IJERST

International Journal of Engineering Research and Science & Technology

ISSN : 2319-5991
Vol. 7, No. 2
May 2018

www.ijerst.com

Email: editorijerst@gmail.com or editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 7, No. 2, May 2018

Research Paper

OPTIMISATION OF PROCESS PARAMETERS FOR GOOD SURFACE FINISH OF AA6082 FLOW-FORMED TUBES

M Srinivasulu[1]* and M Komaraiah[2]

*Corresponding Author: M Srinivasulu ✉ msvasulu.mech@gmail.com

Received on: 5th March, 2018 Accepted on: 15th April, 2018

Flow-forming is an advanced, chip less metal forming process. A single roller flow forming machine has been used to manufacture the thin walled tubes of AA6082 alloy. The effect of process parameters on the surface finish of flow formed tubes have been studied by Taguchi method. The main flow-forming parameters selected for the present investigation are axial feed of the roller, speed of the mandrel, and thickness reduction. The effects of these input parameters on the response, surface roughness (Ra) have been critically analyzed. It has been found that the axial feed of the roller and speed of the mandrel are the most important process parameters influencing the surface roughness of flow formed tube. A finish of 1.20 µm is produced by flow forming process when the process parameters were set at their optimum values.

Keywords: Flow-forming, AA6082 alloy, Taguchi method, Surface finish

INTRODUCTION

Flow-forming is an eco-friendly, chip less metal forming process which employs an incremental rotary point deformation technique. In flow-forming, the pre-form is elongated on a rotating mandrel without changing the internal diameter, which reduces the wall thickness of a tube. Flow-forming employed in the production of cylinders, flanged components, axi-symmetric sheet metal parts, seamless tubes for high strength aerospace and missile applications, etc. Flow-forming is the capable technology for forming thin walled seamless tubes. AA6082 tubes are used in the field of defense, aero space and missile applications.

However, very little work has been done on the flow-forming of AA6082 tubes. The surface finish is one of the important characteristic of flow formed tube for defense applications.

Taguchi approach is a standardized version of Design of Experiments (DOE) proposed by Dr.

[1] Principal, Govt. Polytechnic College, Madhira, Khammam Dist., TS, India.
[2] Dean, Academics, Sreenidhi Institute of Science and Technology, Yamnampet, Medchal Dist, Hyderabad, TS, India.

Genechi Taguchi of Japan. Taguchi technique reduces cost of experimentation. It gives meaningful conclusions with minimum experimental runs. The aim of the present investigation is to study the effect of important process parameters such as roller feed, mandrel speed and thickness reduction on the surface finish of AA6082 flow formed tubes and to select the optimal combination of these parameters to produce good surface finish using Taguchi's approach.

Rajan and Narsimhan studied the development of defects in flow forming of thin walled steel tubes and suggested some methods to reduce the defects during flow forming. The researchers (Alauddin *et al.*, 1997; Ko *et al.*, 1998; Dhavlikar *et al.*, 2003; Vijian and Arunachalam, 2006; and Omer Savas and Ramazan Kayikci, 2007) employed the Taguchi technique to optimize the process parameters for various processes. The literature (Joseph Davidson *et al.*, 2008a and 2008b; and Srinivasulu *et al.*, 2009a and 2009b) reveals that Taguchi Technique can be applied successfully to predict the process parameters of flow forming process for different materials. The present investigation in carried out to optimize the process parameters during the flow forming of AA6082 pre-forms to obtain good surface finish.

EXPERIMENTAL WORK

The present investigation is carried out on a single roller CNC flow-forming machine. The mandrel rotates at a speed, S rpm. The roller travels parallel to the axis of the mandrel with a feed rate, F mm/min and decreases the wall thickness of pre-form when a thickness reduction t (%) is given by radial feed. The thickness reduction is effected by maintaining gap between the mandrel and the roller less than the thickness of pre-form. The axial and radial feeds are maintained by hydraulic power pack through servo motors. The pre-form is reduced to a final wall thickness by elongating it without change in the inside diameter of the tube. Due to volume constancy, this reduction in thickness of the pre-form leads to an increase in length of the tube. It is desired to produce seamless tubes with good surface finish.

Material

The material used for the present investigation is AA6082 alloy. The major alloying elements are Al-1.2Mg-1.0Mn-01.3Si-0.50Fe-0.25Cr-0.1Cu. AA6082 has medium strength alloy with excellent corrosion resistance. Addition of Manganese controls the grain structure, which results in superior strength. The alloy age hardens by formation of Mg_2Si precipitates.

