

Analysis and Optimization of Roller Burnishing Process on Cylindrical Surface Micro Hardness of Aluminium Alloy

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ABSTRACT: Burnishing is a easy and effectual technique for enhancement in surface micro hardness and carried out using existing machines, such as lathe. In this study, a single roller burnishing tool was made to function burnishing processes on Aluminum 6061 metal. The effect of burnishing speed, feed, number of passes and dept of penetration on the surface micro hardness is measured. The outcome revealed that the single roller burnished samples of Aluminum 6061 lead to the enhancement in surface micro hardness. It is observed that depth of penetration is the more important parameter which has significant effect on surface micro hardness (VHN value). Regression equation is derived and presented. Also confirmation tests are conducted and results verified. ANOVA results are validated using Analytic Hierarchy Process (AHP). Burnishing operation is a excellent finishing operation concerning the cold working and plastic deformation of surface to improve the surface integrity and the serviceable effectiveness of a component. The outcome indicates that burnishing parameters have a considerable consequence on surface micro hardness.

KEYWORDS: Burnishing process; Surface micro hardness

I. INTRODUCTION

To get a satisfactory surface quality, many efforts are mainly taken to the enhancement of the cutting tool performance and to the plastic deformation of the machined materials. Traditional machining methods, like turning and milling, leave intrinsic irregularities on the surface, and hence it is necessitate to know different finishing operations. [1, 2] Burnishing operation plays critical role for development of surface roughness and also for surface micro hardness. The need of aeronautic and the mechanical industries has developed the use of very hard materials in numerous fields. [3, 4] Burnishing is a cold forming method, without actual cutting of metal. In burnishing operation a tool is rubbed on the metal surface. This allows the high spots to be compressed out and the valleys filled in. It is a new theory in finishing components. This procedure eliminates Grinding and honing which are costlier processes while improving the surface micro hardness, surface finish of a part.

Burnishing operation helps to eliminate secondary operations for significant time and cost reducing, while at the similar time improving the excellent quality of the product. Roller burnishing is a technique of generating a precisely dimension, super finished and closely flattened surface that resists wear. Hardened polished steel rollers or balls are brought into contact with a softer work piece as shown in figure 1. As the tool is moved in a forward direction to get in contact with work piece and is gradually moved in that direction under controlled condition then the surface is deformed by cold flowing of associated surface material.

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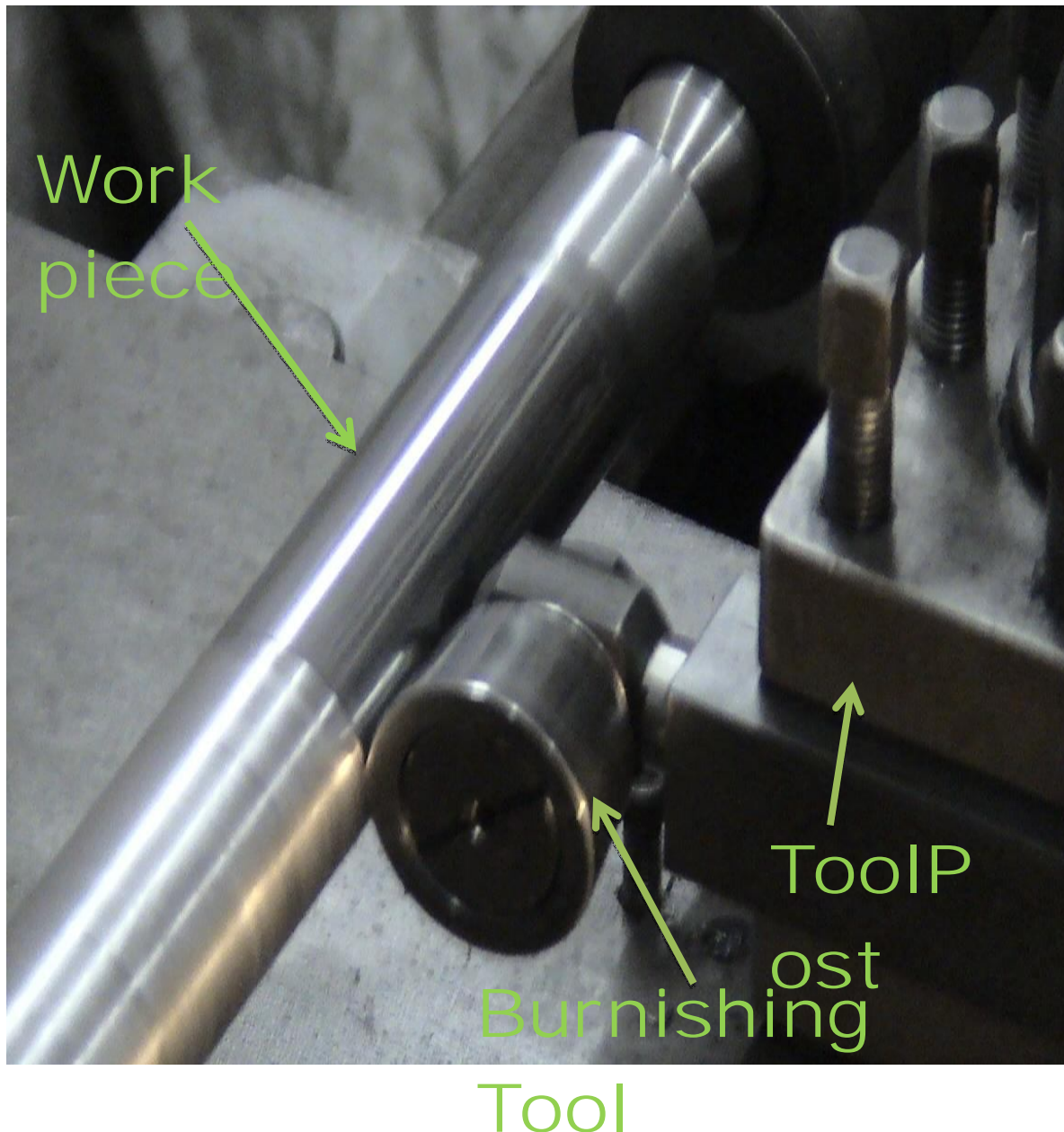


