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Optimization of Lubrication Effect and Die Angle on Cold Forward Extrusion of AA6063

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Abstract:- The aim of the present work is to optimize the process parameters and improve the quality of components in extrusion of AA6063 by using Taguchi based Grey Relation Analysis. In the present analysis, two control factors were taken namely lubricants and die angles were considered. Accordingly, a suitable orthogonal array was selected in Minitab software and experiments were conducted. After conducting the experiments the load, surface roughness and hardness were measured. With the help of graphs, the optimum parameter is obtained and experimental analysis has been employed to optimize the effects of lubrication and die angle on the deformation of aluminium work piece by using Grey relation analysis. The effects of lubrication and die angle on forming loads, surface finish, and hardness was evaluated between die- work piece sliding surfaces. Grease, Engine oil and Castor oil with same amount were used as test lubricant. The lubricant and die angle on the work piece was used as inputs for the experimental work. The resultant optimal parameters combination was determined as Engine oil at 25 0 die angle.

***Keywords**:- Extrusion, load, surface roughness, hardness, Taguchi method, grey relation analysis.*

I. INTRODUCTION

Extrusion is a metal forming process used to create objects of a fixed cross sectional profile. The extrusion process is one of the important production technologies in industry because of its large scale productivity, minimal cost, material savings and quality improvement. In recent years extrusion process is widely used in manufacturing of very complex shapes of components which are used in machine areas like manufacturing of helicopter blades and turbine blades, Light weight construction, and transportation. Quality and productivity can be enhanced through process parameter optimization. There are number of research works related to various extrusion parameters optimization for achieving the better performance characteristics. Among these surface roughness and hardness are important process parameters. So the primary objective of the optimization analysis during extrusion process is to optimize the input parameters.

S.O. Adeosun et al. [1], discussed on the effect of initial temperature and state of wrought aluminium on extrusion with die angle and die material. G.A Chaudhari et al. [2], discussed on effect of die angle on the quality of extruded product i.e. is surface finish of cold extruded aluminium. M. Schikorraet et al.[3], performed extrusion on round profile of AA6060 on a laboratory 10MN press he analyzed the role of friction in the extrusion of AA6060 aluminium alloy. Ambati Vijay Kumar et al. [4], made an investigation to find the effect of die angle of the extruded product. Jayaseelan.V et al.[5], done cold forward extrusion on AA6063 and lubricants like Figite, Molybdenum disulphide (MoS2) and Zinc stearate were tested in the extrusion process of AA6063 against Hot die steel (H13). Srinivas Athreya et al. [6] used Taguchi method to optimize the process parameters of lathe facing operation. Syahrullail. S et al. [7] discussed the viability of palm oil when used as a lubricant in cold forward plane strain extrusion process.

Zoran Jurkovic et al. [8] determined the optimal cold forward extrusion parameters with the minimization of tool load. S.O. Onuh et al. [9], made an experimental investigation on the effects of die reduction in area, die angle, loading rate on the quality of extrusion products. P. Tiernan et al. [10], discussed on experimental and finite element analysis (FEA) of the cold extrusion of high-grade (AA1100) aluminium. K.E.V.S.Prasad et al. [11], discussed on effect of load and surface finish of the extruded part extrusion. U.C Paltasingh et al. [12], discussed about Variations in load and flow direction of metal by the extruded geometry. Raghuraman et al. [13], made an investigation on the optimal process parameters in Electrical Discharge Machining (EDM). Rupesh Kumar Pandey et al. [14] used grey relational method optimizing the multiple quality characteristics in bone drilling operation.

II. MATERIALS AND METHODS

A. Material

The material AA6063 is chosen as a billet material for easy of formability. AA6063 is an aluminium, with magnesium and silicon as the main alloying elements. AA6063 is one of the commonly used aluminium for extrusion because of its good mechanical properties. And it produces very smooth surfaces while extruding complex shapes. So, it is most popular for architectural and highly weldable applications.

