Parametric Evaluation of Ball Burnishing Process on Aluminium Alloy 6061

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Abstract---The main purpose of this paper is to optimization of newly design ball burnishing process parameters in conventional lathe using taguchi method. For this study the work piece material used is Alluminium Alloy 6061 and tool material HSS ball with 8mm diameter is selected. The input parameters during process are burnishing feed, burnishing speed, burnishing spring deflection and number of passes. The response parameter is surface hardness. Taguchi technique is employed in the present investigation to identify the most influencing parameters on surface hardness. Effort is also made to identify the optimal burnishing parameters and the factors for scientific basis of such optimization.

Keywords:-Ball burnishing; surface roughness; surface hardness; Taguchi technique.

I. 1. INTRODUCTION

The principle of the burnishing process, shown in Figure 1, is based on the rolling movement of a tool (a ball) against the work piece's surface, a normal force being applied at the tool. As soon as the yield point of the work piece's material is exceeded, 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 beneficial effect on mechanical properties. Burnishing can improve both the surface strength and hardness.

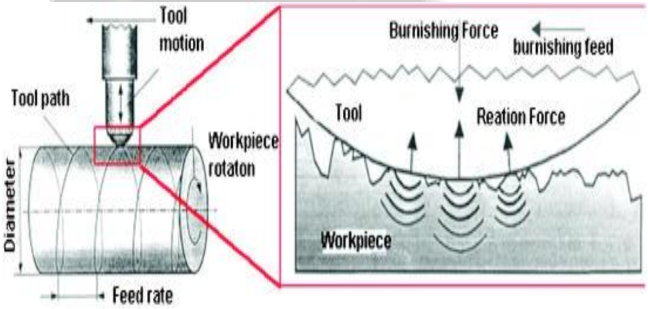

Fig. 1: Principle of burnishing

Accordingly, **burnishing process** offers an attractive post-machining alternative due to its chip less and relatively simple operations. Burnishing is a cold working process in which plastic deformation occurs by applying a pressure through a very hard and smooth ball on metallic surfaces. The burnishing process is made with the intention of improving the surface finish of some pieces that have been previously mechanized. It is a finishing and strengthening process.

II. LITERATURE SURVEY

M.H. El-Axira et al. used simple newly designed internal ball burnishing tool to burnish the internal machined surfaces. The effect of four internal ball burnishing parameters; namely, burnishing speed, feed rate, depth of penetration and number of passes on surface roundness and surface micro hardness using Response surface method (RSM) to design experiment were studied. A significant improvement in out of-roundness and surface micro hardness in aluminum alloy 2014 work piece has been obtained without the need for the difficult to set-up grinding equipment normally used for inner surfaces super-finishing. [1]

M.H. El-Axir et al. investigated the effect of four internal ball burnishing parameters; namely, burnishing speed, feed rate, depth of penetration and number of passes on surface roughness by internal ball burnishing process. The experiment was designed using RSM with Box and Hunter method. The results show that from an initial roughness of about Ra 4μm, the specimen could be finished to a roughness average of 0.14 μm. [2]

Aysun Sagbas et al. have studied the effect of the main burnishing parameters burnishing force, feed rate and number of passes on surface hardness was examined using full factorial design and analysis of variance (ANOVA). Optimal ball burnishing parameters were determined after the experiments of the Taguchi's L9 orthogonal array. As result, the optimal burnishing parameters for surface hardness were the combination of the burnishing force at 200 N, number of passes at 4, feed rate at 0.25 mm/r. [3]

Aysun Sagbas et al studied, an optimization of ball burnishing on 7178 aluminum alloy with stainless steel ball using desirability function approach (DFA) and quadratic regression model was developed to predict surface roughness using RSM with rotatable central composite design (CCD) and considered burnishing force, number of passes, feed rate and burnishing speed were as model variables. They found an absolute average error between the experimental and predicted values for surface roughness was 2.82%. [4]

