Parametric Optimization of Process Parameter for Roller Burnishing Process

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Abstract--Burnishing is a very simple and effective method for improvement in surface finish and can be carried out using lathe machines. In this project work, a roller burnishing tool is used to perform roller burnishing process on Al alloy material under different parameters. Moreover, the burnished surface has a high wear resistance and better fatigue life. It has been used to impart certain physical and mechanical properties, such as corrosion, friction, wear and fatigue resistance. One of the most effective representatives is the roller burnishing. This can simply achieved by pressing a hard and highly polished ball or roller against the surface of metallic work pieces. The impact of burnishing speeds, burnishing force and number of passes of the tool on the surface qualities and tribological properties were investigated to determinate the influence of each process parameter, several tests were carried out. Once the optimum parameters were established, a complete analysis of the surface characteristics was performed. Roller burnishing is an economical process, where skilled operators are not required. Applying Taguchi's design of experiments and analysis of variance (ANOVA) on the specimens, the aim is to find optimized values for enhancing the surface quality and hardness economically. This process can be effectively used in many fields such as Aerospace Industries, Automobiles Manufacturing sector, Production of Machine tools, Hydraulic cylinders, etc.

Keywords: Taguchi method, Surface roughness, Surface hardness

I. INTRODUCTION

Surface treatment is an important aspect of all manufacturing processes. It has been used to impart certain physical and mechanical properties, such as friction, corrosion, wear and fatigue resistance. The function performance of a machined component such as fatigue strength, load bearing capacity, friction, etc. depends to a large extent on the surface as hardness, nature of stress and strain induced on the surface region. During recent years, however, considerable attention has been paid to the post-machining metal finishing operation such as burnishing which improves the surface characteristics by plastic deformation of the surface layers. Roller Burnishing is the plastic deformation of a surface due.

Roller Burnishing is a Super-finishing process. It is a Cold Working process which produces a fine surface finish by the planetary rotation of hardened rollers over a bored or turned metal surface.

Burnishing is a cold rolling process without removal of metal. A set of precision rollers is used to roll on the component surface with adequate pressure. As a result all the Pre-machined peaks get compressed into valleys thus giving a mirror like surface finish. The surface of metal parts worked through turning, reaming or boring operations is a succession of "PROJECTION or PEAKS" and "INDENTATION or VALLEY" when microscopically examined. The roller burnishing operation compresses the "Projection" (Peaks) into the "Indentation" (Valley)

The roller burnishing process comprises of hardened rollers that are guided over the work piece with pressure and displaced the surface peaks into the boundary layer. Roller burnishing is a process for micro finishing metallic surfaces which belongs to the forming processes When roller burnishing, a rolling body, usually a roller is pressed onto the surface and rolled over it. By this means a high compressive stress is created in the surface finish peaks which induce the material to flow. In doing so a forming of the boundary layers in micron range is induced.

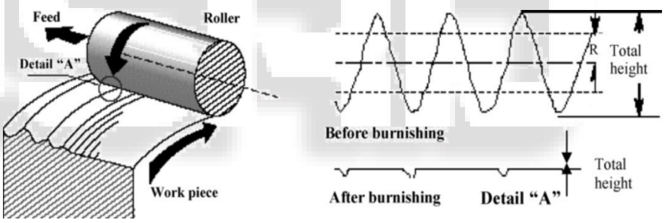

Fig. 1: roller burnishing process.

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II.BASIC PRINCIPLE OF ROLLER BURNISHING PROCESS

Roller burnishing is a process for micro finishing metallic surfaces which belongs to the forming processes When roller burnishing, a rolling body, usually a roller or ROLLER is pressed onto the surface and rolled over it. By this means a high compressive stress is created in the surface finish peaks which induce the material to flow. In doing so a forming of zones with less stresses and in doing so fills the valleys up from below.