B. Experimental Tool Design

The punching rod and die are two main parts designed and analysed for the experimentation of the extrusion. The die with three different die angles is designed in accordance with Ambati Vijay Kumar [4]. The internal part of die is shown in Fig 1. The die consists of 94mm height and 100mm diameter. The die is made of high carbon high chromium (HC-HC) steel. And finally, die is heat treated to increase hardness and grinding the internal and external part of the die for better surface finish. The design model of dies with 30 0,25 0 and 15 0 die angles is analysed in Ansys with static structural analysis. Grease, Engine oil and Castor oil are taken as lubricants with same amount were used as test lubricant.

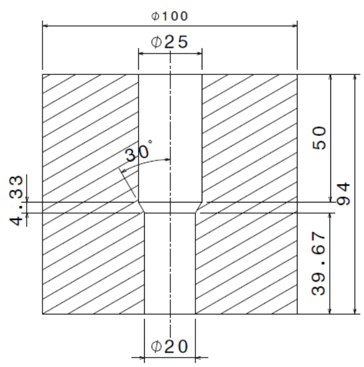

Fig 1:- Die design with 30^0 die angle

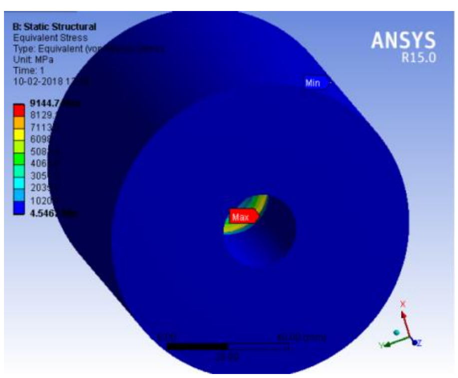

Fig 2:- Analysis of die, with 30^0 die angle

The die is designed in Catia software and the design of die is shown in figure 1. Then completed designed die is analysed by using Ansys software is shown in Fig 2.

C. Experimental Procedure

The Experiments are conducted along Taguchi based design of experiments. The Experiments were conducted on a 100 Ton digitalized UTM for 30 0,25 0 and 15 0 die angles. The load values are taken at every 1mm movement of the ram. The universal testing machine is shown in Fig 3.

Fig 3:- Electronic Universal Testing machine (UTM)

The surface roughness of the extruded parts was measured by using Surface roughness tester. Four random locations have been chosen for surface roughness testing and average value was taken.

The hardness values of finished parts of extrusion are obtained on a Vickers hardness tester at four random locations on the surface in extruded direction.

D. Taguchi Technique and ANOVA

Taguchi method is one of the best techniques used for optimization to solving problems of multiple objectives depends on multiple variables. In this, we use systematic approach called design of experiments. These DOE are used to minimize cost and time of experiments for large number of combinations to solve complex problems in production and manufacturing. In this method, signal-to-noise (S/N) ratio is used to represent performance characteristic. Analysis of variance is a technique is used to find aggregate variability inside the optimization problem at different systematic and random factors. The hypothesis is to check the percentage of contribution.

In this study, we considered lubricants and die angles are taken as factors at three levels. So, for our input data we considered L9 orthogonal array is employed for experimentation to get optimized level of parameters. The two factors and their levels are shown in table 1.

Factors	Levels		
	1	2	3
Lubricant(ml)	Grease	Engine oil	Castor oil
Die angle(^{0})	30	25	15

Table 1. Factors and levels considered for extrusion

E. Grey Relational Analysis

In the grey relational method, the measured experimental values are pre-processed or normalized from 0 to 1. This normalization process is called as a grey relational generation. Then based on this pre-processed or normalized values, the grey relation coefficient was calculated. And finally average the all parameter values of grey relation coefficients to get

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grey relation grade. This grey relation grade is the objective function of grey relational analysis because the overall performance of response is depends on grey relation grade. This GRG optimizes the multiple-response problems into single response problem. In Grey relation generation, normalized data corresponding to lower-the-better (LB) criterion can be expressed by (1)

$$x_i(k) = \frac{\max y_i(k) - y_i(k)}{\max y_i(k) - \min y_i(k)} \qquad (1)$$

Where, $x_i(k)$ is Grey relation generation value, $y_i(k)$ is the experimental output value, min $y_i(k)$ is the lowest value of $y_i(k)$ for k^{th} response, and max $y_i(k)$ is the highest value of $y_i(k)$ for k^{th} response.