J.A Travieso-Rodriguez et al. analyzed the ball burnishing process is done to improve the surface finish of aluminum A92017 and steel G10380 with concave and convex surfaces and considering the curvature radius as parameter along with speed and feed with tungsten carbide ball and concluded that for aluminum AI 92017, better results obtain with a smaller radius in convex surfaces and with a bigger radius in concave surfaces. For steel 1038 the prior peak height as parameter on milling machine, affect the indexes of surface roughness. [5]

PRASAD BHARDWAJ et al**.** investigate effect of burnishing process on the AISI D3 tool steel material using finite element method based software DEFORM-2D DX-160 CNC lathe. That concludes that Surface roughness improves up to 86.18%. Obtained about 0.19μm with force = 220 N, feed = 0.13 mm/rev, speed = 1000 rpm, number of passes = 1. And also determine the minimum and maximum deviation between the experimental and simulation values of surface roughness was 11.7 % and 44.2% respectively. The minimum and maximum deviation between the experimental and simulation values of residual stress for AISI D3 Tool steel was 1.3% and 29.2%.[6]

R. Avilés et al. analyzed improvement in the high-cycle fatigue strength of AISI 1045 normalized steel after low-plasticity ball burnishing with ceramic ball pressed hydraulically by means of pump at max 40MPa. The specimens were tested in a rotating bending fatigue machine. They determine the bending fatigue limit is increased by 21.25%.As an alternative to this coefficient, a UN axial effective mean stress that remains constant in time is defined and obtained for each stress level. [7]

Wit GRZESIK et al. Carried out the functionality comparison for improving the surface finish of low alloy 41Cr4 steel with a hardness of about 57 HRC using CBN hard turning,Si3N4ceramicball burnishing and super finishing techniques and characterized machined surfaces using 3D scanning techniques. They conclude that Dry hard turning produces initial surface profiles with regular tool nose traces and surface roughness with the Ra=0.5mm which was reduced to about 0.2mm by ball burnishing and to about 0.06mm by super finishing.[8]

R. Sadeler et.al investigated the fatigue behavior of AISI 1045 steel with effect of ball burnishing parameters at different Pressures 100, 200 and 300 bars. The hard steel ball was hydrostatically forced toward work piece. They conclude that roughness improve with increasing pressure and also enhance both fatigue life of specimens for each pressure value. [9]

P. S. Dabeer et al. Carried out experiment on brass material with central composite second order rotatable design and develop mathematical model to correlate effect of burnishing parameter on material, using ANOVA techniques and F-TEST effects on surface roughness. They conclude that Optimum Surface finish is obtained at speed of 425rpm, ball diameter of 7mm, normal force of 70N and no. of tool pass was 4. [10]

III. EXPERIMENTAL DETAILS

A. Material Of Work Piece: Aluminum Alloy 6061 is selected as a work piece material for the proposed study. It is a versatile heat treatable extruded alloy with medium to high strength capabilities.The total number of work pieces are 5. The total length of the each work piece is 150 mm and the diameter is 30 mm.

1) Material Properties:

– Good toughness
– Excellent corrosion resistance to atmospheric conditions
– Good weldability and brazability
– Good workability

2) Chemical Composition Of AA 6061

Table 3.1 Chemical composition

constituent	Al	Mg	Si	Ir	Cu	Zn	Ti	Mn	Cr	other
(%) Composition	Balance	0.8 - 1.2	0.4 - 0.8	Max 0.7	0.15- 0.40	Max 0.25	Max 0.15	Max 0.15	0.04- 0.035	0.05

3) Applications : Typical applications for Aluminium alloy 6061 include:

– Aircraft and aerospace components
– Marine fittings
– Transport
– Bicycle frames
– Drive shafts
– Brake components

B. Tool Design : The specification of the ball burnishing tool is given in Table. The ball of burnishing tool is made up of high speed steel (HSS). The nomenclature of the ball burnishing tool is given in Fig.2

