EXPERIMENTAL INVESTIGATION OF VARIOUS PARAMETERS EFFECTS ON MECHANICAL PROPERTIES OF AA 6061 USING BALL BURNISHING PROCESS

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ABSTRACT

In the past burnishing was utilized only for smoothing of shafts and bores. After 1950, this method was applied in Germany and the former Soviet Union for work hardening of railway wagon axles and automotive crankshafts. Then, the usage range became more extensive for inner and outer surfaces of hydraulic components, bearings, sealing surfaces, fillets, etc. Due to new materials, new tools new attachments design made possible the usage of burnishing on CNC machines. In the US this process was first introduced in 1950. After a period of trials it is now accepted in a narrow area of applications. These Experimental work deals with optimization of burnishing process parameters newly design ball burnishing tool on conventional lathe machine using Full factorial method. The work piece material is Aluminium Alloy 6061 and ball material is of high chromium high carbon, four balls of Different diameter are used. The levels of input process parameters are selected on basis of one factor at a time analysis. The input parameters are burnishing Speed, burnishing Ball diameter, and number of passes and the response parameter are surface roughness and hardness a. The experiment is design with Full factorial method carried out with above Three factors and Four levels. The results are analyzed using Design Expert in order to determine ANOVA method and means for surface roughness and hardness. The optimum set of parameter is determined One factor, interaction and predicted vs. Actual graph.

Keyword : - *Ball burnishing , Surface roughness,Surface Hardness, No of passes,No of dia,Cutting speed,Design Expert,ANOVA*

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1. Introduction

In the present scenario of manufacturing good surface finish and dimensional accuracy plays an important role [1]. Surface finish is important not only as an indication of expert workmanship but it has effects on the life and function of the component. Ball burnishing processes are largely considered in industrial cases in order to restructure surface characteristics [11]. Ball burnishing is a chip less finishing method which employs a rolling tool pressed against the work piece in order to achieve plastic deformation [14]. The process is relatively simple and can be easily performed on machine tools. Besides giving a good surface finish it also increases micro hardness, fatigue life and wear resistance of the components.

Burnishing is a cold working surface finishing process which is carried out on material surfaces to induce compressive residual stresses and enhance surface qualities [9]. A burnishing tool typically consists of a hardened sphere which is pressed onto/across the part being processed which results in plastic deformation of asperities into valleys [14] as shown in fig 1 In burnishing process in which initial asperities are compressed beyond yield strength against load. The surface of the material is progressively compressed then plasticized as resultant stresses reach a steady maximum value and finally wiped a superfine finish [8].

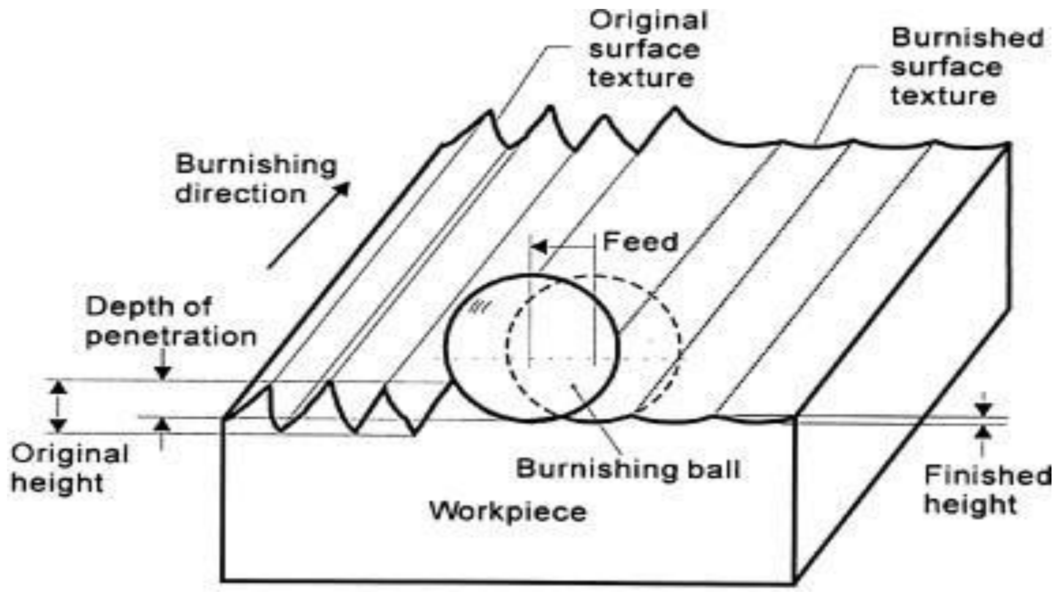


Fig-1:schemetic diagram of ball burnishing process[W5]

A. M. Hassan, H. F. Al-Jalil, A. A. Ebied, This paper deals with the optimization of surface finish for ball-burnishing brass components using the response surface method.

Adel Mahmood Hassan, Ayman Mohammad Maqableh, In This paper the ball diameter of the burnishing tool and the use of different lubricants on this process were studied.

