OPTIMIZATION OF BALL BURNISHING PROCESS FOR AA6061 MATERIAL

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ABSTRACT

These Experimental work deals with the optimization of ball burnishing process by newly design ball burnishing tool. The practical work done on conventional lathe machine. In this process we use full factorial method. The work piece material is Aluminium Alloy 6061 and ball material is high chromium high carbon, four balls of different diameter used. In this process spindle speed , burnishing balls with different and number of passes are input parameters and the response parameters are surface roughness and surface hardness. The results are analyzed using Design Expert in order to determine ANOVA analysis method and means of surface roughness and hardness.

Keyword: - *Surface roughness, Surface hardness*

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1. INTRODUCTION

Machining removes certain parts In the present days, the manufacturing good surface finish and dimensional accuracy plays an important role [1]. Surface finish is very important not only as an indication of expert workmanship but it has huge effects on the life and function of the component. Burnishing processes are considered in industrial cases in order to restructure surface characteristics [11].

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 can be easily performed on machine tools and it is relatively simple. Besides giving a good surface finish it also improves and increases micro hardness, fatigue life and wear resistance of the components. Burnishing is surface finishing process it is cold working process also which carried out on material surfaces to enhance surface qualities and induce compressive residual stresses [9]. A burnishing tool typically consists of a hardened sphere which is pressed on the part which being processed which results in plastic deformation of asperities into valleys [14]. In burnishing process in which asperities are compressed beyond yield strength against load.

The principle of the burnishing process, shown in Figure 1.1 is based on the rolling movement of a tool (a ball or a roller) against the workpiece surface, a normal force being applied at the tool. 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. [11][W1]

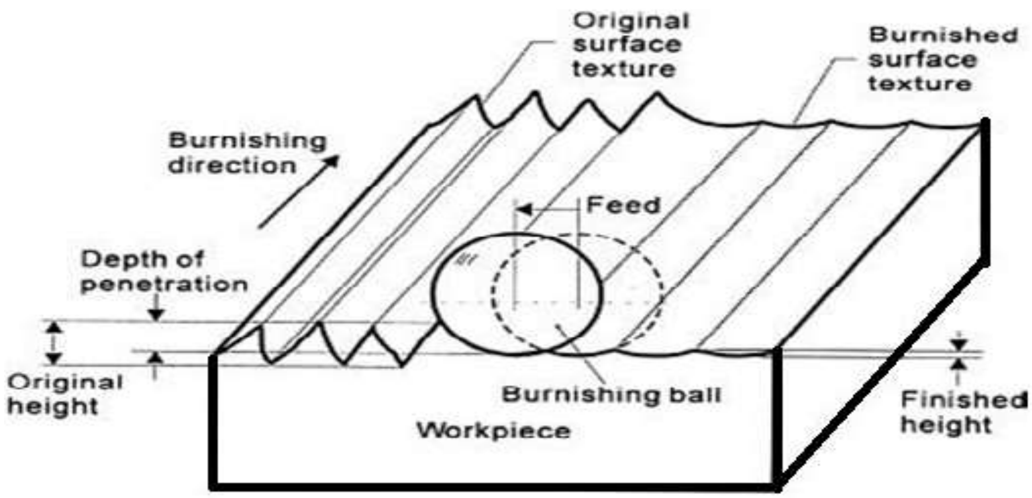

Fig. 1.1 schematic diagram of ball burnishing process

1.2 Historical background

The phenomenon of erosion of metals 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.

Low plasticity burnishing (LPB) is a method of metal improvement that provides deep stable surface compressive residual stresses with little cold work for improved damage tolerance and metal fatigue life. Unlike LPB, traditional burnishing tools consist of a hard wheel or fixed lubricated ball pressed into the surface of an asymmetrical work piece with sufficient force to deform the surface layers, usually in a lathe. In 1950 burnishing became the object of a systematic study including theoretical approach. In present days development of computer techniques and finite element approach made possible creation of models regarding the intimate phenomena in the surface layer.

LPB was developed and patented by Lambda Technologies Company from Cincinnati, Ohio, in 1996. Since then LPB has been developed to produce compression in a wide array of materials to mitigate surface damage, including fretting, corrosion pitting(PC), stress corrosion cracking (SCC), and foreign object damage (FOD).

1.2 Ball Burnishing Process

The most basic burnishing tool is one designed for use in a conventional lathe and CNC lathe machine tool. As chuck on the machine tool rotates the workpiece, the burnishing tools apply the force on it for fast and efficient finishing as shown in fig 2 Applying extra heat to the object during the process often increases the effects of burnishing.