Fig. 1. Burnishing operation on lathe.

A. Classification of Burnishing Processes

Burnishing process can be classified into two categories as

1. Based on deformation element

a. Ball burnishing tool

i. Flexible

ii. Rigid

b. Roller burnishing tool

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2. Based on the motion of the tool, on the surface
 - a. Normal or ordinary
 - b. Impact
 - c. Vibratory

In roller burnishing process the deformation constituent is roller.

The roller material is tough alloy steel. The roller burnishing technology is a finer technology used for finishing of metal components after a pre-machining process. This process gives a very little surface finish and a close dimensional tolerance in high volume production. Since Roller burnishing operation is cold rolling process, the skin micro hardness of the worked surface improves thus giving higher service life of the part due to this surface micro hardness is increased.

II. LITERATURE REVIEW: STUDIES ON SURFACE MICRO HARDNESS

The phenomenon of strain hardening appearing in most metals is a useful benefit for products which become stronger, harder, and consequently have larger influences on wear resistance and fatigue strength [5]. Suitable to the measurement of micro hardness by the dimple method as the most practical and useful method [6], investigations of ball burnishing focused on a type of depth of penetration like Rockwell and another type of left impression such as Vickers.

The study on surface micro hardness involve ball burnishing factors similar to those on surface roughness, e.g., Hassan et al. [7] showed normal force and the number of passes were the most effective factors on surface micro hardness among parameters such as speed, feed, depth of penetration etc. As the depth of penetration is increased the micro hardness also increased. The best possible micro hardness (the highest value) was obtained at highest depth of penetration, medium feed rate, lowest speed, and highest number of passes.

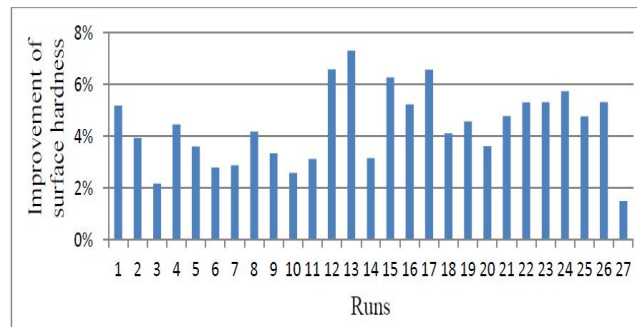


Fig. 2 Improvement of surface micro hardness by ball burnishing [8]

Form the figure 2 it is seen that using ball burnishing the surface micro hardness is improved so it is necessary to do research in roller burnishing operation for the surface micro hardness improvement.