Pre-form Design

The pre-form was designed based on two factors namely maximum possible deformation and constant volume principle. These pre-forms were manufactured by hot forging. Generally 15% allowance is provided on the diameter for machining and other allowances including extra material required for test specimens. The pre-form was then annealed at a temperature of 510-540 °C for two hours and quenched in water. The flow-forming mandrel is made of tool steel. A slight taper is given in the mandrel for easy ejection of the product. The machined pre-form is shown in Figure 1.

Figure 1: Machined Pre-Form

PLAN OF EXPERIMENTS

Taguchi method, a powerful design of experiments tool is used in the present investigation. This method provides a simple, efficient and systematic approach to determine optimal machining parameters. Conventional experimental design methods are too complex and expensive, as large numbers of experiments have to be carried out to study the process. Taguchi method uses an orthogonal array to study the entire process with only fewer experimental runs. Moreover, traditional experimentation involves one-factor-at-a-time experiments, wherein one variable is changed while the rest are held constant. It is also not possible to study all the factors involved in the process and to determine their main effects (i.e., the individual effects) in a single experiment. Taguchi technique overcomes all these drawbacks. Taguchi method is used for optimizing process parameters and identifying the optimal combination of factors for the desired responses. The steps involved are:

1. Identification of process parameters and their levels.
2. Identification of response function and its quality characteristic.
3. Selection of the appropriate orthogonal array.
4. Performing the experiments as per the conditions specified in orthogonal array.
5. Analysis of results through ANOVA and selection of the optimum level of process parameters.
6. Confirmation test to verify the optimal process parameters.

The input parameters chosen for the experiments are: (a) Axial Feed, F (mm/min) (b) Speed of the mandrel, S (rpm) and (c) Thickness reduction (%) while the response function selected is the surface roughness R_a (µm) of flow formed tube. The input parameters and their levels are given in Table 1.

Table 1: Parameters and Their Levels

Symbol	Parameters	Level 1	Level 2	Level 3
F	Axial feed, mm/min	50	75	100
S	Mandrel speed, rpm	150	200	250
t	Thickness reduction, %	25	50	75

Selection of Orthogonal Array

The flow forming process involves material non-linearity, which can be effectively studied by 3-level or 4-level variables. However by considering the cost factors, L9 (3^3) orthogonal array, with three columns and nine rows, which can handle 3-level factors is selected to study the optimize the flow forming process.

The L9 OA requires only nine experiments to formulate the entire process whereas in classical method, full factorial requires, $3^3 = 27$ experiments. The experimental layout using L9 OA is shown in Table 2. The coded values of 1, 2 and 3 represent level 1, level 2 and level 3 of parameters respectively.

Statistical analysis of variance (ANOVA) is performed to find out the signification of the process parameters on the flow forming process which produce tubes with smaller ovality. Optimal combination of process parameters is predicted by ANOVA.

ANALYSIS OF EXPERIMENTS

In the present investigation only single run is performed for each of nine experiments by

Table 2: Experimental Layout Using L9 Array

Experiment Number	Parameter Level			Experimental Result for R_a
	F	S	t	
1	1	1	1	3.5
2	1	2	2	2.8
3	1	3	3	2.5
4	2	1	2	4.6
5	2	2	3	5.6
6	2	3	1	3.7
7	3	1	3	8.3
8	3	2	1	7.6
9	3	3	2	4.5

considering the cost and time factor. The Taguchi analysis is performed based on the average of valued methodology. The experimental results are analyzed by considering the main effects and their differences between the level 1, level 2, and level 2 and level 3 of the factors.

The factor main effects and their differences are analyzed by calculating the mean value of observations of the experiment. The overall mean value of ovality is calculated from the following equation.

$$\text{Mean } (R_a) = [\Sigma_{i=1\text{-}9}(R_a)]/9 = 4.78 \qquad ...(1)$$

The main effect of a parameter level, for example, feed, F at low level 1 (i.e., F = 50 mm/min), on R_a is given by Equation (2).

$$\text{Mean } [(R_a)]_{F = 50 \text{ mm/min}} = (R_{a1} + R_{a2} + R_{a3})/3 = 2.93 \qquad ...(2)$$

The main effects and their differences for the surface roughness are given in Table 3.