In Burnishing rigidly fixed tools creates a solid kinematic link with the workpiece as in turning process. The burnisher is fixed on a machine tool at tool post. With rigid burnishing the burnisher is indented into the surface for a predetermined depth which varies from several microns to several hundredths of a millimeter. The depth depends on the plasticity of the material, surface roughness and burnishing ball radius. The tool is pressed elastically towards workpiece by spring or hydraulically means [5]. Burnishing with a rigidly fixed tool can be recommended for processing of especially precise machined parts for high-precision machines. [W1]

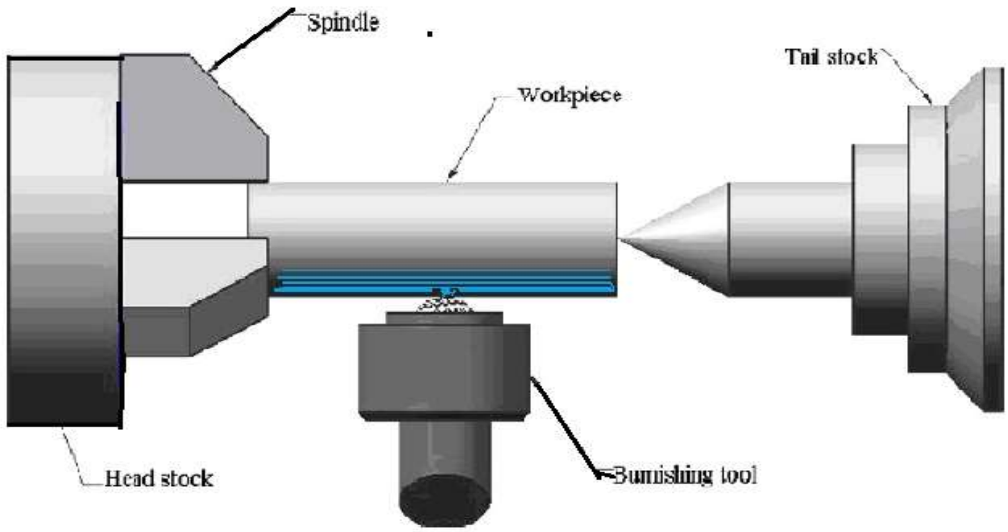

Fig 1.2 schematic representation of ball burnishing setup

2. LITERATURE REVIEW

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. Two non-ferrous work piece materials, namely free machining brass and cast Al-Cu alloy, were used. 1. An increase in initial surface roughness will cause an increase in the surface roughness of the ball burnished work pieces, but it has no effect on the surface hardness of these metallic work pieces. 2. 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. 3. An increase in ball diameter will cause a decrease in: (i) the final surface roughness; (ii) the total amount of the increase in hardness; (iii) the wear resistance. 4. The use of a lubricant in the burnishing process causes a general reduction in surface roughness and in the amount of the increase in surface hardness, but change in the viscosity of the lubricant seems to have no significant effect on either of the above-mentioned properties. (Adel Mahmood Hassan, 2000)

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. A mathematical model was established to correlate the most pronounced parameters, i.e. the burnishing force and the number of tool passes, with the surface finish Hear using ball diameter 10mm used brass work piece (wt.%) where: Cu 58.64; Zn 37.78; Pb 1.9; Sn 0.83; Fe 0.24; Al 0.11; Ni 0.1; and Si 0.07. a speed of 24 m/ min and a feed rate of 0.1 mm 1/rev, a second-order mathematical model has been developed based on the response surface method to relate the surface roughness and the two main burnishing parameters (force and number of tool passes). The theoretical optimum surface roughness obtained was 0.172 mm with a burnishing force of 20.7 kgf (203 N) and two passes of the burnishing ball. (A.M.Hassan, 1998)

Tao Zhang, Nilo Bugtai, Ioan D. Marinescu, In this paper Burnishing of aerospace alloy: A theoretical–experimental approach is done Hear burnishing tools 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 TRIMFIVHPFIE814 soluble oil and 95% water by stirring devices, due to its versatile edge, which can perform well in machining processes and especially 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)

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. The analytical model is verified in the following on the basis of experimental tests. For this purpose, rolling experiments on thermally coated surfaces (WC12Co coating) using a hydrostatic rolling tool (HG13; Ecoroll) with a ball diameter of 12.7 mm were carried out (Lars Hiegemann, 2014)