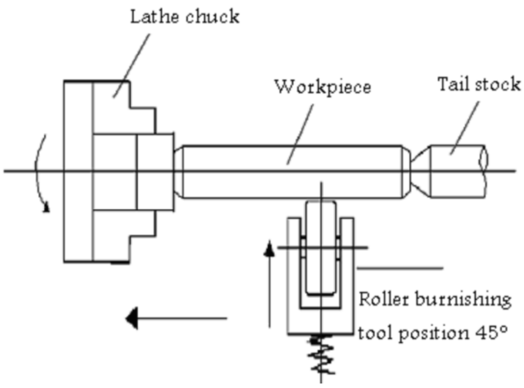

Fig. 2: Layout of work piece on lathe for roller burnishing process

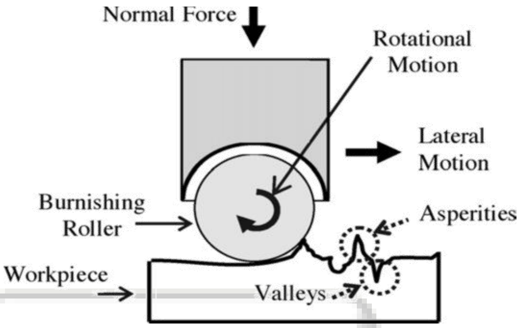

Fig. 3: Schematic Diagram of Basic Principle of Roller Burnishing Process

II. EXPERIMENTAL METHODOLOGY

A. Taguchi design approach

Taguchi's comprehensive system of quality engineering is one of the greatest engineering achievements of the 20th century. His methods focus on the effective application of engineering strategies rather than advanced statistical techniques. It includes both upstream and shop-floor quality engineering. Upstream methods efficiently use small-scale experiments to reduce variability and remain cost-effective, and robust designs for large-scale production and market place. Shop-floor techniques provide cost-based, real time methods for monitoring and maintaining quality in production. The farther upstream a quality method is applied, the greater leverages it produces on the improvement, and the more it reduces the cost and time. Taguchi's philosophy is founded on the following three very simple and fundamental concepts.

1) Quality should be designed into the product and not inspected into it.
2) Quality is best achieved by minimizing the deviations from the target. The product or process should be so designed that it is immune to uncontrollable environmental variables.
3) The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system-wide.

Taguchi proposes an "off-line" strategy for quality improvement as an alternative to an attempt to inspect quality into a product on the production line. He observes that poor quality cannot be improved by the process of inspection, screening and salvaging. No amount of inspection can put quality back into the product. Taguchi recommends a three-stage process: system design, parameter design and tolerance design (Ross, 1988, Roy, 1990). In the present work Taguchi's parameter design approach is used to study the effect of process parameters on the various responses of the roller burnishing process.

B. Experimental Design Strategy

Taguchi recommends orthogonal array (OA) for laying out of experiments. These OA's are generalized Graeco-Latin squares. To design an experiment is to select the most suitable OA and to assign the parameters and interactions of interest to the appropriate columns. The use of linear graphs and triangular tables suggested by Taguchi makes the assignment of parameters simple. The array forces all experimenters to design almost identical experiments.

In the Taguchi method the results of the experiments are analyzed to achieve one or more of the following objectives.

1) To establish the best or the optimum condition for a product or process.
2) To estimate the contribution of individual parameters and interactions.
3) To estimate the response under the optimum condition

Step 1: In this step, the original response values are transformed into S/N ratio values. Further analysis is carried out based on these S/N ratio values. The surface roughness is a lower-the-better performance characteristics, since the maximization of the quality characteristic of interest is sought and can be expressed as

$$\text{S/N ratio} = -\log_{10}\left(\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{y_{ij}^2}$$

Where
n = number of replications and
yij = observed response value
Where
i=1, 2... ....n; j = 1, 2...k.
The surface roughness is the lower-the-better performance characteristic and the loss function for the same can be expressed as

$$\text{S/N ratio} = -\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}y_{ij}^2\right)$$

III. SELECTION MATERIAL AND PROCESS PARAMETERS

Work Material

Al alloy 6351-T6 is use for the present investigation. The table 1 shows the chemical composition of 6351-T6 Al alloy

constituent	Al	Si	Mn	Mg	Ti	Zn	Fe	Cu
% Composition	97.5	0.70	0.40	0.40	0.20	0.20	0.50	0.10

Table. 1: Chemical Composition of 6351-T6 Al alloy

Mechanical properties

Properties	**Values**
hardness	92 BHN
Tensile strength, yield	283 Mpa
Tensile strength,	310 Mpa

Fatigue strength	89.6 Mpa
Shear modulus	26.0 Gpa
Elongation	14 %
Poisson's ratio	0.33

Table. 2: Mechanical Properties of 6351-T6 Al alloy

Physical properties

Properties	**values**
Yield strength	241 Mpa
Density	0.0979 lb/in^3
Thermal expansion	17*10-6/k
Modulus of elasticity	68.9 Gpa
Thermal conductivity	176 w/m-k

Table. 3: Physical Properties of 6351-T6 Al alloy

Number of test will be conducted on AL alloy 6351 –T6 material. By looking at the mechanical and physical properties of the different materials I chose 6351-T6 l as a test specimen for testing shown below fig. And this test will be conduct by Taguchi design approach. The AL alloy 6351-T6 has been used as a work piece material for the experiments.