Lars Hiegemann, Christian Weddeling, Nooman Ben Khalifa, A. Erman Tekkaya, In this paper An analytical model to predict the roughness of a thermally sprayed coating after a ball burnishing process is presented.

Tao Zhang, Nilo Bugtai, Ioan D. Marinescu, In this paper Burnishing of aerospace alloy: A theoretical–experimental approach is done Hear burnishing toolis equipped with a Ø 6 mm silicon nitride ceramic ball with a 15◦angle. The ECOROLL hydraulic system of a high pressure hydraulic pump HGP 4.3 can apply a maximum pressure up to 40 MPa. An emulsion-type coolant was mixed well with 5% oil content of TRIM®VHP®E814 soluble oil and 95% water by stirring devices, due to its versatile edge, which can perform well in machining processes andespecially excel in high-pressure environments with low foaming and chlorine-free hear output is Significant effects of process parameters are established on sur-face roughness that includes the higher pressure leads to rougher surfaces. While the feed slightly decreases the surface roughness from low to middle level, the further increase of feed will increase the surface roughness. The critical effect of speed should be taken into consideration for either low or high levels, but the influence of the turned surface roughness is negligible, (Tao Zhang, 2014)

Biing Hwa Yan, Che Chung Wang, Han Ming Chow, Yan Cherng Lin, This study investigates the feasibility and optimization of a rotary EDM with ball burnishing for inspecting the machinability of Al2O3/6061Al composite using the Taguchi method,

Ravi butola, Jitendra Kumar, Dr Qasim Murtaza, In this Design and Fabrication of Multi Ball Burnishing for Post Machining Finishing Process

Yinggang Tian, Yung C. Shin, In this paper A new hybrid burnishing process, laser-assisted burnishing (LAB) is proposed and investigated experimentally

C. H. Fu, M. P. Sealu, Y. B. Guo, X. T. Wei, In this paper Austenite–martensite phase transformation of biomedical Nitinol by ball burnishing , Conclusions Nitinol (Ni50.8Ti49.2) was burnished at different loads to experi-mentally and theoretically investigate the austenite to martensite phase transformation.

W. Koszela, P .Pawlusa, E. Rejwera, S. Ochwatb, This paper presents method of oil pockets creation by the burnishing (embossing) technique. Steel and ceramic forming elements were used to modify sliding surfaces.

Fang-Jung Shiou, Chien-Hua Chen, In This paper Freeform surface finish of plastic injection mold by using ball-burnishing process. The ball-burnishing surface finish process of a freeform surface plastic injection mold is developed successfully on a machining center in this work

1.1 Advantages

- The ball burnishing process gives better surface finish and higher production rate.
- It gives higher contact stiffness, wear resistance, joint strength, load bearing capacity, oil
- retention capacity.
- Improves the size and finish of revolution like cylinder and complex surfaces.[4]
- Internal and external surfaces can be burnished.
- Improves surface hardness, grain size, wear-resistance, fatigue resistance and corrosion resistance.
- Internal surfaces of non-ferrous materials are difficult to finish due to many problems encountered in grinding
- It eliminates sticking, wheel dulling and overheating.
- Improve cosmetic appearance.

1.2 Application

- Piston of hydraulic and pneumatic cylinders.
- Shaft of Pump
- Plumbing Fixtures.
- Bearing Bores
- Aerospace component

2. Experimental Setup

2.1 Machine Tool

The experiments will be carried out on a HMT TL 20 Lathe machine tool installed at Merchant Engineering College, Basna. The LATHE machine shown in fig 1

Fig- 1:HMT TL 20 lathe machine

2.2 Work Piece Material

The Workpiece material AA 6061

Table 1- chemical composition

Component	**Amount (wt.%)**
Magnesium 0.8	1.2
Silicon 0.4	0.8
Iron Max	0.7
Copper 0.15	0.40
Zinc Max	0.25
Titanium Max	0.15
Manganese Max	0.15
Chromium 0.04	0.35

2.3 Surface Roughness Tester

The surface roughness of all the machined work pieces was measured using a Mitutoyo surf test SJ-201P shown in fig 2. The Technical Specification of Surface

Fig-2:Mitutoyo surf test SJ-201p

2.4 Hardness Tester

The hardness of all the machined work pieces was measured using a Dial gauge operated brinel hardness tester machine fig 3

Fig-3:Dial gauge operated brinel hardness tester machine

2.5 Input & Output Perameter

Table-2:I/O Perameter

Input Parameter	**Output Parameter**
No of ball dia	Surface roughness
Speed	Surface hardness

No of passes	

2.6 Factors with level value

Table 3 Factors with level (1.5 mm thickness)

Table-3:actor With level value

Factors	**Level 1**	**Level 2**	**Level 3**	**Level 4**
No of ball dia	6mm	8mm	10mm	12mm
Speed	1400	1800	2200	
No of passes	3	4	5	

Hear fix as feed-1mm/rev and depth of cut is taking as 1mm. So total numbers of trial runs required for each material are:

$$N = (\text{no. Of levels})^{(\text{no. Of factors})}$$

Where,

N = total number of trials,

F = number of factors and

L = number of levels.