Ravi butola, Jitendra Kumar, Dr Qasim Murtaza, In this Design and Fabrication of Multi Ball Burnishing for Post Machining Finishing Process Using No of balls in the burnishing ool are 16,Radius of each ball is 5.5mm feed of milling table is 38mm/min . The surface roughness with fabrication burnishing tool was found 0.005136µm. (Ravi Butola, 2013

Fang-Jung Shiou, Chuing-Hsiung Chuang, In this paper The optimal plane surface burnishing force for the PDS5 plastic injection mold steel was about 420N for the rolling-contact type and about 470N for the sliding-contact type, based on the results of experiments has also been proposed to improve the surface roughness of the test objects in this study. The surface roughness of a fine milled inclined surface of 60 degrees can be improved from Ra 3.0_m on average to Ra 0.08_m (Rmax 0.79_m) on average using force compensation, whereas the surface roughness was Ra 0.35_m (Rmax 4.56_m) on average with no force compensation.

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, consists of three burnishing balls (f=5 mm, in symmetrical positions, with 120° radial degree) that are held in the component, supported by three screws. The electrode tool was fed downward under servo control into the workpiece in this EDM facility. The machining process in this study proceeds in two separate stages. First, a hollow-tube electrode (f=19 mm, thickness 3 mm) was used to drill through the workpiece. Secondly, an electrode tool of B-EDM was used to machine through the workpiece to obtain a finer surface effect. In The improvement of surface roughness increases from 55 to 92% with various combinations of experimental parameters. 2. The B-EDM process approaches both a higher machining rate and a finer surface roughness. Furthermore, the B-EDM process can achieve an approximately constant machining rate. (Biing hwa yan, 2000)

3. DESIGN OF EXPERIMENT

DOE is a technique of defining and investigating all possible combinations in an experiment involving multiple factors and to identify the best combination. In this, different factors and their levels are identified. Design of experiments is also useful to combine the factors at appropriate levels each within the respective acceptable range, to produce the best results and yet exhibit minimum variation around the optimum results. The design of experiment is used to develop a layout of the different conditions to be studied. And experiment design must satisfy two objectives: first, the number of trials musty be determined; second, the conditions for each trial must be specified.

Three factors are chosen the design becomes a 3 level 3 factor full factorial design. The version 17 of the MINITAB software was used to develop the experimental plan for L27 Orthogonal Array. In this experiment other parameters are fixed,

Table.1 Input parameter with Levels value

Sr. No.	Machining process parameter	Level 1	Level 2	Level 3	Level 4
1	Ball Diameter (mm)	6	8	10	12
2	Spindle Speed(rpm)	400	800	1200	-
3	Number of pass	3	4	5	-

4. EXPERIMENT SETUP

The machine used for experiments is HMT TL-20 Lathe Machine

4.1 Work-piece material

Aluminum alloys are used in many applications in which the combination of high strength and low weight is attractive in air frame in which the low weight can be significant value. Al 6351 is known for its light weight and good corrosion resistance to air, water, oils and many chemicals. Thermal and electrical conductivity is four times greater than steels. It has higher strength amongst the 6000 series alloys. Alloy 6351 is known as a structural alloy, in plate form. This alloy is most commonly used for machining. Though relatively a new alloy the higher strength of 6351 has replaced 6061 alloy in many applications. The AA 6351 aluminum alloy is used in manufacturing due to its strength, bearing capacity, ease of workability and weld ability. The advantages of Al 6351 have several important performance characteristics that make them very attractive for aircraft structures, namely light unit weight, only one third that of steel, strength comparable to typical other aluminum alloys, excellent corrosion resistance, with negligible corrosion even in the presence of rain and other drastic conditions, high toughness and resistance to low-ductility fracture even at very low temperatures.

Table 2 Chemical composition of work-piece material

Material	Mn	Si	C	Zn	Cu	Cr
Aluminum Alloy - 6061	0.984 %	0.561 %	0.047 %	0.025 %	0.199 %	0.020 %

5. EXPERIMENT RESULTS

The effect of process parameters on the machining parameter for both plain brass wire and zinc coated brass wire is recorded in the table. Total 27 experiments done on the WEDM machine based on the full factorial method and summarized in the following table.

