OPTIMIZATION OF PARAMETERS AFFECTING SURFACE ROUGHNESS AND HOLE DIAMETER IN BORING PROCESS

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Abstract

Boring operation is performed on bucket Oriels of earth moving equipment. As in other machining operations, boring process is also influenced by multiple parameters like feed rate, depth of cut, type tool & coolant, speed of cutter, etc. The objective of the present work is to improve the quality of the surface finish (Ra) and the accuracy of bore diameter. The parameters considered for optimization of the boring process are speed and feed rate of the cutting tool, while the depth of cut maintained at a constant value of 1 mm. After the completion of the boring process, each individual Oriel is checked for surface roughness (Ra) and dimensional conformance. Experiments are carried out on 18 different samples (using full factorial). The response data in the form surface finish and diameter of the bore are obtained for each sample.

The Analysis of Variance (ANOVA) is carried out to find the significant factors and their individual contribution on the response functions. The most optimal values for the given boring conditions of speed (1000 rpm), feed rate (100 mm/min) and depth of cut 1 mm expected to give a hole Dia 70.005 mm and surface roughness Ra 1.843 µm. The optimal values are further confirmed by carrying out nine confirmatory tests by three different operators. The results for all the three cases are closely following the optimal solution obtained by DOE process, indicating that the solution adopted is good for the given environment of boring operation.

Key words: *Earth moving equipment, Oriels, bore diameter, surface roughness, DOE, optimization, main and interaction effects, and Response surface & contour plots*

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1. INTRODUCTION

Manufacturing industries are continuously demanding for higher production rate and improved machinability as quality and productivity play a significant role in the manufacturing environment. Higher production rate can be achieved at high cutting speed, feed and depth of cut. The quality of the final product is limited by capability of machine, tooling and requirements on the surface finish. Overall performance of the operation depends on the selection of right cutting parameters and is generally a compromise between several variables. Similarly, a boring process is also influenced by multiple parameters like feed rate, depth of cut, tool used, type of coolant, speed of cutter, etc.

Design of Experiments (DOE) is a powerful technique used for exploring new processes, gaining increased knowledge of the existing processes and optimizing the process parameters for achieving good performance. In the present work an attempt is made to utilize DOE to improve the boring quality and process efficiency. Analysis of Variance (ANOVA), Response surface and contour plots are developed and response optimization is carried out to find the significant factors and their contribution on the output parameters. The most optimal values for the given boring are estimated with speed being 1000 rpm, feed rate being 100 mm/min and depth of cut 1 mm. This condition yielded a bore Dia 70.005 mm and surface roughness Ra 1.843 µm. The optimal values are further confirmed by carrying out nine confirmatory tests. The results are closely following the optimal solution obtained by DOE process, indicating that the solution adopted is good.

2. PREVIOUS WORK

In many manufacturing organizations experiments are performed to increase the understanding and knowledge of various manufacturing processes. For continuous improvement in product/process quality, it is fundamental to understand the process behaviour, the amount of variability and its impact on product / processes. The present work being optimization of boring parameters, the literature related to this subject area is briefly covered

The study of cutting forces of boring process is important for selecting appropriate proper cutting conditions. A predictive cutting force model has been developed and influence of cutting parameters on force components has been studied by Alwarsamy et al., 2011. In their work a new analytical cutting force model obtain from the information related to the work piece and tool signature for a boring operation.

The optimization work done by Gaurav Vohra et al 2013, of the boring parameters for a CNC turning centre such as speed, feed rate and depth of cut on aluminium to achieve the highest possible Material removal rate and at minimum surface roughness by using the Taguchi method. In their work it was found that the depths of cut and cutting speed to be the most influencing parameter, followed by the feed rate.

Kanase Sandip et al 2013 proposed an innovative method to reduce tool chatter and enhance surface finish in boring operation. Their results showed the use of passive damping technique has vast potential in the reduction of tool chatter.

The optimum conditions to obtain better damping in boring process for chatter reduction is identified for various cutting conditions by Prasanna venkadesan et al, 2015.

Yang and Tarng 1998 investigated cutting characteristics of steel bars using tungsten carbide cutting tools using Orthogonal array, the signal to noise Ratios and the analysis various (ANOVA).

Davim et.al 2001 studied the optimum conditions for the surface finish obtained in turning using design of experiment. He established a correlation between cutting velocity feed and depth of cut with roughness.

Lee and Tarng 2001 used computer vision techniques to inspect surface roughness of a work piece under a variation of turning operations and developed a relationship between the feature of the surface image and the actual surface roughness under a variation of turning operations for predicting surface roughness with reasonable accuracy.

Davim 2003 studied the influence of cutting condition and cutting time on turning metal matrix composites and used Taguchi method and (ANOVA) for the analyses. They obtained a correlation between cutting velocity, feed and cutting time with tools wear, the power required and the surface roughness of the job.