So it will be $n = 3^3 = 27+9=36$ for full factorial design

2.7 Design of Experiment

The technique of defining and investigating all possible conditions in an experiment involving multiple factors is known as the design of experiments. Design of experiments refers to the process of planning, design ing and analyzing the experiment so that valid and objective conclusions can be drawn effectively and efficiently. In order to draw statistically sound conclusions from the experiment, it is necessary to integrate simple and powerful statistical methods into the experimental design methodology.

In the context of DOE in manufacturing, one may come across two types of process variables or factors: qualitative and quantitative factors. A factor may take different levels, depending on the nature of the factor-quantitative or qualitative. A qualitative factor generally requires more levels when compared to a quantitative factor We are taking full factorial its table is generated in design of experiment is here

3 Result and Analysis

3.1 OUTPUT

Table-4: Output

STD	RUN	No of ball dia	Rpm	No of passes	Surface roughness	Surface hardness second
15	1	10	1400	4	2.041	113
20	2	12	1800	4	1.877	114
5	3	6	1800	3	1.801	120
31	4	10	1800	5	1.589	111
18	5	8	1800	4	1.738	120
8	6	12	1800	3	2.765	114
30	7	8	1800	5	1.364	117
25	8	6	1400	5	0.874	113
23	9	10	2200	4	1.618	111
17	10	6	1800	4	1.657	117
13	11	6	1400	4	1.412	119
19	12	10	1800	4	1.814	115
14	13	8	1400	4	1.811	121
9	14	6	2200	3	1.931	117
27	15	10	1400	5	1.457	114
24	16	12	2200	4	1.774	116
12	17	12	2200	3	2.968	116
29	18	6	1800	5	1.344	113
26	19	8	1400	5	1.217	119
33	20	6	2200	5	1.718	113
16	21	12	1400	4	2.378	114
36	22	12	2200	5	2.104	115
7	23	10	1800	3	2.162	115
11	24	10	2200	3	2.358	113
21	25	6	2200	4	1.837	117
22	26	8	2200	4	1.537	117
32	27	12	1800	5	1.661	115
10	28	8	2200	3	1.987	118
2	29	8	1400	3	1.987	120
35	30	10	2200	5	1.991	113
4	31	12	1400	3	2.614	115
34	32	8	2200	5	1.814	117
28	33	12	1400	5	1.678	113
1	34	6	1400	3	1.744	121