III. EXPERIMENTAL SETUP & PROCEDURE

In this experimental study, focus is being put on to recognize the enhancement in the surface micro hardness of burnished surface on Aluminum material. Chemical structure of the Al 6061 is given in below table 1.

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Table 1.Composition of Aluminum in %

Mg	Si	Cu	Zn	Mn	Cr	Fe	Ti
0.8 - 1.2	0.4- 0.8	0.15- 0.4	0.25	0.15	0.04- 0.35	0.7	0.15

The test specimen was in the shape of rod diameter of 32 mm. A single roller burnishing tool (Bright Burnishing PVT. Ltd, Coimbatore) of diameter 30 mm was used. A roller burnishing tool shown in Fig. 3. The trials were conducted on the general purpose of lathe machine (Mac Power). This is a high accuracy lathe with 5Hp spindle motor, it has step-less spindle speeds ranging from 76 – 725 rpm. The distance between the centers is 800 mm. It has 300 mm swing over bed and 190 mm swing over cross slide. The chuck size is 148 mm diameter. It has longitudinal feed of 0.4 – 0.9 mm/rev and cross feed of 0.05 – 0.52 mm/rev. The burnishing tool is clamped on tool holder of general purpose lathe machine. Raw material is in the form of rod of 32 mm diameter and 100 mm length. The work piece is clamped with the help of the tailstock center and three jaw chuck machine. No need of coolant when during burnishing process. First, the turning operation is performed using carbide tool and then burnishing operation conducted. The experimental setup used for burnishing are shown in Fig.1 and work piece after burnishing is shown in Fig. 4



Fig.3 Burnishing Tool



Fig.4 Workpiece after burnishing operation.

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IV. DESIGN OF EXPERIMENT (DOE)

Design of experiments (DOE) resolves the model of surveillances to be made with a least amount of experimental attempt, in which effects of multiple factors are studied by running tests at different levels. The points that should be taken, how to merge them, and how several experiments should be performed are subjects of importance in DOE. Design of Experiments (DOE) technique help designers to determine individual and interactive results of many factors that might affect the output results in any design. DOE also provides a occupied insight of interaction between design constituents; therefore, it helps to turn any standard design into a robust one. DOE helps to pin point the sensitive parameters and sensitive areas in design that cause problems. [9]

DOE through Taguchi method, supports to enhance the stability of performance and reduces the time without doing the full factorial experiments. In this approach, a fixed number of orthogonal arrays are used to handle many common experimental situations. Taguchi has developed a number of orthogonal arrays to achieve the experiment design. Every array can be used to suit a numbers of experimental tests. In this study Taguchi L25 Orthogonal array has been used to check the effects of participation parameters. Burnishing operation parameters and their levels are shown in table.2.

Table 2. Maching parameters and level.

FACTORS	LEVELS				
	1	2	3	4	5
Speed [RPM]	100	200	285	460	725
Feed [mm/rev]	0.2	0.3	0.4	0.5	0.6
Depth of Penetration(DOP) [mm]	0.04	0.08	0.12	0.16	0.20
Number of passes(NOP)	1	2	3	4	5

To checked the exactness of model, the analysis of variance (ANOVA) is planned. The result of ANOVA for surface micro hardness is shown in table 4. The ratio of mean sum due to factors to mean sum of experimental error (The F – Ratio) is calculated for the surface micro hardness.

Surface micro hardness after turning operation and after burnishing operation is measured by Vickers micro hardness tester. 100g. force is applied by using diamond indenter on work piece shown in Fig.5. In Fig.6. actual diamond indenter impression is shown. The specification of the micro hardness tester is as below:

Test Load (Automatic)-10gm-1000gm,
Square Base Diamond Indenter Microscopic Attachment with Computer Display,
Magnification Power: 100 X To 600 X

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Fig 5: Micro hardness Tester

