Experimental Investigation of External Burnishing Process Parameters Surface on Cylindrical Work Piece Using Taguchi Approach

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ABSTRACT

The technological revolution in metal cutting is increased in the expectation from the manufacturing industry. The service life of the components has been expected very long, without increasing the operation cost. Challenges in front of engineers have to come up with improved and all over accepted manufacturing processes that address expectations of industries. The life of the parts depends upon the surface properties. So, the significant attention has to pay for finishing operations. The experimental study was conducted to determine the effects of a single roller burnishing process on the surface roughness of aluminum alloy [Al 6061]. Combine effect of four machining parameters namely speed, feed, depth of penetration& number of passes on the output surface roughness are explored by analysis of variance [ANOVA].Optimal machining condition for each performance level is established. The relation between the results shows that the surface roughness is mainly influenced by Number of Passes. The minimum surface roughness obtained is 0.28 µm. Using Minitab software the regression analysis is done.

Keyword: Burnishing, AL 6061, ANOVA, Machining Conditions, Regression Analysis.

I. INTRODUCTION

Machined surfaces by the conventional and non-conventional process such as turning, milling, EDM, Abrasive Machining have irregularities on surfaces and defects like tool marks and scratches that cause energy dissipation (friction) and surface damage (wear). To overcome these defects, surface finishing processes such as grinding, honing and lapping are used. But these methods essentially depend on chip removal to attain the desired surface finish and also the skill of the workers. To resolve these problems, burnishing process is applied for the better surface finish on the post machined components due to its chip less and simple operation. Roller burnishing can help users eliminate secondary operations for substantial time and cost savings, while at the same time improving the quality of a product. Burnishing is a method of producing an accurately sized, finely finished and densely compacted surface. Hardened and highly polished steel rollers are brought into pressure contact with the workpiece. As the pressure exceeds the yield point of the workpiece material, the surface is plastically deformed by cold-flowing of subsurface material.

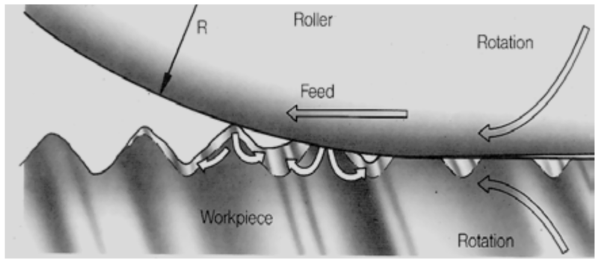

Fig.1: Principle of burnishing:

The principle of the burnishing process [1], shown in Fig. 1, is based on the rolling movement of a tool against the workpiece surface, a normal force is applied to the tool. As soon as the yield point of the workpiece material is exceeded, the plastic flow of the original asperities takes place. This phenomenon leads to a smoother surface. At the same time, compressive stresses are induced in the surface layer, followed by strain hardening and a series of the beneficial effect on mechanical properties. Burnishing can improve both the surface hardness and roughness. Burnishing is a finishing operation improves the surface finish without the use of extra toolings. A conventional lathe can be used for burnishing operation. The tool used for burnishing operation consists of one or more ball or roller, hold in a casing. This tool mounted on the tool post of the lathe for operation. When the burnishing tool comes in contact with the rotating workpiece, the friction force rotates roller of the tool.

Burnishing operations are now widely applied in non-automotive applications such as valves, pistons for hydraulic or pneumatic cylinders, shafts for pumps, shafts running in bushings, bearing bores, and plumbing fixtures.

1. To produce better and longer-lasting seal surfaces;
2. To improve wear life;
3. To reduce friction and noise levels in running parts;
4. To enhance cosmetic appearance.

II. LITERATURE SURVEY

A study of trends and past results in a research area is very important to study the problems and their suitable solutions. The ability of the burnishing process in improving of surface roughness and other surface properties attracted great research fellows. Here, the earlier research carried out by the researchers on the study of the burnishing process and its results are discussed.
M. Kaladhar, K. V. Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao [2] studied multi-characteristics response optimization model based on Taguchi and Utility concept is used to optimize process parameters, such as speed, feed, depth of cut, and nose radius on multiple performance characteristics, namely, surface roughness (Ra) and material removal rate(MRR.)Further, The ANOVA and F-tests are used to analyze the results. Also, the confirmation tests are conducted and the results are found to be within the confidence interval Adel Mahmood Hassan and Ayman Mohammad Maqableh [3] studied the effects of burnishing parameters on non-ferrous materials. They used Carbon chromium as ball material and non-ferrous workpiece materials. They concluded that an increase in initial surface roughness will cause an increase in the final surface roughness of the ball

