels of each. The interactions were neglected.

3. RESULTS AND DESCUTION

Nine different tubes experiments were performed using the design parameter combinations in the specified orthogonal array table. Three specimens were fabricated for each of the parameter combinations. **The completed response table for these data appears in Table 5.** The Signal-to-Noise ratio (S/N) should be as smaller as possible, because the quality characteristic "smaller is better" was used. S/N values were calculated from eq.(1), and the results have been arranged in the last column of array in table (5). The results were analyzed by using main effects for both spring- back values and Signal-to-Noise ratio (S/N), and ANOVA analyses. Then the estimated results which obtained checked experimentally to insure the estimate value. In terms of the average effects, the average value of spring - back and (S/N) ratio for each parameter (A, B, an C) at each level (level 1, level 2, and level 3) were obtained and **the results are summarized in Table 6**.

The graph that shows the main **effects for spring back can be represented as shown in Figure 2, 3, 4 depending on data in Table 5 and Table 6.** Because of using "smaller is better" quality characteristic in this study, the smaller average of spring back that appears in **Figure 2 represents the smaller value of spring back,** so the combination of parameters and their levels A3B2C3 (Rolling (0) direction degree, Punch speed (500 mm/min), and Hold time (30 min.) represents the optimum condition. The difference (max-min) of three levels for each parameter indicates that the Punch speed has the highest effect on the spring back followed by rolling direction and Hold time.

4. ANOVA (ANALYSIS OF VARIANCE)

The relative influence of the three factors on the spring back is determined by the ANOVA method (Analysis Of Variance technique). The method is based on the idea of separating the variance in several component parts in order to determine which of the experimental factors have an influence on the dependent variable, namely on the spring back. Therefore the purpose of the analysis of variance is to investigate which factors significantly affect quality characteristics [**Sang, 2006**]. The percent contribution of each parameter is evaluated to make a decision on how significant the effect of each parameter. **ANOVA table for the spring back test is organized as shown in Table 7.**

5. CONCLUSION

This research gives how to use Taguchi's parameter design to obtain optimum condition withlowest spring back, minimum number of experiments and industrial engineers can use this method.

- The combination of conditions and their levels ($A_3B_3C_3$)(punch speed 500 m/min, rolling direction $(90)^o$ and hold time 30 min) are recommended to order to obtain a lowest spring back for V- die bending aluminum sheet .

- The experimental conducted with Taguchi method and from the analysis of variance

(ANOVA) in **Table 7** has demonstrated that the punch speed is larger effect on spring back then rolling direction and hold time.

- Taguchi gives systematic simple approach and efficient method for the optimum parameters.

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Table 1 The chemical composition for (Al- Si) Alloy

Element	Si	Fe	Cu	Mg	Zn	Cr	Ni	Pb	Mn	Al
%	0.6	0.19	0.01	0.0043	0.019	0.004	0.012	0.006	0.004	99.2

Table 2 The Mechanical Properties of aluminum alloy in different directions.

Property	0 degrees	45 degrees	90 degrees
Young's modulus	69 Gpa	69 Gpa	69 Gpa
Yield Strength	118 Mpa	130 Mpa	137 Mpa
Ultimate Tensile Strength	131 Mpa	142 Mpa	143 Mpa
% Elongation	6.2 %	3.8%	4.5%

Table 3 Level of process parameters

Level				
Symbol	Factor	1	2	3
A	Rolling direction in degree	0	45	90
B	Punch speed (mm/min)	5	50	500
C	Hold time (min.)	10	20	30

Table 4 The Taguchi L9 orthogonal array

Standard order	A Rolling direction Degree	B Punch speed (mm/min)	C Hold time (min.)
1	0	5	10
2	0	50	20
3	0	500	30
4	45	5	20
5	45	50	30
6	45	500	10
7	90	5	30
8	90	50	10
9	90	500	20

Table 5 Bending conditions of experiments, spring back and S/N results

Experiment number	Experiment condition			Individual spring back measured for each experiment degree			Spring- back average degree	S/N
	A	B	C					
	Rolling direction	Punch speed	Hold time	n_1	n_2	n_3		
1	0	5	10	6.3	6	6.3	6.2	-15.85
2	0	50	20	4.9	5.3	4.8	5	-13.98
3	0	500	30	4	3.3	3.2	3.5	-10.93
4	45	5	20	6	5.3	5.2	5.5	-14.85
5	45	50	30	3.9	4.3	3.8	4	-12
6	45	500	10	3.2	2.9	3.2	3.1	-9.83
7	90	5	30	3.4	4	3.9	3.8	-11.54
8	90	50	10	4.2	3.3	3	3.5	-11
9	90	500	20	2.2	2.3	2.5	2.3	-7.4