3	35	10	1400	3	2.14	113
6	36	8	1800	3	2.011	118
				initial	2.318	81

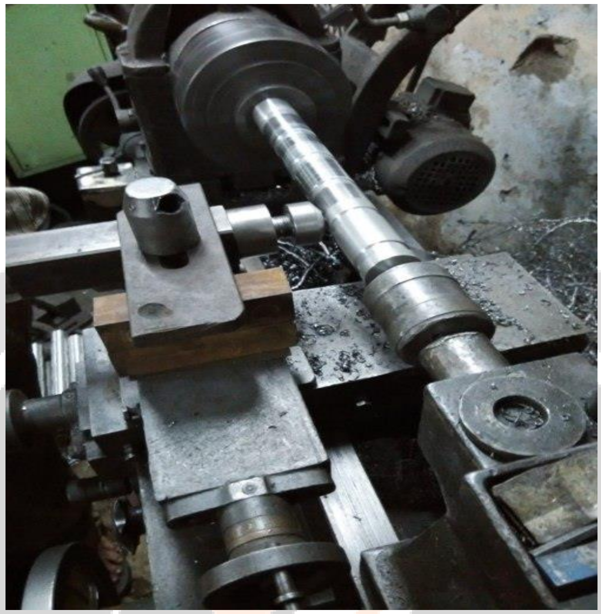


Fig-4:Burnishing Process on conventional lath machine

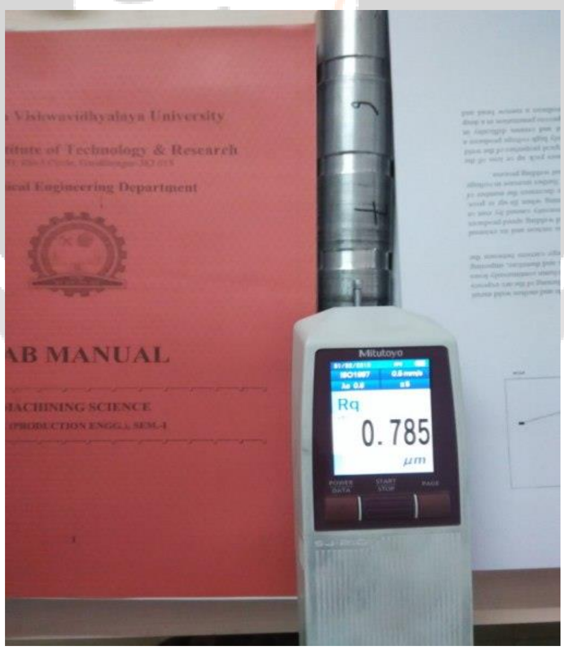


Fig-5: surface roughness measurement by surface roughness tester

Fig-6:surface hardness tester

3.2 ANOVA table for surface roughness

Analysis of variance table [Classical sum of squares - Type II]						
	Sum of		Mean	F	p-value	
Source	Squares	df	Square	Value	Prob > F	
Model	10.99	23	0.48	16.57	< 0.0001	significant
A-Tool Diameter	8.85	3	2.95	102.19	< 0.0001	
B-Speed	0.82	2	0.41	14.26	0.0007	
C-No. of pass	0.40	2	0.20	7.00	0.0097	
AB	0.11	6	0.018	0.62	0.7095	
AC	0.62	6	0.10	3.57	0.0288	
BC	0.19	4	0.048	1.68	0.2188	
Residual	0.35	12	0.029			
Cor Total	11.34	35				

The Model F-value of 16.57 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C, AC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Final Equation in Terms of Coded Factor:

Surface roughness=
+2.11-0.52*A[1]-0.34*A[2]=0.081*A[3]-0.16*B[1] +0.044*B[2]+0.098*C[1]+0.049* C[2] -0.088* A[1]B[1]+0.060* A[2]B[1]+0.035* A[3]B[1]+0.054* A[1]B[2]-0.023* A[2]B[2] -0.090* A[3]B[2]+0.14* A[1]C[1]+0.13* A[2]C[1]-0.066* A[3]C[1] -4.583E-003* A[1]C[2]+0.034* A[2]C[2]+0.051* A[3]C[2]+0.075* B[1]C[1]+0.023* B[2]C[1]-1.778E-003* B[1]C[2]+0.043* B[2]C[2]

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients. The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space. Proceed to Diagnostic Plots (the next icon in progression). Be sure to look at the:

1) Normal probability plot of the studentized residuals to check for normality of residuals.

2) Studentized residuals versus predicted values to check for constant error.

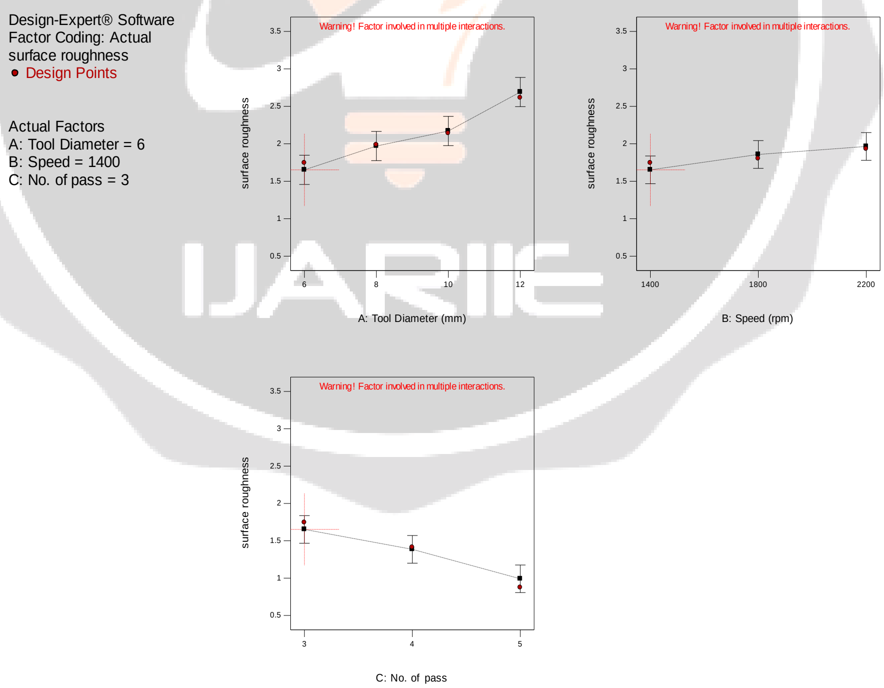
3) Externally Studentized Residuals to look for outliers, i.e., influential values.

4) Box-Cox plot for power transformations.

If all the model statistics and diagnostic plots are OK, finish up with the Model Graphs icon.

3.3 surface roughness graphs

Fig-7:One Factor graph for surface



roughness

- Hear as on graph when we increase tool diameter surface roughness value is also increase
- on based on second graph speed increase surface roughness increase
- on based on third graph no of passes increase surface roughness value decrease.

