Investigation of Influence and Optimization of Various Process Parameters On Springback In UHMWPE

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Abstract- *The use of Ultra High Molecular Weight Polyethylene is in hip, knee and shoulders replacement of human body for over 50 years. Every material having its own different elastic properties, due to elastic recovery of material after unloading the tool force it will try to expand or contract of its initial state. Basically, springback is nothing but elastic recovery of material. The objective of this study to investigate and find the most affecting parameters of springback in UHMWPE. In research study of springback is affected by various factors such as material properties, material thickness, tool geometry and process parameters etc. So, in this paper we are selected three controlling factors like material thickness, punch radius and time to reduce the springback angle and with the help of Taguchi approach to minimize the number of experiments by using L8 orthogonal array. The experiment carried out on v-bending operation because of it is economical and most of the industries are preferred during manufacturing. We validate the experimentation by confirmation experiments.*

Keywords- Springback, UHMWPE, V-Bending Operation, Affecting Parameters.

I. INTRODUCTION

Ultra High Molecular Weight Polyethylene (UHMWPE) isa type of polyolefin. It is made of extremely long chains of polyethylene, which alllign in the same direction. It has extremely long chains with a molecular mass usually between 3.5 and 7.5 million. The longer chain serves to transfer load more effectively [1]. UHMWPE is widely used in defence industry for personal protective equipment's and anti-ballistic application. It's used in clinical history as a biomaterial for used in hip, knee like total joint replacement for over a half century(Kurtz,2009;Charnley,1963) [2]. UHMWPE is used in the manufactured of hydraulicseals and bearings .Its best suited for mechanical medium duties in water ,oil hydraulics ,pneumatics ,and un-lubricated applications. It has a good abrasion resistance but its better suited to soft mating surfaces [15].

UHMWPE has highest impact strength among the other engineering polymers along with excellent abrasion and wear resistance ,bio-compatibility ,noise resistance, very low coefficient of friction, good chemical resistance and electrical insulation resistance. Static and dynamic coefficient are significantly lower than steel and most plastic materials [2]. In bending operation the sheet metal part is converted into desired shape also known as structural stamping parts. The various type of bending processes like air bending, and coining. But in our project experiments are conducted on v-bending because of its economical and most of the industries are carry out these process during manufacturing [16]. The elastic stresses remaining in the bend area after bending pressure is released will cause a slight decrease or increase in the bend angle.This movement of deformed material is called as Springback.Various factors are affected on springback such as material properties, material thickness, tool geometry and process parameters etc [17]. But in this project study we are selected three controlling factors like material thickness, punch radius and time.Taguchi is used for designing experiments.The factors influencing springback effectofUHMWPE material have been predicted quantitatively using the Taguchi Design of Experiment method. Analysis of variance of is an important technique for analyzing the effects of factorsofresponse. To validate result by performing confirmation experiments.

Farzana Ansari, Robert O. Ritchie (2016), stated UHMWPE has extremely long chains with a molecular mass usually between 3.5 and 7.5 million. The longer chain serves to transfer load more effectively [1].Sutasn Thipprakmas (2012) stated the use of coined bead technique. According to his findings the conventional coined-bead technique could only prevent the spring-back. In contrast, the sided coined-bead could prevent both the spring-back and the spring-go by setting a suitable geometry and position. The spring-back and spring go generations depended on the setting of the process parameters. The FEM simulation results showed a good agreement with the experimental results with reference to the bending forces and bending angles. He also stated that this technique could also be applied to control the spring-back by decreasing the bending characteristic in the bending allowance zone [3].D. K .Lee, studied the effects of process parameters on the V-bending process for steel sheets using the FE method [4].Ozgur Tekaslan et al. (2007), Used modular V-shaped dies to experimentally determine the spring-back of stainless steel sheet metals. They concluded that holding the punch longer on the material reduces the spring-back [18]. Daw-Kwei Leu (2014), determine the effect of process parameters such as punch radius, material strength, and sheet thickness on the spring back angle are experimentally to determine the dominant parameters for reducing the spring back angle in the sheet bending process for high-strength steel sheets [5].Sutasn Thipprakmas (2012), Conventional coined-bead technique and sided coined-bead technique were clearly identified. In the precision V-bending process, the conventional coined-bead technique could only prevent the spring back [6].Peng Chen (2008),investigate the effect of variation in material(mechanical properties) and process(blank holder force and friction) on the springback variation for an open channel shaped part made of dual phase (DP) steel[10].Narayan A Maske (2013)The factors influencing the springback found for of plane sheet of aluminium materials have been predicted quantitatively using the Taguchi Design of Experiment method. The bending process is chosen as an evaluation problem because of its larger springback effect [11]. (Dhurai raj and Padmnabhan, 2011), Stated Bending is widely used metal formingprocess in various sheet metal products suchas automobile panels, supermarket shelvesand housing utensils [12].