Table 6 Main effect table for spring back

Symbol	Spring back parameters	Average of spring back			Max-min
		$Level_1$	$Level_2$	$Level_3$	
A	Rolling direction degree	4.9	4.2	3.5^*	1.4
B	Punch speed (mm/min)	5.21	4.16	3^*	2.21
C	Hold time (min.)	4.3	4.26	3.76^*	0.583

Table 7 ANOVA table for the spring back

Symbol	Sum of Squares	Degrees of Freedom	Mean Squares
A	11.94	2	5097
B	16.561	2	8.281
C	5.296	2	2.648
Total	33.797	6	

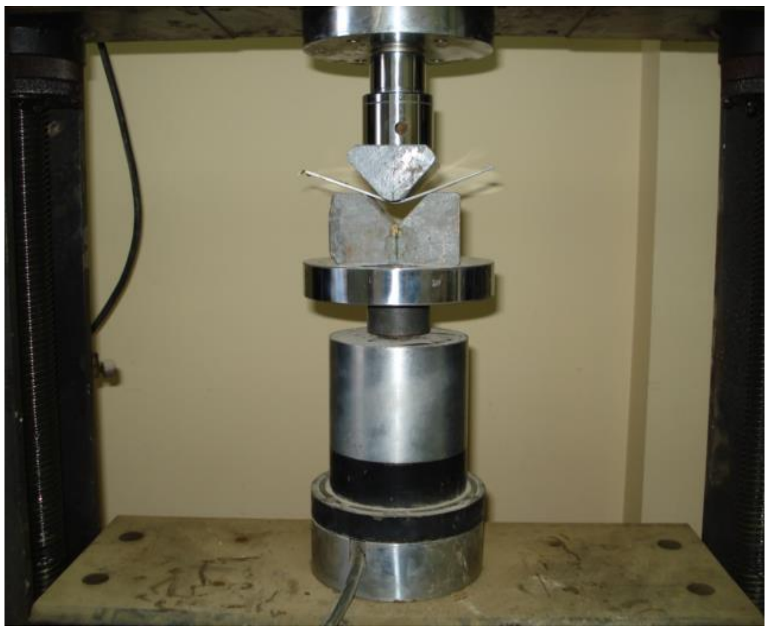

Figure 1 The experimental setup for the V-die bending

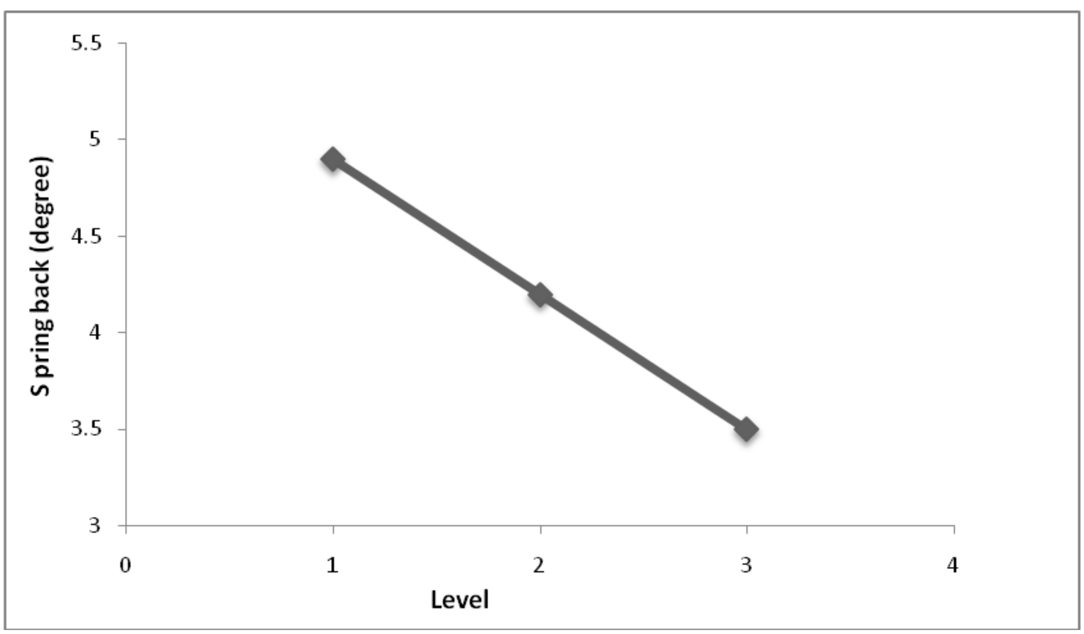

Figure 2 Main effects graph for spring back with rolling direction

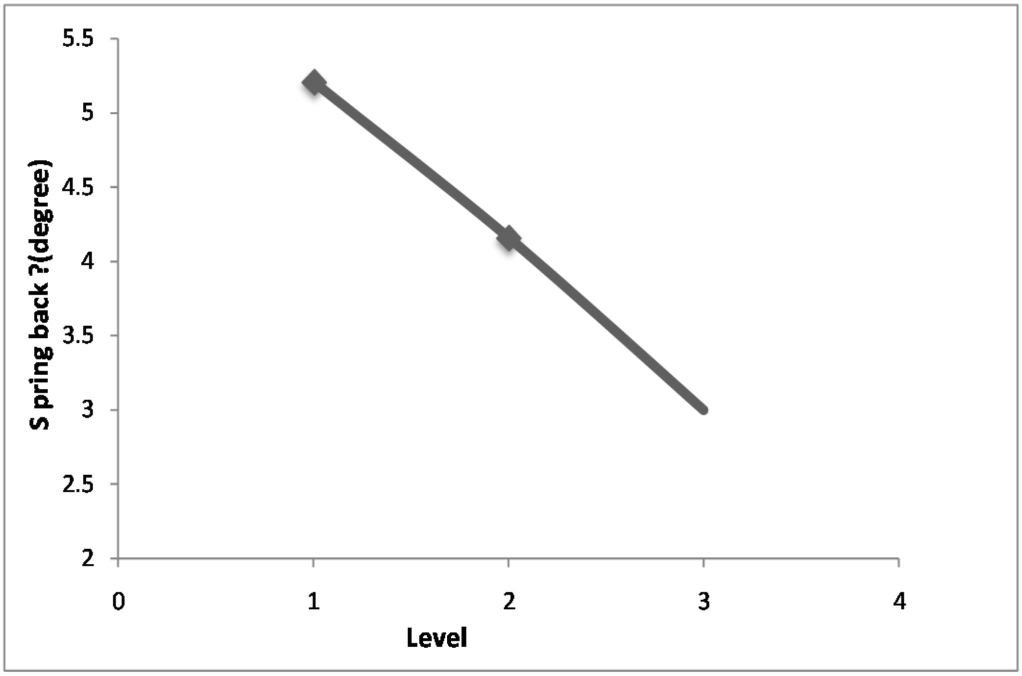

Figure 3 Main effects graph for spring back with punch speed

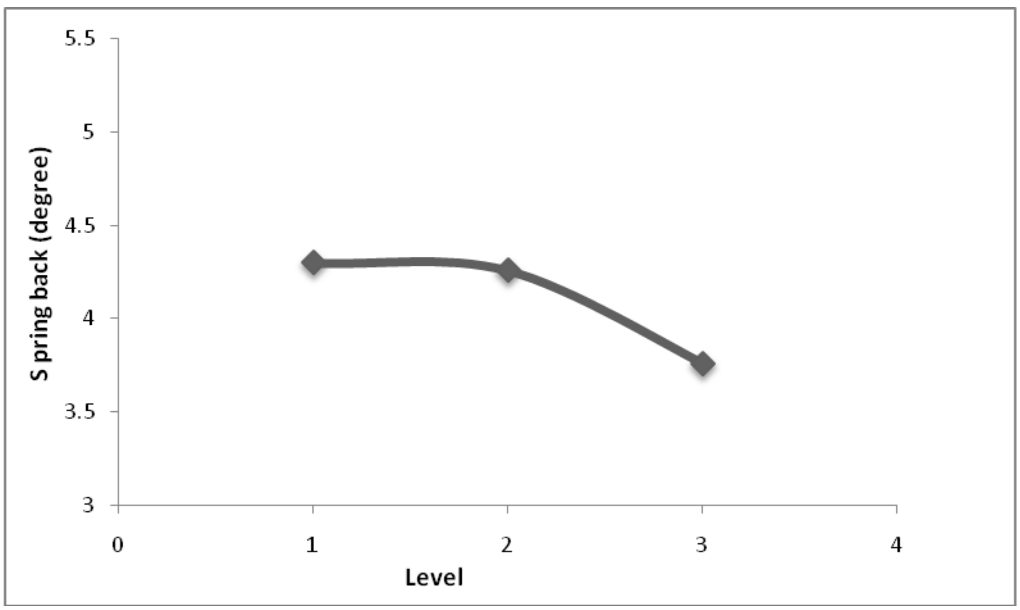

Figure 4 Main effects graph for spring back with hold ti**me.**