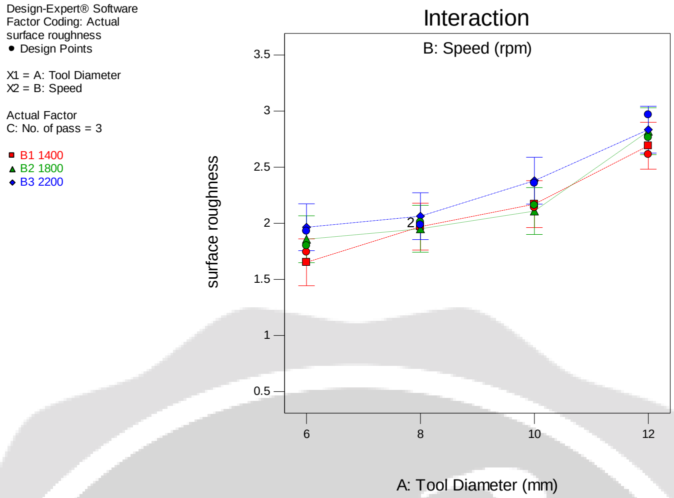


Fig-8:Interaction graph for AB vs surface roughness

- Hear tool dia and speed interaction vs surface roughness graph is generated.
- hear for minimum no of dia using good surface roughness and when increase ball diameter surface roughness value is increase
- as usual seed is minimum surface roughness value is minimum but when speed increase surface roughness value increase
- for 1400RPM and 6 no of dia surface roughness value is minimum and for 2200 RPM and 12 mm of dia surface roughness maximum

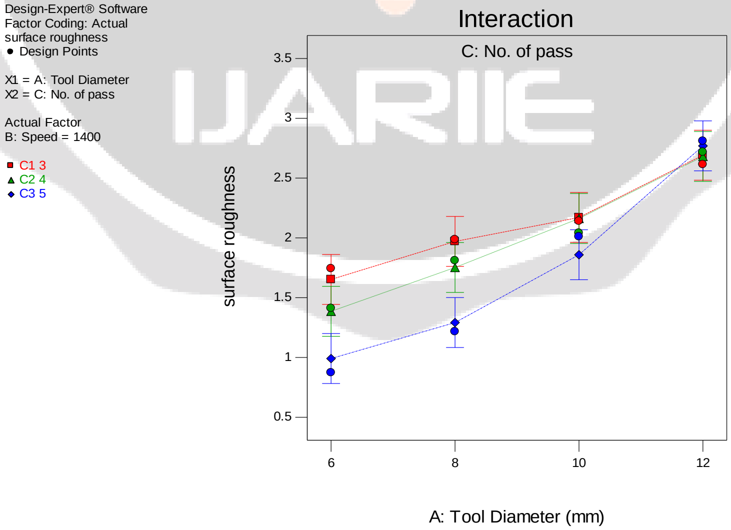


Fig-9:Interaction graph of AC vs surface roughness

- Hear tool dia and no of passes interaction with surface roughness graph is generated.

- Hear minimum dia getting good surface roughness mean surface roughness value is decrease as diameter decrease
- as usual no of passes increase surface roughness value is also decrease
- but for 12 mm dia for no of passes not much affected
- mean at some amount of no of dia surface roughness values increase but minimum no of dia 6 mm and 5 no of passes getting good surface roughness and for 6 mm dia and 5 no of passes maximum surface roughness

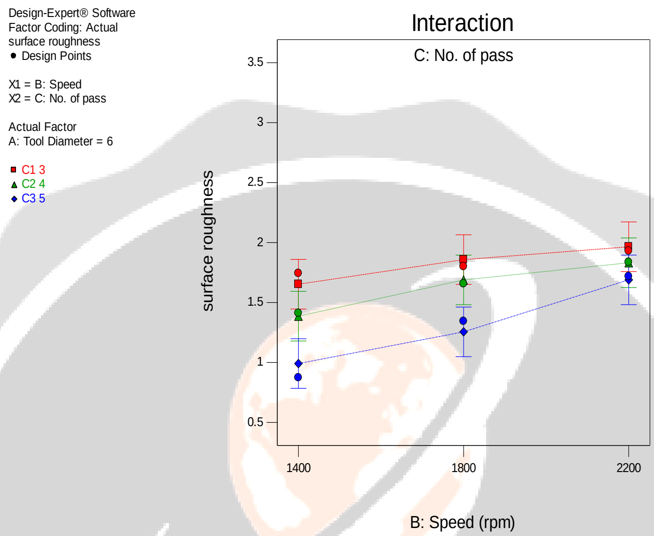


Fig-10:Interaction graph of BC vs surface roughness

- Hear speed and no of passes interaction with surface roughness graph is generated.
- hear for minimum speed applied getting good surface roughness and when increase no of passes surface roughness value is dicrease
- as usual seed is minimum sourface roughness value is minimum but when speed increase surface roughness value increase
- for 1400RPM and 5 no of passes surface roughness value is minimum and for 2200 RPM and 5 no of passes surface roughness maximum