Then the grey relation coefficient values were calculated by (2).

$$\varepsilon_i(k) = \frac{\Delta_{min} + \varphi\,\Delta_{max}}{\Delta_{oi}(k) + \varphi\Delta_{max}} \qquad (2)$$

Where $\Delta_{oi} = \|x_o(k) - x_i(k)\|$ = difference of absolute value x_o (k) and x_i (k); φ is the distinguishing coefficient. Here the value of φ is taken as 0.5 in most situations

$\Delta_{min} = \forall j^{min} \in i \forall k^{min} \|x_o(k) - x_j(k)\| =$ The smallest value of Δ_{oi}.

$\Delta_{max} = \forall j^{max} \in i \forall k^{max} \|x_o(k) - x_j(k)\| =$ The largest value of Δ_{oi}.

Then the GRG values were calculated by (3).

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \varepsilon_i(k) \qquad (3)$$

Where, n is process response number.

E. Conformation Test

The conformation test is used to verify the experimental results obtained. The predicted load, surface roughness, hardness and GRG values at optimal combination of factors or parameters is calculated by (4).

$$\hat{Y}_0 = Y_{0m} + \sum_{i=1}^{k}(\bar{Y}_{0i} - Y_{0m}) \qquad (4)$$

Where, Y_0 is the estimated value, Y_{0m} is the total mean value, $\bar{Y}_{0i}$ is the mean value at the optimal level and k is the no. of parameters affecting the multiple responses.

III. RESULTS AND DISCUSSION

After completed experimentation, the load, surface roughness and hardness values are obtained. The digitalized surface roughness tester is used to get surface roughness values and digitalized Vickers hardness tester is used to get hardness values.

Exp No.	Lubricant	Die angle	Load	Surface roughness	Hardness
1	Grease	30^0	188.50	0.559	140.34
2	Grease	25^0	196.50	0.539	141.65
3	Grease	15^0	209.00	0.493	145.23
4	Engine oil	30^0	204.50	0.303	145.62
5	Engine oil	25^0	217.00	0.273	148.59
6	Engine oil	15^0	238.75	0.294	149.20
7	Castor oil	30^0	212.00	0.293	146.00
8	Castor oil	25^0	227.75	0.258	148.47
9	Castor oil	15^0	259.50	0.283	149.31

Table 2. Design of Experiments and Experimental Results

Table 2 shows Taguchi L9 orthogonal array and design of experiments with experimental results. The columns 2 and 3 indicates inputs namely lubricants and die angle. The columns 4, 5 and 6 indicates performance responses namely load, surface roughness and hardness.

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value	%Contribution
Lubricant	2	0.146793	0.146793	0.073396	361.45	0.000	56.70%
Die Angle	2	0.111300	0.111300	0.055650	274.05	0.000	42.99%
Error	4	0.000812	0.000812	0.000203			0.31%
Total	8	0.258905					100.00%

Table 3. Analysis of Variance of Combined S/N ratios

The combined response values of ANOVA is shown in table 3 and it is done by using MINITAB software. The value of % contribution for lubricant is 361.45 and it is more compared to other parameter. This means that lubricant is much effecting than die angle along combined response.

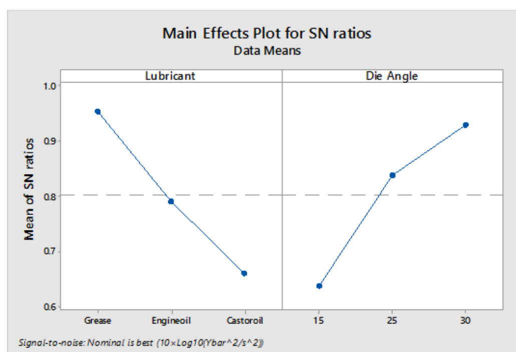

Fig 4:- S/N ratios for Combined Responses

Fig 4 shows S/N ratio of combined response on the effect of lubrication and die angle. It describes the optimal parameters combination is lubricant as Engine oil and die angle is 25^0.

A. Grey Relational Analysis

The experimental values for the load, surface roughness and hardness are normalized using (1). The lower-the-better condition is taken for load and surface roughness because, when minimize the load to increase the tool life of machine. When surface roughness values are low to get better smoothness of material. The higher-the-better condition is taken for hardness. The pre-processing or normalized values are shown in table 4.