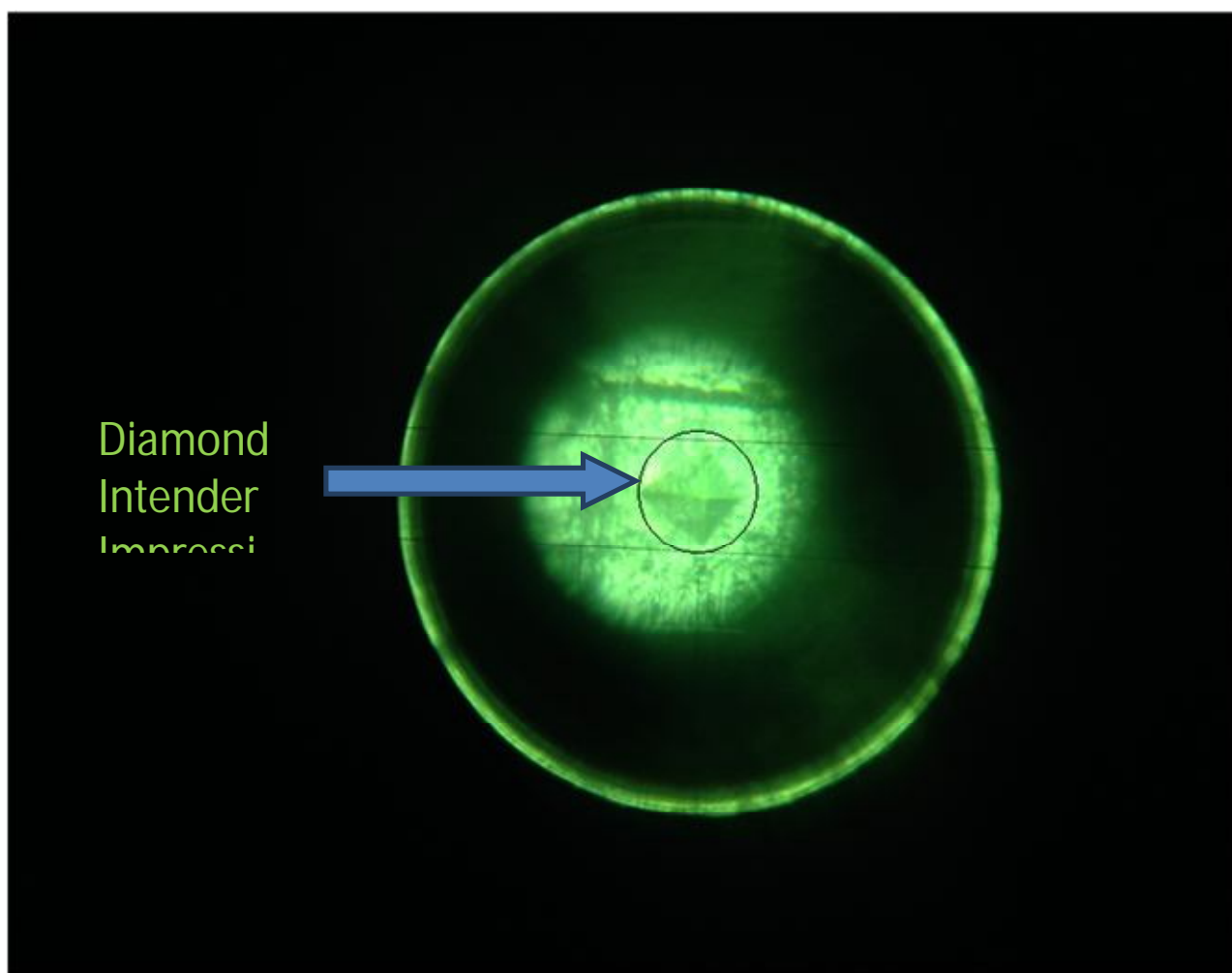


Fig. 6 Diamond Indenter Impression

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V. RESULTS & DISCUSSION

The trials are conducted as per the Taguchi analysis with L25 orthogonal array. The trials are conducted with different factors & their levels are shown in table 2. Following observations were recorded from the experiments conducted on experimental setup.

Table 3. Observation Table obtained from experimental analysis

Speed	Feed	DOP	NOP	Micro hardness	s/n ratio
1	1	1	1	116	42.2118
1	2	2	2	127	42.0074
1	3	3	3	129	42.4115
1	4	4	4	126	41.9382
1	5	5	5	132	42.0761
2	1	2	3	125	42.1442
2	2	3	4	127	42.4770
2	3	4	5	128	41.8684
2	4	5	1	133	42.0074
2	5	1	2	124	42.2118
3	1	3	5	126	42.4115
3	2	4	1	129	41.7981
3	3	5	2	132	42.0761
3	4	1	3	123	42.2118
3	5	2	4	127	42.2789
4	1	4	2	129	42.0761
4	2	5	3	130	42.1442
4	3	1	4	127	42.0761
4	4	2	5	128	42.2789
4	5	3	1	127	42.0074
5	1	5	4	130	42.0761
5	2	1	5	126	42.1442
5	3	2	1	127	42.0761
5	4	3	2	128	42.2118
5	5	4	3	127	42.0074

From the experiments, it is detected that there are major changes in surface micro hardness due to the deviation in parameters.