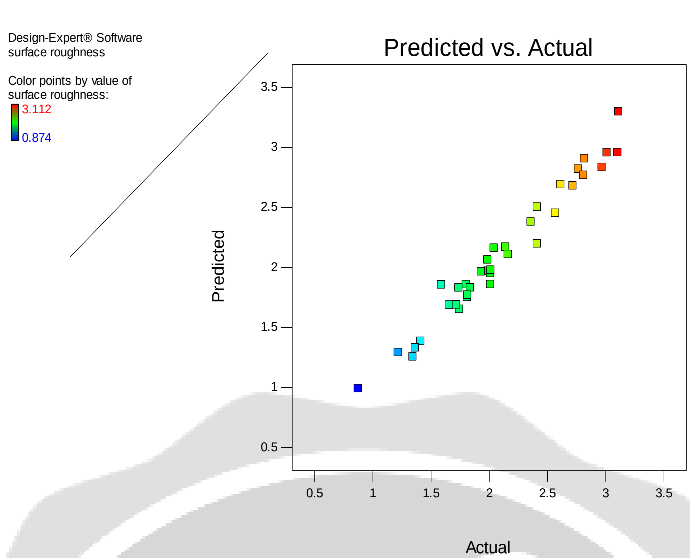


Fig-11:Pridicted vs Actual graph

- Hear as seen in graph predicted vs actual graph is generated
- and in this graph all reading is near at predicted line
- so getting good surface roughness value and graph is significant generated

3.4 ANOVA table for surface hardness

Analysis of variance table [Classical sum of squares - Type II]

	Sum of		Mean	F	p-value	
Source	**Squares**	**df**	**Square**	**Value**	**Prob > F**	
Model	250.69	23	10.90	6.52	0.0008	Significant
A-Tool Diameter	151.64	3	50.55	30.24	< 0.0001	
B-Speed	6.00	2	3.00	1.80	0.2080	
C-No. of pass	33.50	2	16.75	10.02	0.0028	
AB	18.44	6	3.07	1.84	0.1737	
AC	37.61	6	6.27	3.75	0.0245	
BC	3.50	4	0.88	0.52	0.7205	
Residual	20.06	12	1.67			
Cor Total	270.75	35				

The Model F-value of 6.52 implies the model is significant. There is only a 0.08% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, C, AC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Final Equation in Terms of Coded Factors:

surface hardness=
+115.75+0.92* A[1]+2.81* A[2]-2.64* A[3]+0.50* B[1]+0.000* B[2]+0.92*C[1]+0.42* C[2]+0.50* A[1]B[1]+0.94* A[2]B[1]-0.28* A[3]B[1]+0.000* A[1]B[2]-0.22* A[2]B[2]+0.56* A[3]B[2] +1.75* A[1]C[1]-0.81* A[2]C[1]-0.36* A[3]C[1]+0.58* A[1]C[2]+0.36* A[2]C[2]-0.53* A[3]C[2]+0.083* B[1]C[1]+0.083* B[2]C[1]+0.083* B[1]C[2]+0.33* B[2]C[2]

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

Proceed to Diagnostic Plots (the next icon in progression). Be sure to look at the:

1) Normal probability plot of the studentized residuals to check for normality of residuals.

2) Studentized residuals versus predicted values to check for constant error.

3) Externally Studentized Residuals to look for outliers, i.e., influential values.

4) Box-Cox plot for power transformations.

If all the model statistics and diagnostic plots are OK, finish up with the Model Graphs icon.

3.5 surface hardness graphs

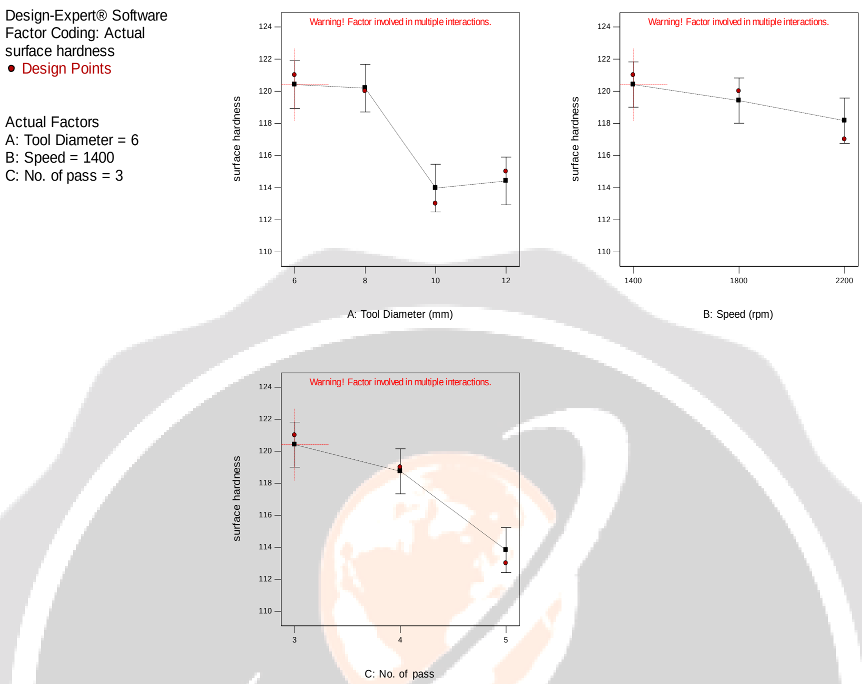


Fig-12:One factor graph for surface hardness

- Hear as on graph when we increase tool diameter surface hardness value is also decrease.
- on based on second graph speed increase surface hardness decrease
- on based on third graph no of passes increase surface hardness value decrease.
- In first graph tool diameter 10mm at that diameter surface hardness value is minimum. but then hardness value is increase for 12mm dia but its not nominal effect is shown in that graph.