IV. PARAMETERS EFFECT ON ROLLER BURNISHING PROCESS

A. Burnishing speed

The surface finish in the burnishing process was found to be Much superior with increase in the speed, after certain level Of speed the surface finish was deteriorating. At lower speeds ,roller material and the work piece material will adhere and cause damage of surface, but at higher speeds, less time is available for contact and chance for adherence will be less and less damage on the surface. At lower speeds the possibility for adhesion between roller material and work material is less due to presence of coating. But at higher speed the coating was not having much influence on the performance namely the surface finish of the components.

B. Effect of feed

The influence of the feed rate on the surface roughness is firstly decreases with an increase in feed and then it starts to increase slightly with a further increase in burnishing feed. This may be due to the change of the contact area between the roller and work piece, which is dependent on the burnishing parameters especially at very low feed and low forces.

C. Effect of the burnishing force

The effect of burnishing force on surface roughness of roller-burnished aluminium specimen, The surface roughness decreases with the increase in burnishing force to a minimum value, after which it starts to increase.

D. Effect of the number of burnishing tool passes

The effect of the number of tool passes on surface roughness of roller-burnished aluminium .the surface roughness reaches a minimum value with increase in the number of burnishing tool passes, after which it starts to increase with further increase in the number of passes.

V. SELECTION OF RESPONSE PARAMETER

A. Surface Roughness

Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if small, the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. The parameter mostly used for general surface roughness is Ra. It measures average roughness by comparing all the peaks and valleys to the mean line, and then averaging them all over the entire cut-off length. Cut-off length is the length that the stylus is dragged across the surface; a longer cut-off length will give a more average value, and a shorter cut-off length might give a less accurate result over a shorter stretch of surface.

Symbol	**Control Factors**	**1**	**2**	**3**	**4**	**5**
A	Speed	73	125	250	350	500
B	Feed	0.06	0.12	0.24	0.50	0.75
C	Burnishing force	5	10	15	20	25
D	Num of pass	1	2	3	4	5

Table. 4: Results of Surface Roughness with different control factors.

VI. SELECTION OF MACHINE TOOL

The experiments will be carried out on a HMT LATHE MACHINE TOOL installed at LDRP-ITR. The LATHE machine tool has the following technical specifications:

Centre height	200mm
Admit between center	1000m
Swing over bed	420mm
Swing over wings	350mm
Swing over cross slide	230mm
Bed width over ways	280mm
Spindle nose-standard	A_2-5 mm
Spindle bore	38mm
Spindle bore taper	Morse taper 5
No. of spindle speeds	8
Range of spindle speed-standard	63 to 1400 rpm
Cross slide travel	225 mm
Top slide travel	125 mm
Longitudinal feed No/mm/rev.	12,0.06 to 1.92 (in 4 set ups)
Cross feed No/mm/rev.	12,0.03 to 0.96 (in 4 set ups)
Pitch of the lead screw/diameter	6/30 mm/mm
No of metric thread pitches	No's 20
Range	0.5 to 24 (in 4 set ups)
Spindle travel	155 mm
Sleeve dia/bore taper	70/MT 4 mm
Main motor	4 HP
Machine weight	800 kgs
Height of center above floor	1050 mm
Total length of machine	2100 mm
Floor space required	900×2300 mm
Centre height	200mm
Admit between center	1000m

Table. 5: Technical Specifications of LATHE machine tool used in experiment

The AL alloy 6351 –T6 round bar of 40 mm diameter and 304.8mm length size has been used as a work piece material for the present experiments. Aluminum alloy 6351 T6 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.

In present work discussed about the experimental work which is consist about formation of the L-25 orthogonal array based on Taguchi design, and Experimental set up, selection of work piece, tool design, and taking all the value and calculation of SURFACE ROUGHNESS.