1.1 Springback Effect :

It is defined as a change in the final bend angle after the blank undergoes bending by the release of the elastic component of the bending moment. The effect of spring back in air bending is the dimensional change of the formed part after the pressure of forming tool has been released. It results from the changes in strain produced by elastic recovery when the load is released. The final shape of the formed part is seriously affected by springback phenomenon [13].

The elastic stresses remaining in the bend area after bending pressure is released will cause a slight decrease or increase in the bend angle.This movement of deformed material is called as **Springback.**

Two methods have been performed for controlling the springback deviations. The first has reduction of springback by increasing sheet tension during forming process (mechanical method). Applying such methods causes greater plastic zone during forming and less amount of springback occursduring unloading.. In the second method, the purpose is to compensate springback error by modification of tool design, in a way that the target shape results after springback. In such methods, the amount of springback is considerable but by accurate springback analysis and applying trial-error algorithms, this error would be compensated by correction of die geometry [11]. Air bending process is the most commonly used bending process because of its flexibility and reduction in punch load [19].

1.2 Design Of Experiment and Taguchi Method:

Design of experiments (DOE) techniques enable designers to determine simultaneously the individuals and interactive effects of many factors that could affect the output results in any design. DOE also provides a full insight of interaction between design elements; it helps turn any standard design into robust one. Simply DOE helps to pin point the sensitive parts and sensitive areas in designs that cause problems in response variable. Then these problems can be fixed and can be used to produce vigorous results. Design of experiment is based on the use of orthogonal arrays suggested by Taguchi. The approach is suitable for conducting small, highly fractional factorial to larger full factorial experiments [14].

Taguchi used the signal-to-noise (S/N) ratio as the quality characteristic of choice. S/N ratio is used as a measurable value instead of standard deviation due to the fact that as the mean decreases, the standard deviation also decreases and vice versa. In other words, the standard deviation cannot be minimized first and the mean brought to the target. Taguchi has empirically found that the two-stage optimization procedure involving S/N ratios indeed gives the parameter level combination, where the standard deviation is minimum while keeping the mean on target [14].

This method also suggests analyzing variation using an appropriately choose signal-to noise (S/N) ratio. These S/N ratios are derived from the quadratic loss function, and three of them are considered to be standard and widely applicable. These are:

1. Lower the better (LTB)
2. Higher the better (HTB)
3. Nominal the best (NTB)

II. PLANNING FOR EXPERIMENT

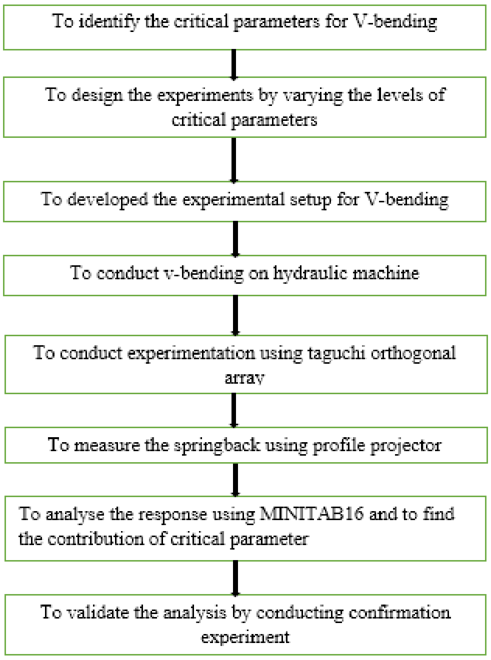

Fig 1: Flow of work

Above fig 1. is the methodology to plan experiment and completedeach stage one by one. In fig 2..is the UHMWPE specimens (6*3 cm) for conducting experiment.