For plain brass wire

Table 3 Experiment Results

STD	RUN	Ball Diameter(mm)	Speed of spindle (rpm)	No of passes	Surface roughness(micro meter)	Surface hardness second(BHN)
15	1	10	400	4	2.041	113
20	2	12	800	4	1.877	114
5	3	6	800	3	1.801	120
31	4	10	800	5	1.589	111
18	5	8	800	4	1.738	120
8	6	12	800	3	2.765	114
30	7	8	800	5	1.364	117
25	8	6	400	5	0.874	113
23	9	10	1200	4	1.618	111
17	10	6	800	4	1.657	117
13	11	6	400	4	1.412	119
19	12	10	800	4	1.814	115
14	13	8	400	4	1.811	121
9	14	6	1200	3	1.931	117
27	15	10	400	5	1.457	114
24	16	12	1200	4	1.774	116

12	17	12	1200	3	2.968	116
29	18	6	800	5	1.344	113
26	19	8	400	5	1.217	119
21	20	6	1200	5	1.718	113
16	21	12	400	4	2.378	114
36	22	12	1200	5	2.104	115
7	23	10	800	3	2.162	115
11	24	10	1200	3	2.358	113
33	25	6	1200	4	1.837	117
22	26	8	1200	4	1.537	117
32	27	12	800	5	1.661	115
10	28	8	1200	3	1.987	118
2	29	8	400	3	1.987	120
35	30	10	1200	5	1.991	113
4	31	12	400	3	2.614	115
34	32	8	1200	5	1.814	117
28	33	12	400	5	1.678	113
1	34	6	400	3	1.744	121
3	35	10	400	3	2.14	113
6	36	8	800	3	2.011	118
				initial	2.318	81

6. RESULT AND DISCUSSION

After performing the experiment for all 36 runs and measuring the output parameters like surface hardness and surface roughness for aluminum alloy 6061, whatever results generated are discussed in this chapter.

6.1 Main effect plots for input parameter v/s output parameter for plain brass wire

The equation in terms of coded factors can be used to make proper predictions about the response for given levels of each factor respectively. By default, high levels of the given factors are coded as +1 and the low levels of the given factors are coded as -1. All of coded equations are useful for identifying the relative impact of the factors by comparing the given factor's coefficients. This equation in the terms of actual factors can be used to make some predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each of the factors

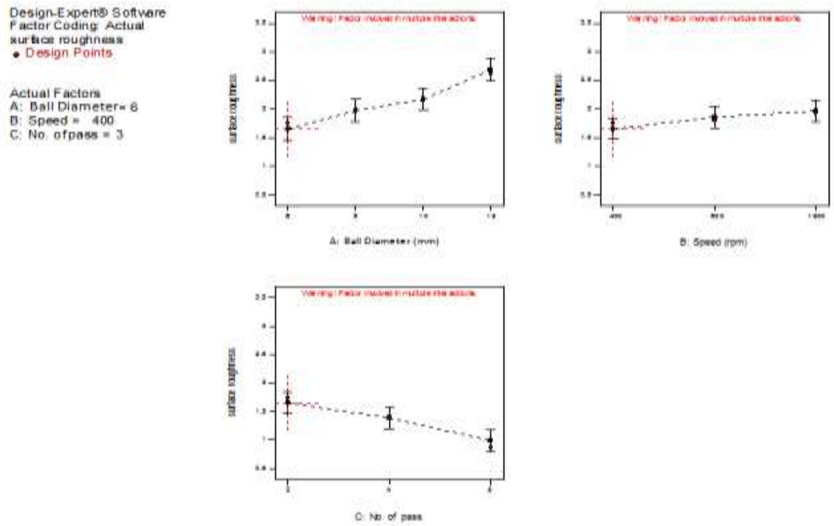

Figure 6.1 One Factor graph of surface roughness

Hear as from 6.1 when we increase ball diameter in the process then the surface roughness value is also increase with it. From the second graph we can say when speed increase surface roughness increase and from the third graph we can see that when no of passes increase surface roughness value decrease.