Balamuruga and Sugumaran 2013 developed a Gaussian process regression model to predict the surface roughness based on tool post vibration and cutting conditions. In their work the data obtained from their experiments and collected from previous studies, have been used to validate the model. This model is used to test relative biases, has ability to extrapolate.

Badadhe et. al., 2012, optimized combination of cutting parameters to achieve the minimum value of surface roughness. In their work, the experimentation was carried out with the help of lathe machine, with three machining parameters such as spindle speed, feed and depth of cut taken as control factors. During the machining, the boring bar is subjected vibrations in different directions; the impact of these vibrations on the surface roughness which is an important quality parameter of the bored surface was estimated.

Table 1 Full factorial and response data from boring experimentation

SPEED (RPM)	DEPTH OF CUT mm	FEED RATE mm/min	HOLE DIAMETER mm	SURFACE FINISH (RA) µ m
800	1	40	70.025	2.320
900	1	40	70.010	2.306
1200	**1**	**40**	**70.015**	**1.618**
800	**1**	**80**	**70.000**	**1.968**
900	1	80	69.999	1.954
1200	1	80	70.025	1.709
800	1	120	70.015	2.766
900	1	120	70.020	2.306
1200	1	120	70.020	1.742
800	1	160	70.015	2.616
900	1	160	70.020	2.566
1200	1	160	69.980	2.320
800	1	200	70.010	2.814
900	1	200	69.985	2.667
1200	1	200	69.980	2.592
800	1	240	70.012	4.902
900	1	240	70.006	3.306
1200	1	240	70.025	2.742

3. METHODOLOGY

The entire process of experimentation is done in L&T construction equipment Ltd, Bangalore. The following pictures help to provide a better understanding of the process adopted to arrive at the optimal parameters for the boring operation on the bucket oriels. Figure 1 shows a typical manufacturing sequence for the earth moving equipment. In the current boring operation two input factors expected to influence the response a) Rate of feed , mm/min and b) Speed of cut, rpm and the 3rd variable, depth of cut which is assumed to be maintained at a constant value of 1 mm. It is expected that the present DOE to obtain a set of optimal feed and speed which might result in maintaining bore diameter at 70 mm and surface roughness, Ra within 2 µm. MINITAB SOFTWARE (Ver 16) is used to analysis the data. ANOVA, Surface and Contour plots were obtained which represented the effects of speed and feed on surface roughness and diameter of the bore. Interaction plots were also obtained which represented the behaviour of changing surface roughness and diameter values at various feed and speed for comparison. Using the data the optimization plots were generated which indicate the best values to be used for the boring operation.

4. ANALYSIS OF BORING PARAMETERS USING DOE

The Table 1 represents the different combinations of feed and speed values as generated by Minitab. A total of 18 different experiments are carried out. For each experiment six different levels of feed and three levels of speed combinations are used. At the end of each experiment the resulting surface roughness Ra and bore diameter were measured using surface tester and bore gauge respectively. Table.1 represents all the data for bore diameter and surface roughness Ra obtained with respect to different speed and feed rate for the given depth of cut of 1 mm. Figure 2. gives the DOE analysis process adopted to arrive at the optimal values for the boring operation. The steps involved in statistical analysis are given below

- Statistical analysis -> DOE -> Factorials – used to generate a table of influencing factors
- Statistical analysis -> ANOVA -> Balanced ANOVA ->Main Effect plot and Interaction Effect Plot are derived
- Statistical analysis -> DOE -> Response Surface and Contour plots are developed