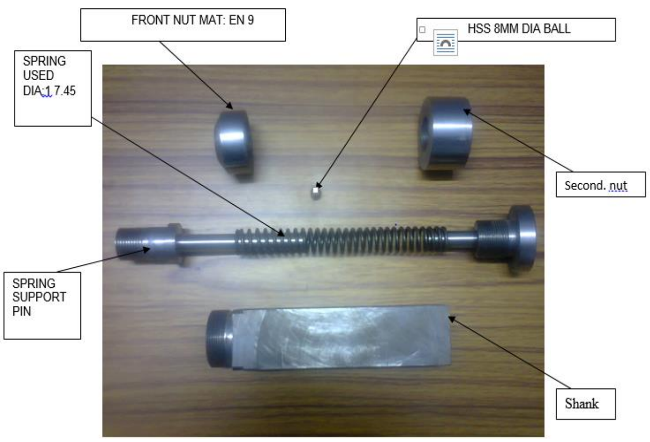

Fig. 2: Nomenclature burnishing tool

Table. 3.2: Specifications of the ball burnishing tool

Tool material	Ball burnishing tool (HSS)
Specifications	Burnishing ball diameter – 8mm
	Spring support pin – Mat.: EN 9
	Front nut : Mat.: EN 9
	Spring diameter - 1 7.45
	Rod dia – 2.5mm
	Length : 150mm

Fig. 3: burnishing tool

C. Machine : The experiments will be carried out on a LATHE MACHINE TOOL. The ball burnishing tool will be fitted in the tool post and work piece material also shown in these fig 4.

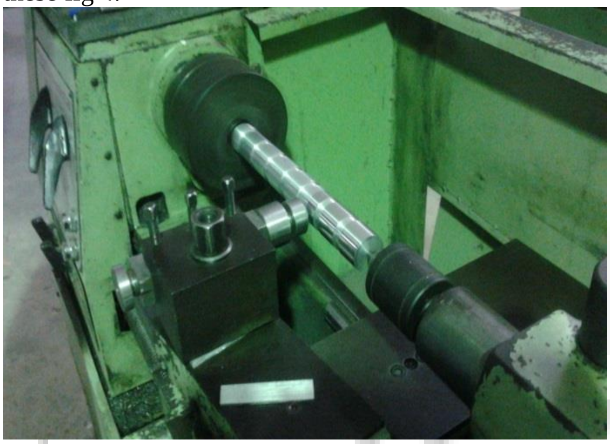

Fig. 4: Lathe Machine Tool

D. Parameter Selection : Input process parameters such as speed (A), feed (B), no .of pass (C) and burnishing spring deflection (D) used in this study are shown in Table. Each factor is investigated at 5 levels to determine the optimum settings for the lathe process. These parameters and their levels were chosen based on the review of literature, experience, significance and their relevance as per the few preliminary pilot investigations. The smallest standard 5-level OA L25 is chosen for this case from using software MINITAB 16. The discussions related to the measurement of lathe experimental parameters e.g. Speed, Feed, no of pass and burnishing spring deflection are presented in the following subsections.

Table. 3.3: Select Parameter & their Range

Factors	**Parameter Range**				
Speed (m/min)	63	125	250	350	500
Feed, f (mm/rev)	0.6	0.12	0.15	0.24	0.30
spring defl^{n} (mm)	2	4	6	8	10
No. of tool passes	1	2	3	4	5

IV. METHODOLOGY

A. Taguchi Design Experiments In Minitab : MINITAB provides both static and dynamic response experiments in a static response experiment; the quality characteristic of interest has a fixed level. The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors. MINITAB calculates response tables and generates main effects for:

– Signal-to-noise ratios (S/N ratios) vs. the control factors.
– Means (static design) vs. the control factors.