burnished workpieces, but it has no effect on the surface hardness of these metallic workpieces. An increase in the initial surface hardness will cause a decrease in the reduction of surface roughness, and in the total amount of the increase in surface hardness. M.H.El-Axir[4] published his work on an investigation of roller burnishing by using Response Surface Method and taking Steel-37 as a workpiece. It was shown that the spindle speed, burnishing force, burnishing feed and number of passes have the most significant effect on both surface microhardness and surface roughness, tend to have many interactions and recommended spindle speeds that resulted in high surface microhardness and good surface finish are in the range from 150 to 230 rpm. M.M.El-Khabeery, M.H. El-Axir, [5] worked upon the experimental techniques for studying the effects of milling roller-burnishing parameters on the surface integrity. They have used 6061-T6 Aluminium alloy workpiece to investigate the effect of roller-burnishing upon surface roughness, surface, and residual stresses. They have used response surface method to investigate the effect of the burnishing process parameters. They concluded that the mathematical models for burnishing responses (mean roughness, burnished surface microhardness, and maximum residual stress) are identified by GMDH considering burnishing speed, depth of penetration and number of passes. The literature study shows that the increasing both the number of passes and the burnishing depth of penetration causes the changes in mean roughness, surface, and maximum residual stress. An experimental analysis was undertaken by Nemat and Lycons [6] on ball burnished mild steel and aluminum using a purpose-built burnishing tool. The analysis was designed to assess the effects of burnishing feed, force, and speed and the number of tool passes on the surface roughness and surface hardness of mild steel and an aluminum workpiece. In some cases, experiments showed that improvements of as much as 70% in surface quality were obtained when varying the mix of parameters.M.H. El-Axira [7] has studied the inner surface finishing of aluminum alloy 2014 by ball burnishing process. He reviled that from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14μm. As a result of this study, it was concluded that an increase in internal ball burnishing speed leads to a slight decrease in surface average roughness. He has concluded that an increase in internal burnishing feed leads to a decrease in surface average roughness, reaching a minimum value at burnishing feed of (0.15-0.25mm/rev). The best results obtained at both a high number of passes with low burnishing speed and high number of passes with low burnishing feed. N.S.M.El-Tayeb, [8] investigated the influence of roller burnishing contact width and burnishing orientation on surface quality and tribological behavior of Aluminium 6061. Here optimum ranges of burnishing speed and force were identified to be 250-420 rpm for 1mm roller contact width. Krishankant, JatinTaneja, [9] used Taguchi method with mini tab application for investigating machining parameters. S. Thamizhmanii et.al.[10] worked on multi-roller burnishing on non-ferrous metals where the burnishing process was carried on lathe and vertical/ horizontal milling machines with suitable fixtures to hold the workpiece with various spindle rotations, feed rate and depth of penetration and the authors identified that the surface roughness on various non-ferrous metals improved by high spindle rotations with high feed rate and depth of penetration and also observed that

2.1 Observations from the literature survey

From the Literature survey, it was observed that the

a) Burnishing process used to reduce production cost
b) Burnishing process is used to enhance surface finish and surface hardness.

c) Burnishing is capable of generating the high degree of surface roughness value ranging from 0.2 μm to 0.8 μm.

III.EXPERIMENTATION

Experimentation, basically, involved not only the burnishing process but selecting tool and testing the roughness value. Material used for the process was aluminum rod (Al 6061) (Ø 30 mm).

3.1 Burnishing Tool

Burnishing tool available following materials can be considered.

1. High Carbon High Chromium (HCHCr) steel   2. Tool steel.

Fig. 2.Single Roller External Burnishing Tool

Due to their hardness, toughness and wear resistance. In this research work, the tool steel [D3] is used.The tool is bought from Master Tools, Thane. Fig. 2 below shows the actual pictorial view of the tool. There are two main components of the tool.

3.2 Setup of Burnishing Process.

Fig.3. Burnishing Process

Fig.3 Shows the Experimental setup for the conducting the experiment. Here conventional lathe machine is used for conducting an experiment.

3.3 Roughness Value (Ra) Testing

To test the roughness value (Ra) Mitutoyo Surftest (Model No.211) is used. The instrument has a stylus and rider arrangement. The Fig.4 above shows the actual photograph of the Mitutoyo Surftest used.

IV.DESIGN OF EXPERIMENT (DOE)

Design of experiment is the statistical process where we plan, conduct, analyze and interpret the test parameters. It is a systematic information gathering exercise, where the variation is present. These variables may control the experiment. In this process, we will get the most significant factor in the process. Once the factors and their levels are decided the next step is, according to the number of factors and levels, the orthogonal array is decided. Here we have four factors and three levels, Table.1.

Table 1.Factor Information

Factor	Values
Feed	0.03, 0.04, 0.05
Speed	300, 490, 760
DOP	0.04, 0.06, 0.08
NOP	3, 4, 5

V.RESULTS & DISCUSSION

The orthogonal array selected in this study was L 9, Table 2 below.