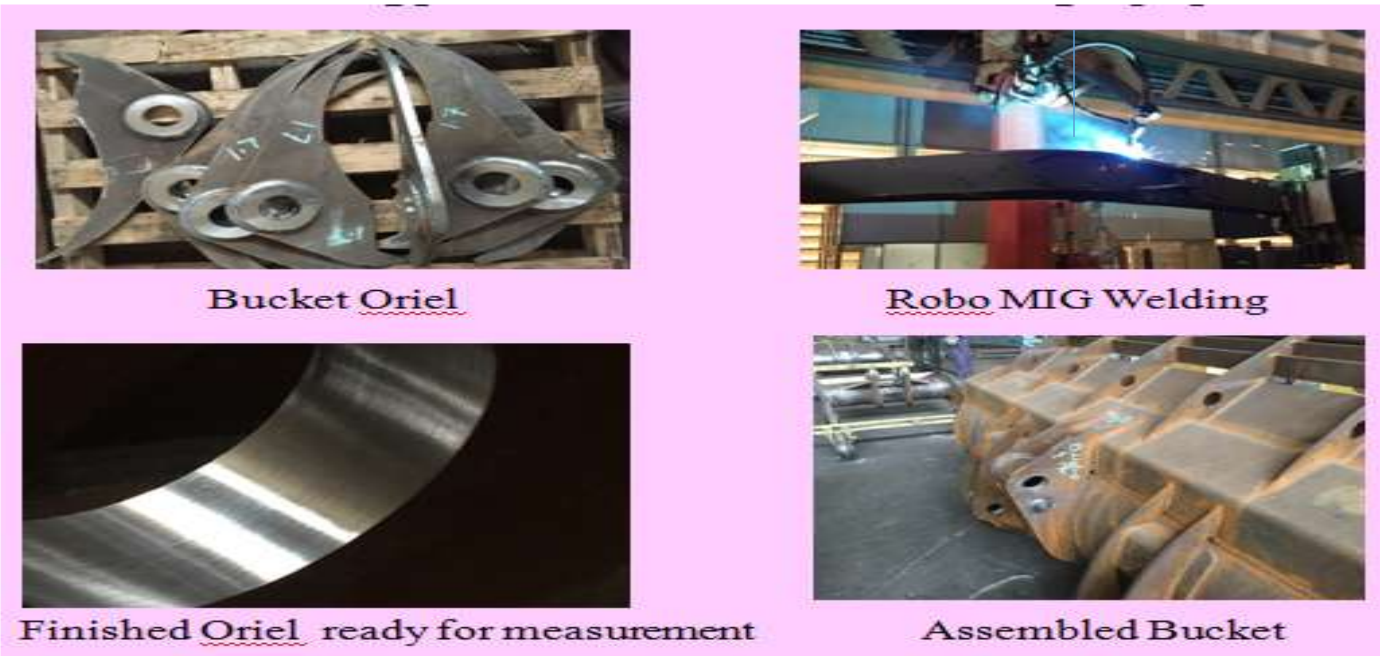

Figure 1. Manufacturing Process **Figure 2:** DOE Process

Table 2 Confirmatory test data

Operator	sample No	depth in mm	feed in mm/min	Speed in RPM	diameter in mm	Ra in µm	Mean Dia in mm	Mean Ra in µm	Std Deviation in Dia mm	Std Deviation in Ra µm
A	1.1	1	100	1000	70.013	1.616				
	1.2	1	100	1000	69.985	1.999	70.0046	1.7107	0.0171	0.2545
	1.3	1	100	1000	70.016	1.517				
B	2.1	1	100	1000	70.018	1.742				
	2.2	1	100	1000	70.021	1.614	70.013	1.7226	0.01135	0.10004
	2.3	1	100	1000	70	1.812				
C	3.1	1	100	1000	69.994	1.954				
	3.2	1	100	1000	70.024	1.886	70.022	1.8496	0.02705	0.1264
	3.3	1	100	1000	70.048	1.709				

Statistical analysis -> DOE -> Selection of optimal design > Response optimization

•Model validation-> Use optimal factors, confirmatory tests of boring operation are performed and measured the respective bore diameter and surface roughness.3.2 Results and discussions

It can be observed from table 1. That, the most optimum value in diameter readings i.e. 70 mm and the most optimum value in surface finish is 1.618 µm and they are highlighted. The data is processed using DOE software Minitab Ver 16 through various moduli such as ANOVA for main and interaction effects, DOE for regression analysis and get a set of surface and contour plots and finally the data run through Doe optimization procedure to arrive at the optimal values of speed and feed which might results a diameter of bore 70 mm and surface roughness Ra < 2 µm. All these sequences are depicted in Fig.2.The final optimized speed and feedare 1000 rpm and 100 mm/min respectively.

5. VERIFICATION AND VALIDATION

The optimal values are further confirmed by carrying out nine confirmatory tests. The results for all the cases are closely following the optimal solution obtained by DOE process as shown in Table 2, indicating that the solution adopted is good for the given environment of boring operation

CONCLUSIONS

In the present work, a combination of cutting parameters which will result in better surface finish and diameter of bore to be estimated using DOE. Three parameters viz. spindle speed, and feed are selected as key parameters while depth of cut is maintained at a constant value. Three variations of speed and six variations in feed rate are selected for the experimentation. All the experiments are conducted at L& T plant on the MX-5 machine. The experiments are performed as per full factorial approach to deal owith the response from multi-variables. In DOE process, analysis of variance and surface response are carried out to find the significant factors and their contribution for evaluating the response function i.e. surface roughness (Ra) and diameter of the bore.

The most optimal values for boring operation are estimated to be speed 1000 rpm and feed rate 100 mm/min respectively. This gives rise to a bore Dia of 70.005 mm and Ra of 1.843 µm. Three operators are selected to perform the confirmatory tests, each of these operators performed three boring operation on three different samples and the response data from all the operators are analysed. The range of variation of bore diameter and the surface roughness is estimated to be between 69.9876 and 70.0490 mm for Dia and 1.456 to 2.0231 µm for Ra, respectively. These numbers indicate that the optimal solution adopted is good for the given environment of boring operation.

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