From the F-table it is clear that the depth of penetration is most considerable factor for surface micro hardness. Taguchi Orthogonal Array is calculated in Minitab17 to calculate S/N ratio.

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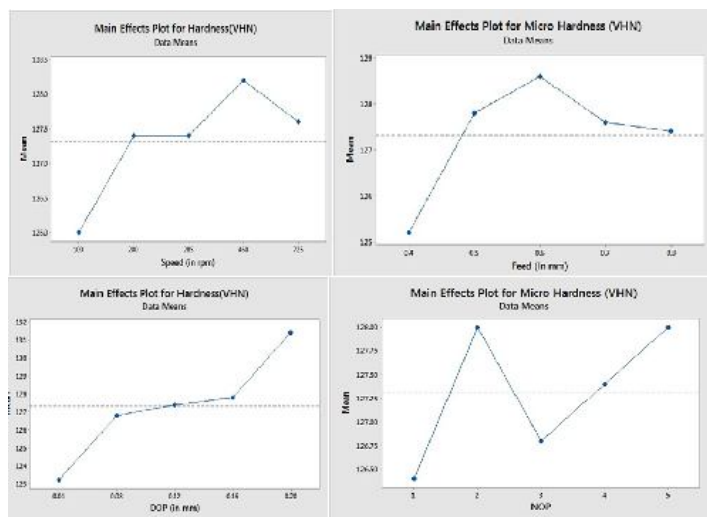
Table 4.ANOVA table for surface micro hardness

Factor	DoF	SS	%SS	MS	F
Speed	4	8.56	0.9056	3.260	0.60
Feed	4	8.56	0.9056	8.060	1.49
DOP	4	887.36	96.01	42.660	7.89
NOP	4	6.16	0.666	2.560	0.47
ERROR	8	13.52	1.46		
TOTAL	24	924.16			

Surface micro hardness, “larger is better” type of characteristic is selected; the S/N ratio for this type of response was used and recorded.

$$S/N = -10 \cdot \log (\Sigma (Y^2)/n)).....(a)$$

The result of different burnishing parameters on surface micro hardness are calculated and plotted. The S/N ratios is also calculated to catch the results of various burnishing parameters on surface micro hardness. The use of both ANOVA method and S/N ratio makes it simple to examine the results and to find out the conclusion.



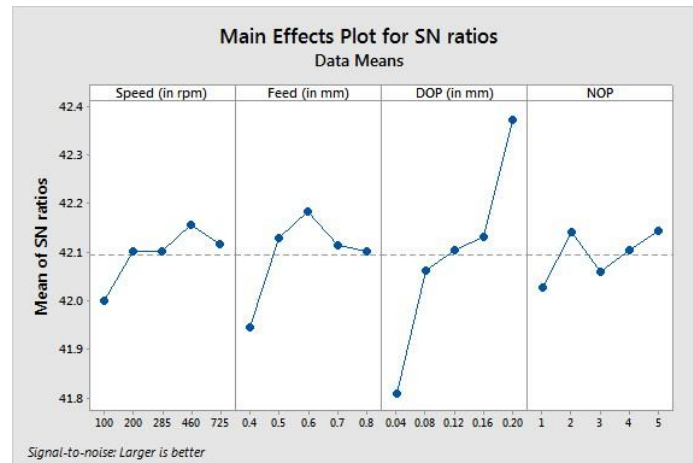
Graph 2: Main effects plot of micro hardness Vs various burnishing process parameter.

From Main effects plot of micro hardness against various burnishing process parameter Graph 2 it can be concluded that DOP has major influence on micro hardness value, as DOP is increased micro hardness is also increased and also same can be observed in main effect plot for S/N Ratio Graph 3