The change of Roller feed from 25 to 50 mm/min and from 50 to 75 mm/min increases the main effect from an average value of 2.93 to 4.63

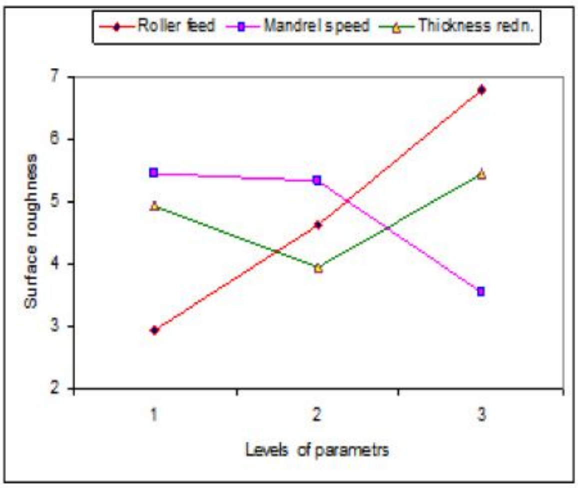
Table 3: Main Effects and Their Difference on the Percentage Elongation

Factors	Level 1 (L_1)	Level 2 (L_2)	Level 3 (L_3)	Difference Between Levels		
				L_2-L_1	L_3-L_1	L_3-L_2
F, mm/min	2.93	4.63	6.79	1.7	3.86	2.16
S, rpm	5.46	5.33	3.56	-1.34	-1.9	-1.77
t, %	4.93	3.96	5.46	-0.96	0.53	1.5

and 4.63 to 6.79. The raise of main effect is maximum when the feed changes from level 2 to level 3.As the feed increases the height of micro irregularity increases and produces higher surface roughness.

The change of mandrel speed from 150 to 200 rpm decreases the average value of response function 5.46 to 5.33, and also the increase in speed from 200 to 250 rpm further reduces the main effects from 5.33 to 3.56. At the lower mandrel speed, the sticking of roller to the surface of tube results in higher surface roughness, i.e., poor finish. The increase in the speed of mandrel unifies surface defects and produces good surface finish.

Figure 2: Main Effects of Process Parameters on Surface Roughness



The change of thickness reduction from 25 to 50% results the decrease in the main effects from 4.93 to 3.96. However the change of thickness reduction from 50 to 75% increases the main effects from 3.96 to 5.46.

A low thickness reduction ratio results is non uniform deformation of pre form and produces tubes with higher roughness. The thickness reduction reaches to uniform plastic zone (Level 2), the process produces tubes with minimum surface roughness. When the thickness reduction reaches to level 3, which is beyond the uniform plastic zone, again a lead to non-uniform plastic deformation and results in higher surface roughness.

Figure 2, shows the main effects and their differences between the levels of parameters on the surface roughness. The relative slope of linear graph indicates the significance parameters. In the present investigation, it is clear that, the slope of line indicating the roller feed is more as compared to slopes of other parameters. From the main effects and graphs of factor parameters, it is evident that the roller feed is having significant influence on the surface roughness of flow formed tube, followed by mandrel speed and thickness reduction.

The results of ANOVA performed for the response parameter are shown in Table 4. For a process parameter to be significant, the calculated F-ratio should be more than the F-ratio from tables. The F-ratio from the tables, F (2, 2) is 18. ANOVA table indicates that the roller feed is the most significant process parameter influencing the surface roughness of flow formed total followed by mandrel speed. Thickness reduction is least significant parameter. This also confirms in the graph shown in Figure 3.

The contour plot of roller feed and mandrel speed on surface roughness is shown in Figure