Figure 2: UHMWPE specimens (6*3 cm)

The table no.1 shows the properties of UHMWPE material are as follows:

Table 1. Mechanical properties for UHMWPE

Density (g/cc3)	0.94
Tensile yield strength (Pa)	2.5e7
Wear loss (mg)	100 Max
Poisson ratio	0.46
Elongation (%)	250
Shore hardness (D)	64-65

2.1 Design of orthogonal array :

Basically, the objective of this study to investigate and find the most affecting parameters of spring-back in UHMWPE. The critical parameters affecting Springback selected for experimentation through available literature are: **punch radius, material thickness** and **time**. The experiments are designed and conducted by taking the combination of levels of all critical parameters.

Table2:Levels of design selected critical parameters

	Punch Radius (mm)	Material Thickness (mm)	Time (minute)
Level 1	2	10	3
Level 2	3	12	6

Taguchi's design of experiment used to design the experiments. The three factors are material thickness, punch radius, time were considered as the critical factors affecting on Springback in V bending and 2 levels of each factor were taken; it is the 2^3 full factorial design as shown in table no. 2.

Orthogonal array gives more reliable estimation of factor effects with less number of experiments, Hence total 8 (2^3) numbers of experimental runs were conducted. The sequence of bending operation is as shown in figure table no. 3.

The springback was considered as the response as shown in table no. 3

Table3: L8 Orthogonal array for selected levels of critical parameters

Exp. No	Punch Radius (mm)	Material Thickness (mm)	Time (minute)
1	2	10	3
2	2	10	6
3	3	10	3
4	3	10	6
5	2	12	3
6	2	12	6
7	3	12	3
8	3	12	6

2.2 Actual Experimentation & Angle Measuremen

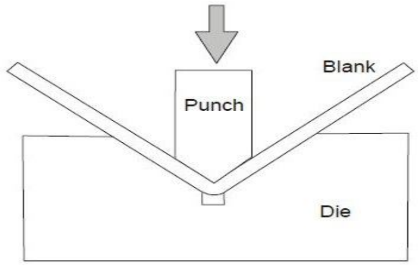

Figure3: Punch and die geometry for V bending

The geometrical details of punch and die set used for V bending are shown in figure 3. The detailed schematic of the actual set up shown in figure 4.Experimention is performed on hydraulic machine.

Figure 4: Actual experimental set up for v-bending

The profile projector is used to measured angle of deformed specimens.The springback was examined using the Optical Profile projector of AURA make having a least count of 5´ (5 minutes).

2.3 Result and discussion:

After measurement of angle on profile projector the springback values are got and that values are shown in table no. 4

Table 4: Springback response for UHMWPE

Runs	Material thickness (mm) Factor 1	Punch radius(mm) Factor 2	Time (min) Factor 3	Springback (°)
1	10	2	3	49
2	10	2	6	46
3	10	3	3	38
4	10	3	6	37
5	12	2	3	32.6
6	12	2	6	32
7	12	3	3	31.5
8	12	3	6	22.2

The data is analysed using signal to noise ratio (SN ratio). Smaller the better criterion is used as the Springback (response) is desired to be minimum. The data is also analysed for the mean values table no. 5 which gives same results as that of SN ratios.

Table 5: SN data ratio of 8 runs for UHMWPE

Runs	1	2	3	4	5	6	7	8
S/N	-33.803	-33.255	-31.5957	-31.3640	-30.264	-30.103	-29.966	-26.927