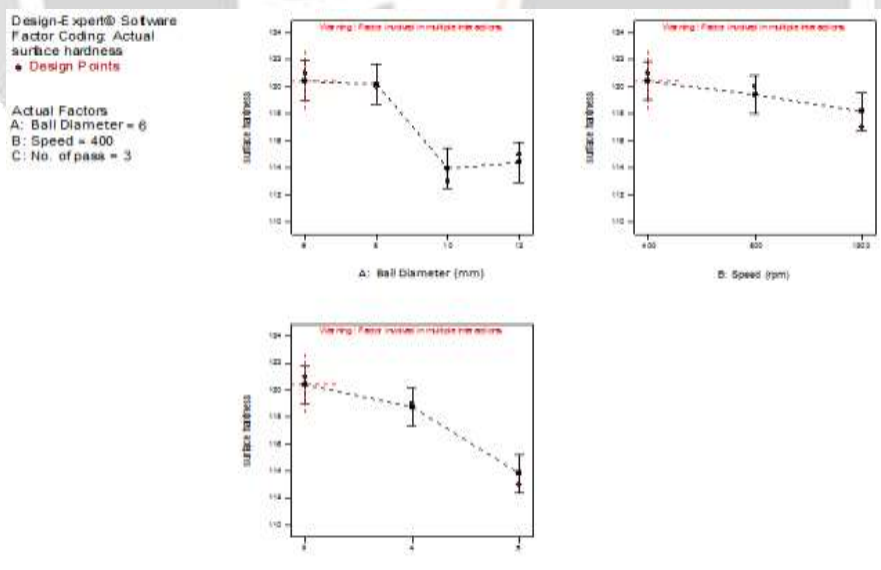

Figure 6.2 One factor graph for surface hardness

Hear as on graph when we will increase the ball diameter surface hardness value will also decrease. From the second graph we can say that the speed increase surface hardness decrease. Third graph no of passes suggest that increase ball dia surface hardness value decrease. In first graph ball diameter is 10mm at that diameter surface hardness value is minimum. but then hardness value is increase for 12mm dia but it is not nominal effect is shown in that graph.

6.2 Main effect plots for input parameter v/s output parameter for zinc coated brass wire

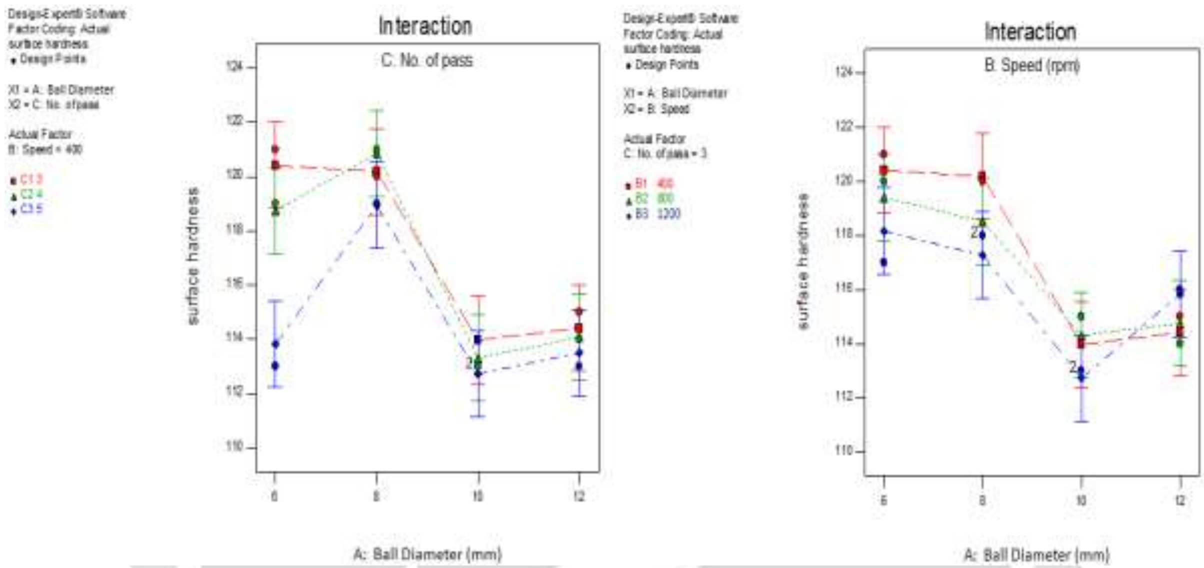

Figure 6.3 Interaction graph of AC VS Surface roughness

Hear as in graph ball diameter and number of passes vs surface hardness is describe. From the graph we can say when no of passes increase but hardness value is decrease. As per result from graph for 8mm dia and 4 no of passes hardness value is maximum. For 5 no of passes and 10 mm dia surface roughness value will be minimum we find.