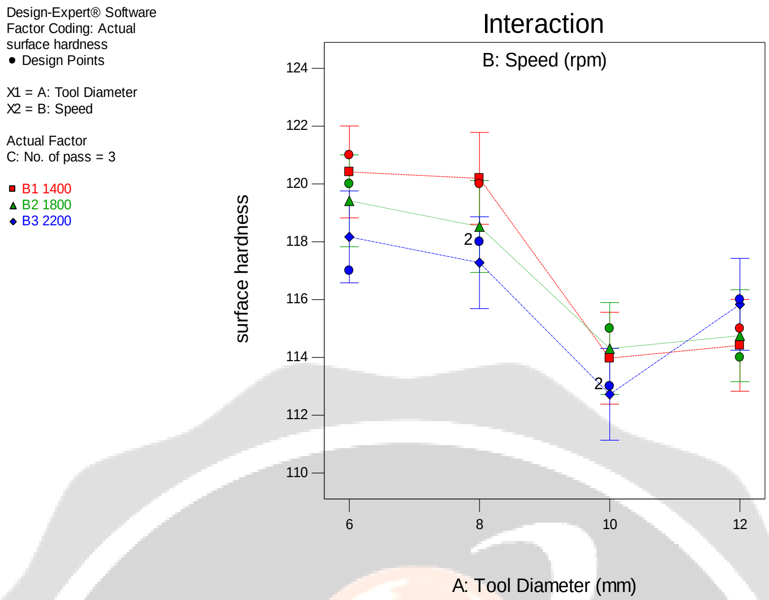


Fig-13:Interaction graph of AB vs surface hardness

- Hear tool dia and speed interaction vs surface hardness graph is generated.
- hear for minimum no of dia using good surface hardness and when increase ball diameter surface roughness value is decrease
- as usual seed is minimum surface hardness value is maximum but when speed increase surface hardness value decrease.
- for 1400RPM and 6 no of dia surface hardness value is maximum and for 2200 RPM and 10 mm of dia surface hardness minimum.
- but 12 mm dia some amount of hardness value is increase.

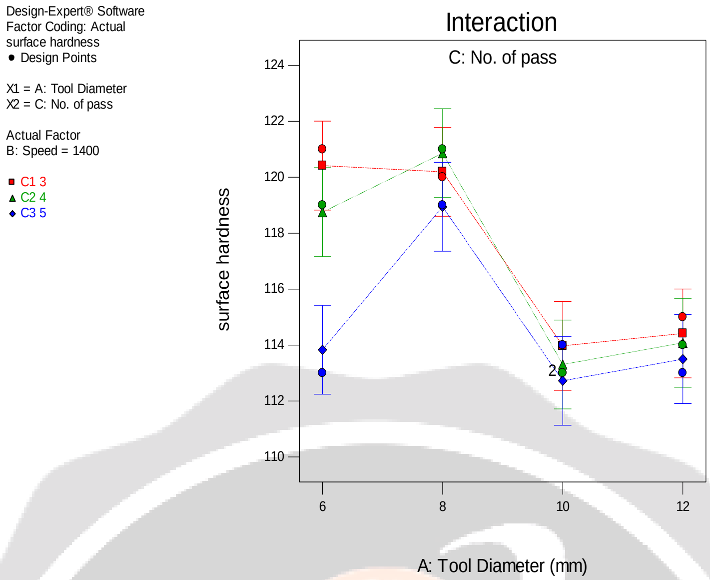


Fig-14:Interaction graph of AC vs surface hardness

- Hear as in graph ball diameter and no of passes vs surface hardness is describe.
- but as seen in graph when no of passes increase but hardness value is decrease.
- as per result for 8mm diameter and 4 no of passes hardness value is maximum.
- for 5 no of passes and 10 mm diameter surface roughness value is minimum find.