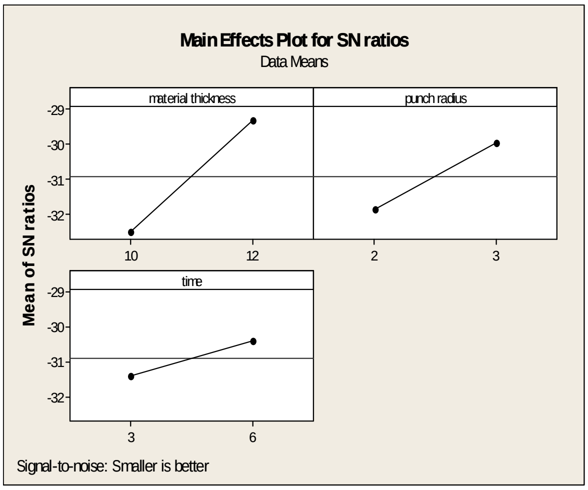

Figure 5: Main effect plot of SN ratio for UHMWPE

The delta value of the material thickness in table no. 6 is highest and rank 1 is given to it, hence it is considered as the most affecting parameter for Springback on UHMWPE. According to the effect of each parameter, the ranks are given. Punch radius is given rank 2 and time is given the rank 3 as it is the least affecting parameter. It can be easily seen from figure.21 that the variation of the material thickness is greater as compared to the variation of the other two factors. Hence, material thickness is the most affecting parameter for Springback in UHMWPE.

Table 6: Table response S/N ratio for UHMWPE.

Level	Material Thickness	Punch Radius	Time
1	21.25	19.95	18.89
2	14.79	16.09	17.15
Delta	6.46	3.86	1.74
Rank	1	2	3

The figure 12. also shows the maximum variation in the mean values of bending angle.

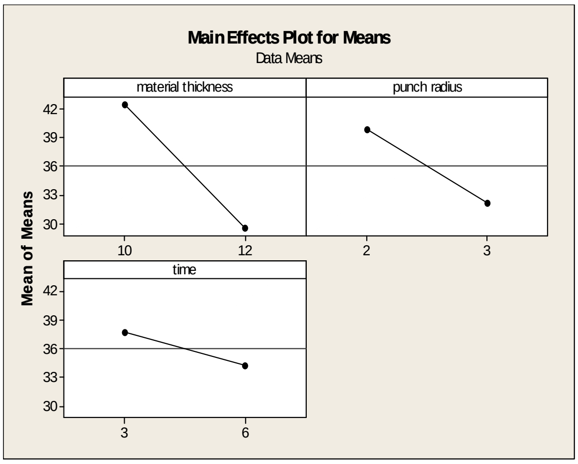

Figure 6:- Main effects plot for Means for UHMWPE

Hence, the material thickness is found to be the most affecting parameter for spring Go in V bending process for UHMWPE.

The percentage contribution of each factor under study is represented by the pie chart shown in figure23. To investigate the degree of importance of process parameters, the ANOVA technique was carried out in case of spring-back and spring-go. The "smaller the better (SN_s)" characteristics as shown in Eq.(1) were considered for the spring-back and spring-go. The mean value of overall *S/N* i.e. $\overline{(S/N)}$ is expressed as Eq. (2) where *k* is the number of experiments. The sums of squares owing to the overall mean (SS) and mean process parameters (SS_i) are expressed as equations (3) and (4) respectively.

The percentage contributions as shown in Eq. (5) were calculated by considering the degree of importance of each process parameter.

$$SN_s = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} {y_i}^2\right) \quad (1)$$

$$\overline{\left(\frac{S}{N}\right)} = 1/8\sum_{k=1}^{8}\left(\frac{S}{N}\right)_k \quad (2)$$

$$SS = \sum_{i=1}^{8}\left(\left(\frac{S}{N}\right)_{ij} - \overline{\left(\frac{S}{N}\right)}\right)^2 \quad (3)$$

$$SS_i = \sum_{j=1}^{3}\left(\left(\frac{S}{N}\right)_{ij} - \overline{\left(\frac{S}{N}\right)}\right)^2 \quad (4)$$

$$\%\ contribution_i = \frac{SS_i}{SS} \times 100 \quad (5)$$

Table 7. S/N ratio, Sum of squares and percentage contribution for UHMWPE

Process parameters	Material thickness (t)(mm)		Punch radius (R_p) (mm)		Time (minute)	
	10	12	2	3	3	6
$\left(\frac{S}{N}\right)_{ij}$	-32.50	-29.31	-31.85	-29.96	- 31.4	-30.41
Sum of squares SS_i	5.05		1.7865		0.4905	
% contributions	**55**		**33**		**17**	

The $\left(\frac{S}{N}\right)$, SS and percentage contribution calculated for each process parameter is illustrated in table (16). The percentage contributions for springback of material thickness, punch radius and time 55%, 33% and 17% respectively.