The smallest standard 5-level OA L25 is chosen for this case from using software MINITAB 16.The levels of experiment parameters Speed (S), Feed (f), Spring deflection (F) and No of Passes are shown in Table and the design matrix is depicted in Table.

Table 4.1: Factors and their levels

Factors	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Speed (m/min)	63	63	63	63	63
Feed, f (mm/rev)	0.06	0.12	0.15	0.24	0.30
Spring defl^{n}, F(N)	2	4	6	8	10
No. of tool passes	1	2	3	4	5

B. Orthogonal Array : OA plays a critical part in achieving the high efficiency of the Taguchi method. OA is derived from factorial design of experiment by a series of very sophisticated mathematical algorithms including combinatory, finite fields, geometry and error- correcting codes. The algorithms ensure that the OA to be constructed in a statistically independent manner that each level has an equal number of occurrences within each column; and for each level within one column, each level within any other column will occurs an equal number of times as well. Then, the columns are called orthogonal to each other. OA are available with a variety of factors and levels in the Taguchi method. Since each column is orthogonal to the others, if the results associated with one level of a specific factor are much different at another level, it is because changing that factor from one level to the next has strong impact on the quality characteristic being measured. Since the levels of the other factors are occurring an equal number of times for each level of the strong factor, any effect by these other factors will be ruled out. The Taguchi method apparently has the Following strengths:

– Consistency in experimental design and analysis.
– Reduction of time and cost of experiments.
– Robustness of performance without removing the noise factors.

The selection of orthogonal array depends on:

– The number of factors and interactions of interest
– The number of levels for the factors of interest

Aluminium alloy 6061 material particulate was used in present work. And the LATHE MACHINE was used. Table shows the nine cutting experimental runs with the assigned levels of the process parameters according to the selected L25 orthogonal layout

An experiment was done for selected sets of parameters by Minitab software and surface hardness for those sets of parameters. surface hardness for these sets are given in the table.

Table 4.2: Result table for SURFACE HARDNESS

Exp. No.	Speed (m/min)	Feed (mm/rev.)	Spring def^n (mm)	Number of passes	Surface Hardness
1	63	0.06	2	1	110.04
2	63	0.12	4	2	108.35
3	63	0.15	6	3	109.3
4	63	0.24	8	4	104.97
5	63	0.3	10	5	103.29
6	125	0.06	4	3	116.81
7	125	0.12	6	4	115.12
8	125	0.15	8	5	116.06
9	125	0.24	10	1	93.34
10	125	0.3	2	2	92.15
11	250	0.06	6	5	123.07
12	250	0.12	8	1	102.98
13	250	0.15	10	2	103.93
14	250	0.24	2	3	100.11
15	250	0.3	4	4	98.42
16	350	0.06	8	2	111.53
17	350	0.12	10	3	109.84
18	350	0.15	2	4	111.29
19	350	0.24	4	5	106.97
20	350	0.3	6	1	86.88
21	500	0.06	10	4	117.2
22	500	0.12	2	5	116.01
23	500	0.15	4	1	98.56
24	500	0.24	6	2	94.23
25	500	0.3	8	3	92.55

C. Response Curve Analysis : Response curve analysis is determining influential parameters and their optimum levels. It is graphical representations of change in performance characteristics with the variation in process parameter. The curve gives a view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another. Fig shows significant effects for each factor for five levels. The S/N ratio for the performance curve were calculated at each factor level and average effects were determined by taking the total of each factor level and dividing by the number of data points in the total.The greater difference between levels, the parametric level having the highest S/N ratio corresponds to the parameters setting indicates highest performance.

From above Figure, the mean is an average value for reading taken for a particular parameter. From the graph, the mean value is the maximum (108.35) for 63 (m/min) speed and minimum (103.85) for 500 (m/min) speed. The mean value is the maximum (116.81) for 0.06 (mm/rev.) feed. and minimum (92.55) for 0.30 (mm/rev.) feed. The mean value is the maximum (106.97) for 4 N spring deflection and minimum (103.93) for 10 N spring deflection. The mean value is the maximum (103.29) for 5 number of passes and minimum (98.56) for 1 number of passes.