Figure 3: Flow Formed Tube

Figure 4: Contour Plot of Roller Feed and Mandrel Speed on Surface Roughness

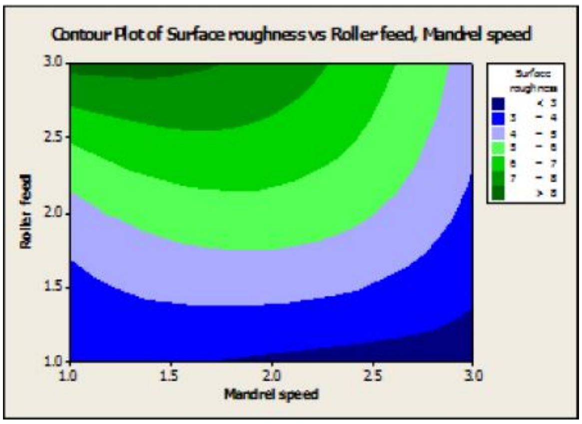


Table 4: ANOVA

Factor	Symbol	D.O.F	Sum of Squares, S	Variance, V	F-Ratio, F	Pure Sum, S	Percent, (%)
Feed	F, mm	2	22.54	11.27	76.25	22.23	67.3
Speed	S, rpm	2	6.75	3.37	22.83	6.45	19.53
Thick. Redn	t, mm	2	3.46	1.73	11.73	3.17	9.61
Others/Error		2	0.29	0.14			3.56
Total		8	33.04				100

4. The lower surface roughness can produced when lower feed is combined with higher speed of mandrel.

The contour plot of roller feed and mandrel speed on surface roughness is shown in Figure 5. Lower value of feed is required to produce the tubes with lower surface roughness.

The contour plot of mandrel and thickness reduction on surface roughness is shown in Figure 6. The lower surface roughness can obtained when the mandrel speed and thickness reduction are set at their mid-level (i.e., Level-2).

Figure 5: Contour Plot of Roller Feed and Thickness Reduction on Surface Roughness

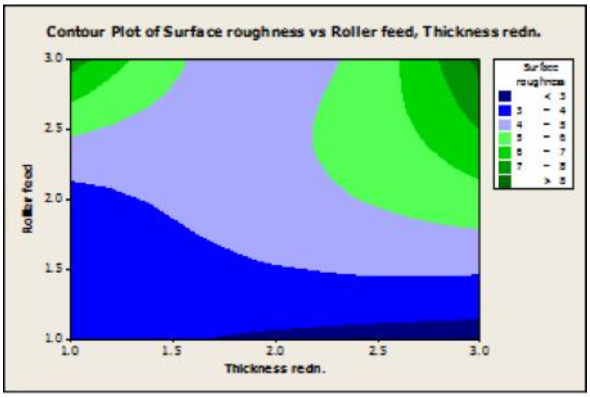


Figure 6: Contour Plot of Mandrel Speed and Thickness Reduction on Surface Roughness

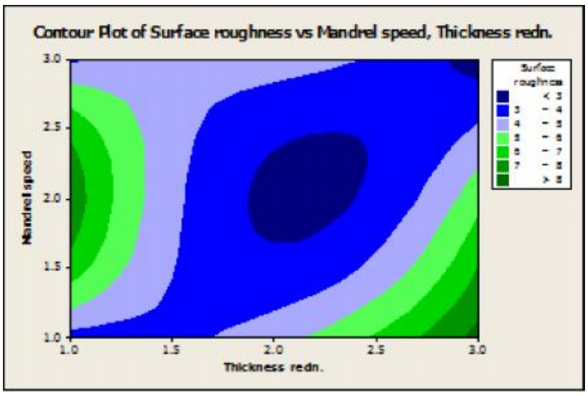
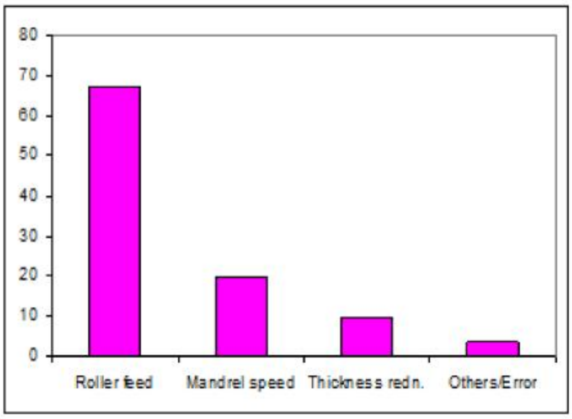


Table 5: Optimum Conditions and Performance for Minimum Surface Roughness

Factors	Level Description	Level	Contribution
F, mm/min	50	1	-1.85
S, rpm	250	3	-1.22
t,%	50	2	-0.82

Figure 7: Influences of Parameters on Surface Roughness



CONFIRMATION TEST

In Taguchi method a confirmation test is required to verify the optimum conditions and to compare the results with expected conditions. The optimum condition for smaller surface roughness is shown in Table 5. It reveals that the roller feed should be at level 1, the thickness reduction should be at level 2 and the mandrel speed should be at level 3 for production of flow formed tube with good surface finish, i.e., with smaller surface roughness. The model predicts an optimum value of 0.90 µm for surface roughness. A confirmation test is conducted by setting the parameters at their optimum values and response parameter obtained is 1.20 µm, which is with in the range of predicted value.