Fig. 4: Pictorial View of lathe machine

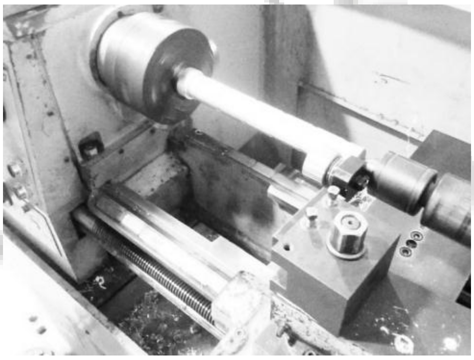

Fig. 5: Preparation of specimen

Exp. No.	Control Factors				Responses
Sr. no	A	B	C	D	Surface Roughness (Ra)
1	63	0.06	5	1	1.45
2	63	0.12	10	2	0.93
3	63	0.24	15	3	0.52
4	63	0.50	20	4	0.78
5	63	0.75	25	5	1.80
6	125	0.06	10	3	0.65
7	125	0.12	15	4	0.85
8	125	0.24	20	5	1.33
9	125	0.50	25	1	1.23
10	125	0.75	5	2	0.98
11	250	0.06	15	5	0.90
12	250	0.12	20	1	1.07
13	250	0.24	25	2	1.03
14	250	0.50	5	3	0.89
15	250	0.75	10	4	0.91
16	350	0.06	20	2	0.62
17	350	0.12	25	3	0.79
18	350	0.24	5	4	1.53
19	350	0.50	10	5	0.94
20	350	0.75	15	1	1.32
21	500	0.06	25	4	1.18
22	500	0.12	5	5	1.59
23	500	0.24	10	1	1.62
24	500	0.50	15	2	0.98
25	500	0.75	20	3	0.55

Table. 6: Results of Surface Roughness under experiment

Data (utility values) have been analyzed for signal-to-noise (S/N) ratio. Since utility is a lower-the-better (LB) type of quality characteristic for Surface roughness obtained from table 6 and also graph figure 6, 7 using MINITAB 16 statically software.

The S/N ratio, as stated earlier, is a concurrent statistic. A concurrent statistic is able to look at two characteristics of a distribution and roll these characteristics into a single number merit. The S/N ratio combines both the parameters (the mean level of the quality characteristic and variance around this mean) into a single metric (Barker, 1990). A high value of S/N implies that signal is much higher than the random effects of noise factors. Process operation consistent with highest S/N always yields optimum quality with minimum variation. The S/N ratio consolidates several repetitions (at least two data points are required) into one value.

Exp. No.	Control Factors				S\N ratio
Sr. no	A	B	C	D	Surface Roughness (Ra) (LB)
1	63	0.06	5	1	-3.22736
2	63	0.12	10	2	0.63034
3	63	0.24	15	3	5.67993
4	63	0.50	20	4	2.15811
5	63	0.75	25	5	-5.10545
6	125	0.06	10	3	3.74173
7	125	0.12	15	4	1.41162
8	125	0.24	20	5	-2.47703
9	125	0.50	25	1	-1.79810
10	125	0.75	5	2	0.17548
11	250	0.06	15	5	0.91515
12	250	0.12	20	1	-0.58768
13	250	0.24	25	2	-0.25674
14	250	0.50	5	3	1.01220
15	250	0.75	10	4	0.81917
16	350	0.06	20	2	4.15217
17	350	0.12	25	3	2.04746
18	350	0.24	5	4	-3.69383
19	350	0.50	10	5	0.53744
20	350	0.75	15	1	-2.41148
21	500	0.06	25	4	-1.43764
22	500	0.12	5	5	-4.02794
23	500	0.24	10	1	-4.19030
24	500	0.50	15	2	0.17548
25	500	0.75	20	3	5.19275

Table. 7: Results for SNR under experiment

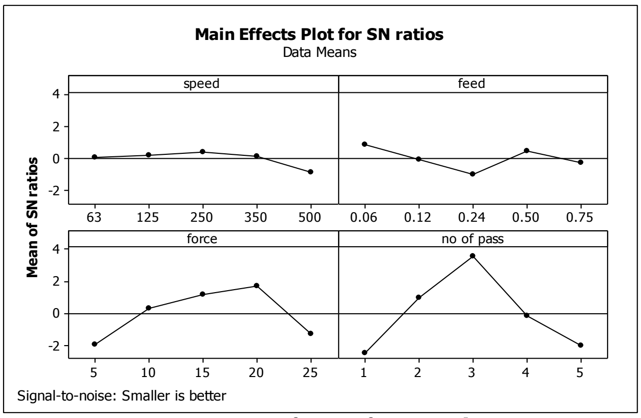

Fig. 6: SN ratio for Surface roughness

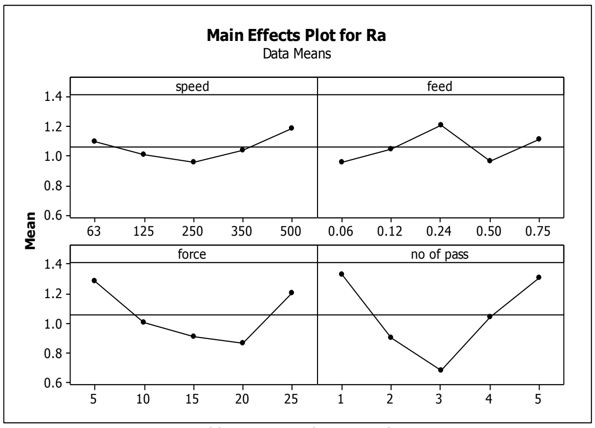

Fig. 7: Main effect plot for Surface roughness

Taguchi Analysis: Ra versus Speed, Feed, Force, Num of pass Response Table for Signal to Noise Ratios, Smaller is better