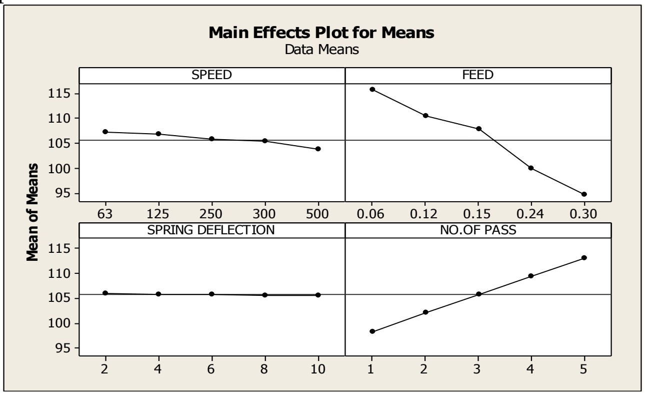

Fig. 5:

Table. 4.3: Response Table for Means

Level	SPEED	FEED	SPRING DEFLECTION	PASSES
1	107.19	115.73	105.92	98.35
2	106.70	110.47	105.81	102.04
3	105.72	107.82	105.72	105.72
4	105.29	99.91	105.62	109.41
5	103.70	94.66	105.52	113.07
Delta	3.49	21.07	0.40	14.72
Rank	3	1	4	2

Taguchi Analysis: HARDNESS versus SPEED, FEED, SPRING DEFLECTION, NO.OF PASS

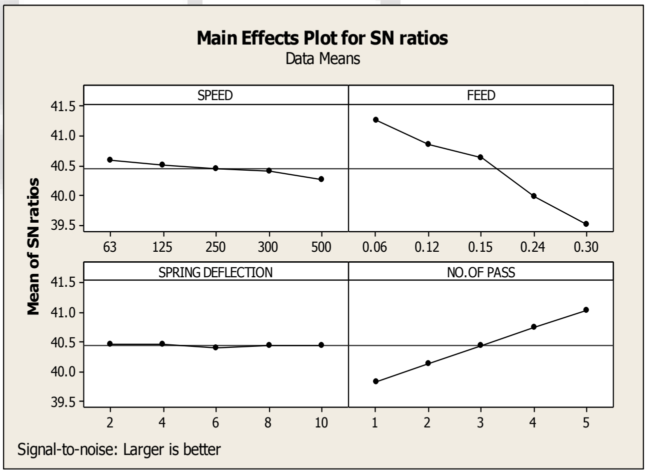

Fig. 6:

Table. 4.4: Response Table for Signal to Noise Ratios Larger is better

Level	SPEED	FEED	SPRING DEFLECTION	PASSES
1	40.60	41.26	40.47	39.83
2	40.51	40.86	40.47	40.15
3	40.45	40.64	40.41	40.45
4	40.41	39.98	40.45	40.76
5	40.27	39.51	40.44	41.05
Delta	0.33	1.75	0.06	1.22
Rank	3	1	4	2

D. Factor Levels For Predictions:

Table. 5:

SPEED	FEED	SPRING DEFLECTION	PASSES
63	0.06	4	5

S/N Ratio	Mean
42.0366	124.640

V. CONCLUSION

The Taguchi method was found to be an efficient technique for quantifying the effect of control parameters. To analyze the effect of burnishing parameter on material. To develop mathematical model using taguchi method for optimizing parameters of ball burnishing process. The greater difference between levels, the parametric level having the highest S/N ratio is 42.0366 corresponds to the parameters setting indicates highest performance and means value is 124.640. The experimental results for Surface hardness are measure by larger is better and feed is most efficient parameter.

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