III. PERCENTAGE CONTRIBUTION

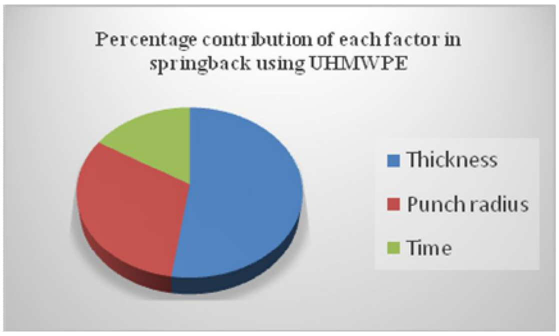

Figure 7:- Percentage contribution of each factor in springback using UHMWPE

IV. VALIDATION

Validation is the most important stage of any experimentation work. The validation of the entire experimentation is done by conducting the confirmation experiments. This is the last step of the Design of Experiments (DOE) process.

4.1 Confirmation experiments:

A confirmation experiment is performed by conducting a test using a specific combination of factors and levels previously evaluated.

The purpose of the confirmation experiments is to validate the conclusions drawn during the analysis phase. The confirmation experiments are conducted by using the combination of factor levels which are obtained after the analysis and are identical to those used in the initial experiments. The sample size used is also same.

From initial experiments:

$$C.I. = \sqrt{F_\alpha; 1; \gamma_e V_{ep}[\left(\frac{1}{\eta_{eff}}\right) + (\frac{1}{r})]}$$

Where,

$$V_{ep} = \frac{SS_e}{v_e\ (error\ dof)}$$

$$\eta_{eff} = \frac{N}{1 + dof}$$

r = sample size of the confirmation experiments $F_{95\%}; 1; 4 =$ Value of F at 95% Confidence Interval with 1 degree of freedom of the factor and 4 degree of freedom of the error from standard table

$$\hat{\mu}_{B_2} = \overline{B_2} - \bar{T}$$

$$\bar{T} = \frac{\text{Total response of all initial experiments}}{\text{Total no. of trials}}$$

$$\bar{B}_2 = \frac{B_2}{4}$$

Table 8:- Variables required for C.I from initial experiments for UHMWPE

V_{ep}	η_{eff}	r	$F_{95\%}; 1; 4$	$\bar{T}$	$\bar{B}_2$	$\hat{\mu}_{B_2}$	$C.I.$
29.44	4	8	7.71	36.0375	-8.45	-44.2375	22.66

From confirmation experiments:

$$\mu = \overline{B_2} - \bar{T}$$

$$\bar{T} = \frac{\text{Total response of all confirmation experiments}}{\text{Total no. of trials}}$$

$$\bar{B}_2 = \frac{B_2}{4}$$

Table 9: Variables required for C.I from confirmation experiments UHMWPE

$\bar{T}$	$\bar{B}_2$	μ
49	-8.45	-57.45

If the following condition gets satisfied, then it is treated as validation through confirmation experiments.

$$\hat{\mu} - C.I < \mu < \hat{\mu} + C.I$$

By confirmation experiment

80.11< **- 57.45** <-34.79

As the above condition is getting satisfied, hence the experimental results are validated through the confirmation experiments.

V. CONCLUSION

Springback is the geometric change made to a part at the end of the forming process when the part has been released from the forces of the forming tool.In the forming processes, the spring back can be considerably minimized by controlling the design process parameters. The spring back depends upon the factors related to the material and factors related to the bending process i.e. material thickness, punch radius, time.The percentage contribution for material thickness, punch radius and time are 55%, 33% and 17% respectively.From the observation material thickness is the most affecting parameter.

VI. FUTURE SCOPE

This work is completely based on the experimental results. The validation is done by conducting confirmation experiments. It could be interesting to do the mathematical modelling of the entire V bending process. Also the Finite Element Analysis (FEA) could also be very effective for the same. The application of neural network or fuzzy logic could also be an interesting topic for further study.

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