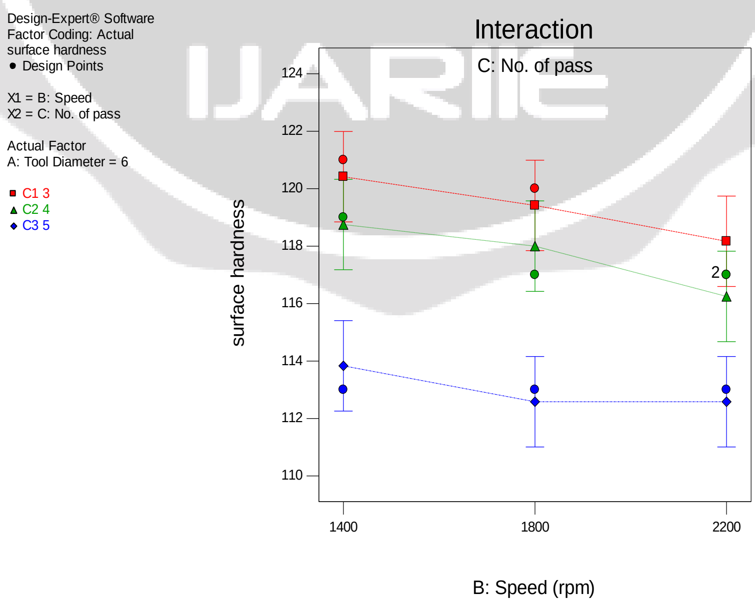


Fig-15:Interaction graph of BC vs surface hardness

- Hear speed and no of passes interaction with surface hardness graph is generated.
- hear for minimum speed applied getting good surface hardness and when increase no of passes surface hardness value is decrease
- as usual seed is minimum surface hardness value is maximum but when speed increase surface hardness value decrease.
- for 1400RPM and 3 no of passes surface hardness value is maximum and for 2200 RPM and 5 no of passes surface roughness minimum.

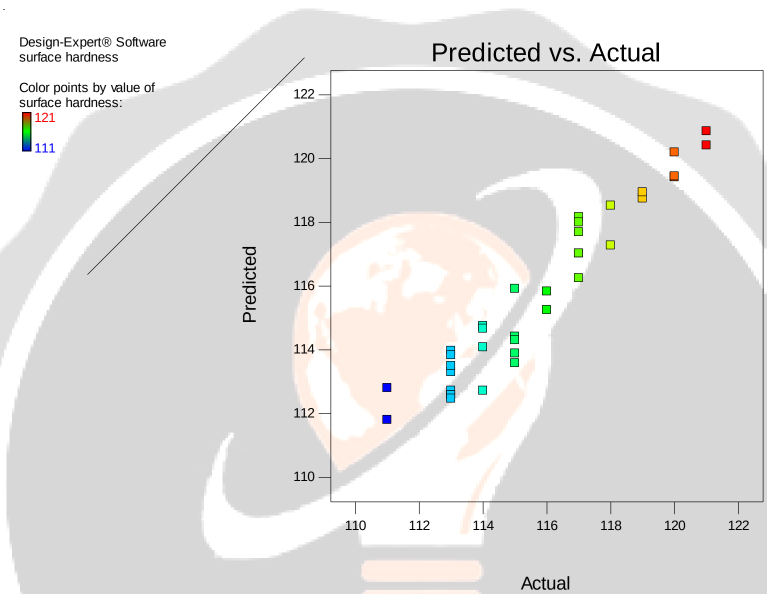


Fig-16:predicted VS actual graph for surface hardness

- Hear as seen in graph predicted vs actual graph is generated
- and in this graph all reading is near at predicted line
- so getting good surface hardness value and graph is significant generated

4. CONCLUSIONS

4.1Surface roughness

- Increase tool diameter surface roughness value is also increase.
- Speed increase surface roughness increase.
- No of passes increase surface roughness value decrease.
- For minimum no of diameter using good surface roughness and when increase ball diameter surface roughness value is increase
- Speed is minimum surface roughness value is minimum but when speed increase surface roughness value increase
- For 1400RPM and 6 no of diameter surface roughness value is minimum and for 2200 RPM and 12 mm of diameter surface roughness maximum
- Minimum diameter getting good surface roughness mean surface roughness value is decrease as diameter decrease

- No of passes increase surface roughness value is also decrease
- For 12 mm diameter for no of passes not much affected
- Mean at some amount of no of diameter surface roughness values increase but minimum no of dia 6 mm and 5 no of passes getting good surface roughness and for 6 mm dia and 5 no of passes Hear speed and no of passes interaction with surface roughness graph is generated.
- Hear for minimum speed applied getting good surface roughness and when increase no of passes surface roughness value is decrease
- As usual seed is minimum surface roughness value is minimum but when speed increase surface roughness value increase
- For 1400RPM and 5 no of passes surface roughness value is minimum and for 2200 RPM and 5 no of passes surface roughness maximum.

4.2 Surface hardness

- Increase tool diameter surface hardness value is also decrease.
- Speed increase surface hardness decrease
- No of passes increase surface hardness value decrease.
- Hear tool diameter and speed interaction vs surface hardness graph is generated.
- Minimum no of diameter using good surface hardness and when increase ball diameter surface roughness value is decrease
- Minimum surface hardness value is maximum but when speed increase surface hardness value decrease.
- For 1400RPM and 6 no of diameter surface hardness value is maximum and for 2200 rpm and 10 mm of diameter surface hardness minimum.
- 12 mm diameter some amount of hardness value is increase.
- No of passes increase but hardness value is decrease.
- For 8mm diameter and 4 no of passes hardness value is maximum.
- For 5 no of passes and 10 mm diameter surface roughness value is minimum find.
- For minimum speed applied getting good surface hardness and when increase no of passes surface hardness value is decrease
- Speed is minimum surface hardness value is maximum but when speed increase surface hardness value decrease.
- For 1400 rpm and 3 no of passes surface hardness value is maximum and for 2200 rpm and 5 no of passes surface roughness minimum.

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