Level	speed	feed	force	No of pass
1	0.02711	0.82881	-1.95229	2.44298
2	0.21074	-0.10524	0.30768	0.97534
3	0.38042	-0.98759	1.15414	3.53481
4	0.12635	0.41703	1.68766	0.14851
5	-0.85753	-0.26591	-1.31010	2.03157
Delta	1.23795	1.81640	3.63995	5.97780
Rank	4	3	2	1

Table. 7: SN data for Surface roughness

VII. ANALYSIS OF VARIANCE (ANOVA)

The optimum condition is identified by studying the main effects of each of the factors. The process involves minor arithmetic manipulation of the numerical results. The main effects indicate the general trends of the influence of the factors. Knowing the characteristics, i.e., whether a higher or lower value produces the preferred results, the level of the factors which are expected to produce the best results can be predicted. The knowledge of the contribution of individual factors is a key to deciding the nature of the control to be established on a production process.

A. Analysis of variance (ANOVA) terms & notations

In the analysis of variance many quantities such as degrees of freedom, sums of squares, mean squares, etc., are computed and organized in a standard tabular format.

C.F. = Correction factor
n = Number of trials
r = Number of repetition
e = Error
P = Percent contribution
F = Variance ratio
T = Total of results
f = Degree of freedom
S = Sum of squares
f_e = Degree of freedom of error
S' = Pure sum of squares
f_T = Total degree of freedom

The response table for signal to noise ratio for Surface roughness shown in table, And the corresponding ANOVA table is shown in Table from using MINITAB SOFTWARE. For Surface roughness the calculation of S/N ratio follows "Smaller the Better" model. Here with indicated in this ANOVA tale Num of pass and Speed is higher effects on response Ra.

Source	DF	Seq. SS	Adj. SS	Adj. MS	F	P
Speed	4	0.14874	0.14874	0.03718	0.84	0.539
Feed	4	0.21702	0.21702	0.05425	1.22	0.375
Force	4	0.66594	0.66594	0.16648	3.74	0.375
no of pass	4	1.54182	1.54182	0.38545	8.66	0.053
Error	8	0.35615	0.35615	0.04452		0.005
Total	24	2.92966				

Table. 8: Experimental Reslts for ANOVA

VIII. CONFIRMATION TESTS

The confirmation experiment is the final step in the first iteration of the design of the experiment process. The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. The confirmation experiment is performed by conducting a test with a specific combination of the factors and levels previously evaluated. In this study, after determining the optimum conditions and predicting the response under these conditions, a new experiment was designed and conducted with the optimum levels of the Roller burnishing process parameters.

The improvement in S/N ratio from the starting Roller burnishing parameters to the level of optimal Roller burnishing parameters is 2.49 dB and Actual Confirmation test is 2.15 dB respectively. Therefore, the Surface roughness is greatly improved by using the Taguchi method.

Response	Optimal Set of Parameters	Predicted Optimal Value	Actual Value (confirmation experiments)
Surface roughness	A3B4C4D3	0.75 µm	0.78 µm
S/N Ratio value	A3B4C4D3	2.49	2.15

Table. 9: Results of the Confirmation Experiment

The predicted S/N ratio (2.49) is very close to the experimental S/N ratio (2.15) under optimal burnishing conditions. Based on the result of the confirmation test, the surface roughness is decreased

IX. CONCLUSION

In this work, various process parameters like Speed, feed, Burnishing force and No of passes have been evaluated to investigate their influence on surface roughness. Based on the result obtained, it can be concluded as follows:

Roller burnishing produce superior finish. Ra value observed is finest up to 0.89 micrometer.

The optimal roller burnishing parameters for Aluminum 6351-T6 are the combination of the burnishing force (20 kgf), the burnishing feed (0.50mm/Rev),num of pass(3), Burnishing speed (250 rpm) found in this research.

The best result for average roughness is obtained when applying No of pass 3 and Maximum Force 20kgf.
The recommended spindle speeds that result in good surface finish are in the range from 250 to 350 Rpm.

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