CONCLUSION

In the present investigation, the effects of process parameters on the surface roughness of AA6082 flow formed tube have been studied using Taguchi method. The influences of parameters on the surface surface roughness are shown in Figure 7. It is concluded that the parameters that have relative significant influence on surface roughness are roller feed (67.30%), mandrel speed (19.53%), and thickness reduction (9.61%) respectively. The optimum conditions for smaller surface roughness are roller feed at 50 mm/min, mandrel speed at 250 rpm and thickness reduction at 50%. It has been proved that the improvement of response function is significant, when the process parameters set at their optimal values.

ACKNOWLEDGMENT

The authors wish to express their thanks to Late Sri R K Gelli, Managing Director and Sri Koushik Gelli, Director M/s Spinmet Engineers Pvt. Ltd., Secunrdabad, India, for providing all the facilities to carry out the experiments for their support and assistance in performing this work.

REFERENCES

1. Alauddin M, Baradie M A El and Hashmi M S J (1997), "Prediction of Tool Life in End Milling by Response Surface Methodology", *Journal of Materials Processing Technology,* Vol. 71, No. 3, pp. 456-465.

2. Dhavlikar M N, Kulkarni M S and Mariappan V (2003), "Combined Taguchi and Dual Response Method for Optimization of a Centerless Grinding Operation", *Journal of Materials Processing Technology,* Vol. 132, Nos. 1-3, pp. 90-104.

3. Joseph Davidson M, Balasubramanian K and Tagore G R N (2008b), "Surface Roughness Prediction of Flow-Formed AA6061 Alloy by Design of Experiments", *Journal of Materials Processing Technology,* Vol. 202, pp. 41-46.

4. Joseph Davidson M, Balasubramnian K and Tagore G R N (2008a), "Experimental Investigation on Flow Forming of AA 6061 Alloy—A Taguchi Approach", *Journal of Material Processing and Technology*, Vol. 200, pp. 283-287.

5. Ko D C, Kim D H, Kim B M and Choi J C (1998), "Methodology of Perform Design Considering Workability in Metal Forming by the Artificial Neural Network and Taguchi Method", *Journal of Material Processing and Technology*, Vols. 80-81, pp. 487-492.

6. Omer Savas and Ramazan Kayikci (2007), "Application of Taguchi's Methods to Investigate Some Factors Affecting Micro Porosity Formation in A360 Aluminum Alloy Casting", *Material and Design*, Vol. 28, pp. 2224-2228.

7. Rajan K M and Narsimhan K, "An Investigation of the Development of Defects During Flow Forming of High Strength Thin Wall Steel Tubes", *Journal of Material Processing and Technology-ASMJ. Pract. Failure Anal.*, Vol. 1, No. 5, pp. 69-76.

8. Ross P J (1989), *Taguchi Techniques for Quality Engineering,* McGraw-Hill, New York.

9. Srinivasulu M, Krishna Prasada Rao C S, Appa Rao S and Komaraiah M (2009a), "Optimisation of Process Parameters for Flow Forming of SAE 4130 Steel—A Taguchi Method", *Journal of Aerospace Quality and Reliability*, Vol. 3, No. 2, Vol. 4, Nos. 1 & 2, Vol. 5, No. 1, pp. 30-36.

10. Srinivasulu M, Krishna Prasada Rao C S, Appa Rao S and Komaraiah M (2009b), "Experimental Studies on Flow Forming of SAE 4130 Steel—A Taguchi Appoach", Proceedings of National Conference on Aerospace Engineering, NCAE-09, December, pp. 155-158.

11. Vijian P and Arunachalam V P (2006), "Optimization of Squeeze Cast Parameters of LM6 Aluminum Alloy for Surface Roughness Using Taguchi Method", *Journal of Material Processing and Technology*, Vol. 180, pp. 161-166.

International Journal of Engineering Research and Science & Technology
Hyderabad, INDIA. Ph: +91-09441351700, 09059645577
E-mail: editorijlerst@gmail.com or editor@ijerst.com
Website: www.ijerst.com

ISSN 2319-5991