Table 2. Orthogonal Arrey L9

Exp. No.	Feed (f)	Speed (V)	Depth of Penetration (DOP)	No. of Passes (NOP)	Surface Roughness (Ra)	S/N Ratio
	mm/rev	m/min	mm	No.	(µm)	
1	0.03	300	0.04	3	0.68	3.35
2	0.03	490	0.06	4	0.62	4.152
3	0.03	760	0.08	5	0.38	8.404
4	0.04	300	0.06	5	0.32	9.897
5	0.04	490	0.08	3	0.66	3.609
6	0.04	760	0.04	4	0.51	5.849
7	0.05	300	0.08	4	0.42	7.535
8	0.05	490	0.04	5	0.28	11.057
9	0.05	760	0.06	3	0.56	5.036

The Experiments are planned according to Taguchi DOE with an L9 orthogonal array. As per Taguchi method, there are total 9 different experiments conducted. Each experiment is performed with the factors in the above mentioned table. After the experimentation, the Roughness value (Ra) is recorded. Using the Minitab 17 statistical software ANOVA is performed and given below Table3. From the ANOVA results, it is clear that NOP (Number of Passes) is the major influencing factor for the surface roughness. Table 4 states the model summery, where the stated model is valid.

Main effects plots are used to examine the differences between level means for all factors. There is a main effect when different levels of a factor affect the response differently. A main effects plot graphs the response mean for each factor level connected by a line. The main effects plot below Fig.5 displays the means for each group within a categorical variable.

Table 3.Analysis of Variance

Factors	DF	Adj SS	Adj MS	F-Value	P-Value
Feed	2	0.02949	0.01474	0.6	0.579
Speed	2	0.003622	0.001811	0.06	0.94
DOP	2	0.000289	0.000144	0	0.995
NOP	2	0.14376	0.071878	12.91	0.007
Error	6	0.14767	0.02461		
Total	8	0.17716			

Table 4. Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.07461	81.15%	74.86%	57.58%

A line connects the points for each variable. Look at the line to determine whether the main effect is present for a categorical variable. Minitab also draws a reference line at the overall mean. Interpret the line that connects the means as follows:

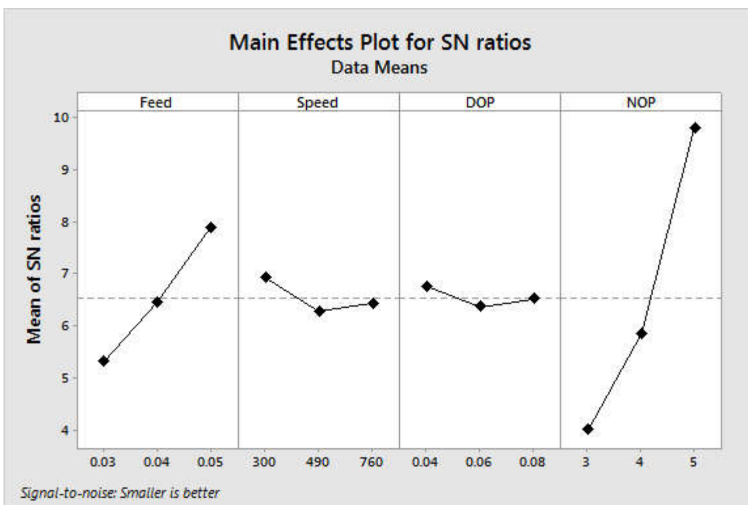

Fig.5 Main Effects Plot

VI.VALIDATION

5.1 Regression Equation

Ra Value=1.385 - 7.00 A+ 0.000011 B - 0.083 C - 0.1533 D

A = mm/rev, B = Speed in rpm, C = Depth of Penetration in mm,D =Number of passes

5.2 Validation Test

The experimental validation test is the final step in which the results are drawn based on Taguchi's design approach. Numbers of validation tests conducted are two and the observations are recorded below in Table 5.

Table. 5 Validation Test Results

Sr.No.	Feed	Speed	DOP	NOP	$(Ra)_{Th}$	$(Ra)_{Ac}$	% Difference
1	0.08	200	0.4	2	0.49	0.56	12.96
2	0.04	725	0.2	3	0.64	0.55	13.59

VII.CONCLUSION

In this experimentation, Master Burnishing Tool with of single roller is used. Using the regression equation further optimization can be possible. Current experiment results have concluded the following.

1. The Master Burnishing Tool can be successfully used to finishing the operation.
2. It has been established that Taguchi analysis is an effective optimization technique.
3. A mathematical model for surface finish, burnishing response is identified by the Taguchi method considering speed, feed, DOP & NOP.
4. The established model is useful in predicting the response which by selecting proper input parameters that were used in this research work before performing the burnishing process.
5. The extent of influence of the selected variable on burnished surface roughness can be deduced quantitatively from the model.
6. The ANOVA has revealed that the NOP is much more pronounced than the effect of burnishing speed /feed/NOP on surface roughness. This fact is confirmed by the AHP method.
7. It has been found that the optimal cutting parameters machining process;

   a. Number of Passes: As NOP increases surface roughness improves, the graph shows a linearity trend.NOP has the major influence on the roughness value.

   b. Feed: Feed also shows the linear behavior which is the second influencing parameter.

   c. Speed: As Speed increases, the small change in surface roughness value and the further increase in speed surface roughness increases again

   d. Depth of Penetration: Speed and DOP shows almost same behavior.

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