Experiment No.	Preprocessing data of experimental results		
	Load	Surface roughness	Hardness
1	1	0	0
2	0.8873	0.0664	0.1460
3	0.7112	0.2192	0.5451
4	0.7746	0.8504	0.5886
5	0.5985	0.9501	0.9197
6	0.2922	0.8803	0.9877
7	0.6690	0.8837	0.6309
8	0.4471	1	0.9063
9	0	0.916	1

Table 4. Normalized values of Experimental Results

From the normalized data the grey relation coefficient are calculated by (2) and the values are shown in table 5. This GRC is used to find grey relation grade (GRG).

Experiment No.	Grey relation coefficient		
	Load	Surface roughness	Hardness
1	1	0.3333	0.3333
2	0.8160	0.3487	0.3692
3	0.6338	0.3903	0.5236
4	0.6892	0.7697	0.5486
5	0.5546	0.9092	0.8616
6	0.4139	0.8068	0.9759
7	0.6016	0.8112	0.5753
8	0.4748	1	0.8421
9	0.3333	0.8561	1

Table 5. Grey Relation Coefficient of Experimental Results

The grey relation grade (GRG) values are shown in table 6. From grey relation grade highest value is the optimized level at experiment number 5. So the optimized parameters are namely lubricant=Engine oil, die angle = 25^0.

Experiment No.	Grey relation grade	Rank
1	0.5555	7
2	0.5113	9
3	0.5159	8
4	0.6691	5
5	0.7751	1
6	0.7322	3
7	0.6627	6
8	0.7723	2
9	0.7298	4

Table 6. Grey Relation Grade Results

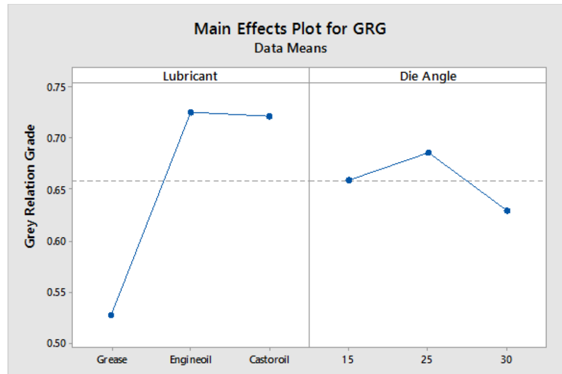

Fig 5:- Response plot for GRG

Fig 5 represents the optimum combination of responses in grey relation grade.

From fig 5 the graph represents the optimal combination of parameters are lubricant as Engine oil and die angle is 25^0**.**

H. Conformation Test

The predicted and experimental values for the load, surface roughness, hardness and grey relation grade we observed that predicted values of grey relation grade is less when compared to experimental grey relation grade values. This means that grey relational analysis is effectively used for different optimization problems. And there is a good agreement between surface roughness and hardness at optimal level of parameters. The conformation experiment results are shown in table 7.

	Optimal Process Parameters	
	Predicted	Experimented
Level	A2B2	A2B2
Load	216.778	217.00
Surface Roughness	0.280	0.273
Hardness	147.99	148.59
GRG	0.7534	0.7751

Table 7. Conformation Experimental Results

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IV. CONCLUSION

Taguchi Technique and Grey Relational Analysis were applied in this work to improve characteristics such as load, Surface roughness and hardness of Aluminium alloy 6063 during the Extrusion process. The conclusions are summarized as follows.

- The optimal parameters combination was determined as Engine oil at 25 0 die angle for the highest grey relation grade (GRG) and is best setting for minimum load, surface roughness and maximum hardness during extrusion process.
- After conformation test, there is a good agreement between predicted and experimental results at optimum level.
- Through ANOVA it was conformed that lubrication was the major significant factor followed by load and surface roughness and hardness.
- It was found that the load required to deforming the billet during extrusion for Engine oil and Castor oil is higher as compared to Grease for AA6063.
- There is a negligible variation in surface finish with variation in die angle and the average hardness values at 15 0 die angle is higher compared to 25 0 and 30 0 die angles.

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