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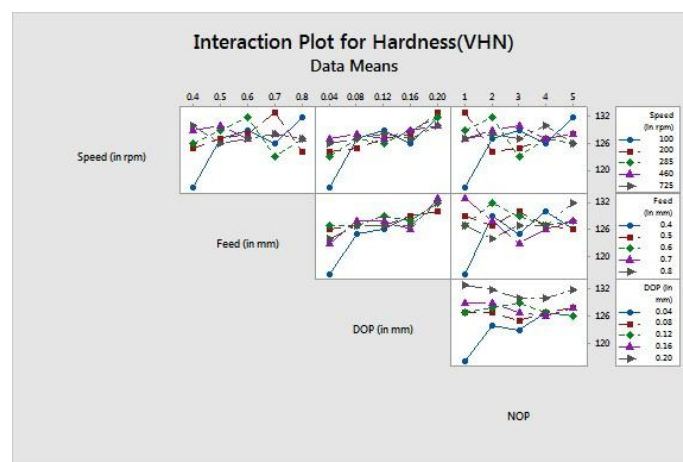
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Graph 3: Mean effect for S/N Ratio

Graph 4 shows the interaction of various parameters for micro hardness.



Graph 4: Interaction plots of micro hardness

VI. REGRESSION EQUATION

The proposed multiple regression models are a two-way interaction equation:

$$\text{Micro hardness} = 118.05 + 0.00213A + 4.20B + 43.50C + 0.26D$$

Where,

A = Spindle Speed in RPM.

B = Feed rate mm/rev,

C = Depth of Penetration in mm

D = No. of passes

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	A	B	C	D	Value(V)	Product(P)	Ratio(P/V)
A	1	1	5	1	0.3221	1.4503	4.5033
B	1	1	5	2	0.3654	1.4503	3.9689
C	1/5	1/5	1	2	0.1379	0.7162	5.1943
D	1	1/2	1/2	1	0.1746	0.5872	3.3636
CI							0.0858
CI/RI							0.095

VII. AHP

Analytic Hierarchy Process (AHP) was developed by Thomas Saaty. AHP is a method for decision making in situations where several objectives are present. In this method pair-wise comparison matrix is used to determine the relative value. AHP can prevent subjective judgment errors and increase the likelihood that the results are trustworthy. ANOVA results are validated using Analytic Hierarchy Process (AHP).

i. Priority of Requirements

Table 5. Priority of requirements for performing experiments.

	A	B	C	D
A	1	1	5	1
B	1	1	5	2
C	1/5	1/5	1	2
D	1	1/2	1/2	1

ii. Normalized comparison matrix

Table 6. Comparison matrix

	A	B	C	D
A	0.31	0.37	0.43	0.16
B	0.31	0.37	0.43	0.33
C	0.062	0.07	0.08	0.33
D	0.31	0.18	0.04	0.16

iii. Scores for requirements

Table 7. Score of requirement

	A	B	C	D	Value(V)
A	0.3125	0.3737	0.4388	0.1633	0.3221
B	0.3125	0.3737	0.4388	0.3367	0.3654
C	0.0625	0.0707	0.0816	0.3367	0.1379
D	0.3125	0.1818	0.0408	0.1633	0.1746

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VII. CONFIRMATION TEST

The result drawn based on Taguchi's design approach is finally verified by confirmation test. In this test 2 confirmation tests are conducted, following are the observation's.

Table 8. Comparison of actual experiments and Theoretical calculations

A	B	C	D	Actual Micro Hardness	Theoretical Micro Hardness
2	3	2	3	124	124.41
5	4	1	5	126	126.47

VII. CONCLUSIONS

Roller burnishing method of cylindrical surface can be carried out on standard machine with help of Master Burnishing tool consisting of single roller made of D3 tool steel. Following are the conclusions after performing the experimentation

1. Surface quality improvement is evident and can be visually identify when comparison of two parts before and after burnishing is conducted.
2. The present study make known that the burnishing operation can improve surface micro hardness by using Master Burnishing Single Roller Tool.
3. Taguchi analysis is very effective optimization technique and also Mathematical model is identified considering speed, feed, DOP, NOP. This model can be used to predict the parameters to achieve desired response without actual performing the burnishing operation.
4. The ANOVA has revealed that the raise in depth of penetration increases the surface micro hardness. Other parameters are not much influencing on micro hardness value. This result is confirmed by AHP method. Following are the influence of burnishing parameters on micro hardness value,

a. Depth of Penetration

As DOP increases the surface micro hardness improves, this is observed in graphs.

b. Feed

Initially at low feed micro hardness value is less after that when feed is increased there is increase in micro hardness up to certain level, after that again there is drop in surface micro hardness value.

c. Number of Passes

Initially it is observed that when number of passes increases micro hardness value also increases but at same time when speed is increased micro hardness value drops down.

d. Speed

From graph it can be observed that there is no pattern to be followed in speed against micro hardness value.

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