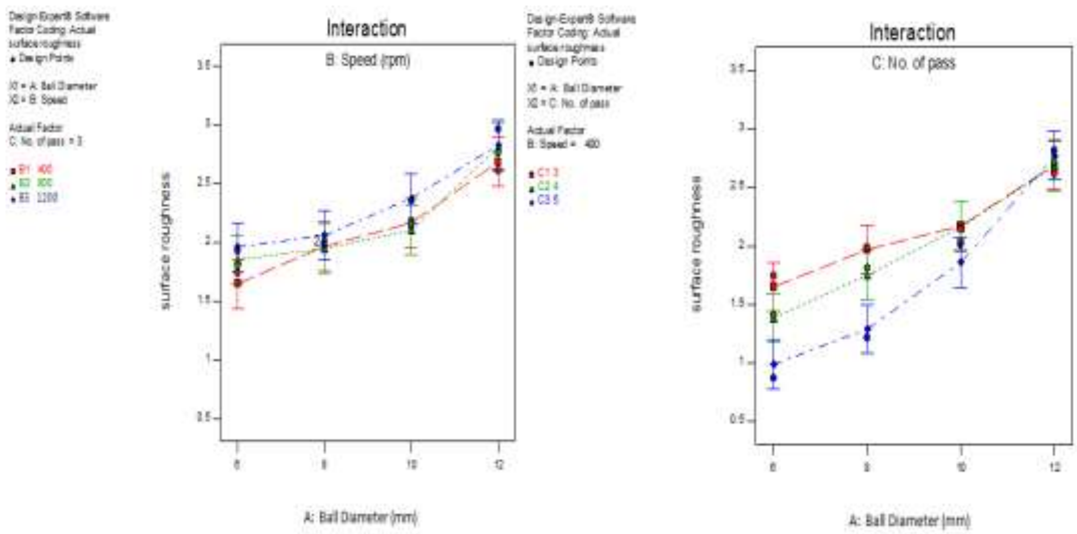

Figure 6.4 Interaction graph for AB versus surface roughness

The ball diameter and speed interaction verses surface roughness graph is generated here in figure. Hear, when we use for minimum no of ball diameter the surface roughness of the work piece increase ball diameter surface roughness value is increase. When the speed is minimum the surface roughness's value is minimum but when it increase surface roughness value gradually increase, For 400 RPM and 6 no of ball diameter surface roughness's value is minimum and for 1200 RPM and 12 mm of ball diameter surface roughness maximum.

7. CONCLUSION AND FUTURE SCOPE

In the presented work, experiments are carried out for Surface hardness, surface roughness with variables as ball diameter, spindle speed and number of pass. There are 36 experimental readings taken for all variables to conduct the parametric study.

Finally it can be concluded that:

- 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 400RPM and 6 no of diameter surface roughness value is minimum and for 1200 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 diameter 6 mm and 5 no of passes getting good surface roughness and for 6 mm diameter 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 400RPM and 5 no of passes surface roughness value is minimum and for 1200 RPM and 5 no of passes surface roughness maximum.

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FUTURE SCOPE

- The model can be developed with different work piece and different input parameter.
- Responses like roughness, strength, machining cost etc are to be considered in further research.
- The results can be analyzed using other optimization techniques such as neural network, fuzzy logic, genetic algorithm, particle swarm optimization etc., and their effectiveness can be compared.

8. REFERENCES

1. A.M.Hassan, H.-J. (1998). Burnishing force and number of ball passes for the optimum surface finish of brass components. ELSEVIER , 176-179.

2. Adel Mahmood Hassan, A. M. (2000). The effects of initial burnishing parameters on non-ferrous components. ELSEVIER , 115-121.

3. Biing hwa yan, C. c. (2000). Fesibility study of rotary electrical discharge machining with ball burnishing for composite. Pergamon, 1403-1421.

4. C H fu, M. P. (2014). Austenite-martensite phase transformation of biomedical nitinol by ball burnishing. ELSEVIER , 3122-3130.

5. Fang jung shiou, C. h. (2003). Freeform surface finish of plastic injection mold by using ball-burnishing process. ELSEVIER , 248-254.

6. Fang-jung shiou, C.-H. C. (2010). Precious surface finish of the nold steel PDS5 using an innovative ball burnishing tool embedded with a load cell. ELSEVIER , 76-84.

7. Lars Hiegemann, C. W. (2014). Analytical prediction of roughness after ball burnishing of thermally coated surfaces. ELSEVIER , 1921-1926.

8. M H El-Axir, O. M. (2008). Improvements in out-of-roundness and microhardness of inner surface by internal ball burnishing process. ELSEVIER , 120-128.

9. M H El-Axir, O. M. (2008). Study on the inner surface finishing of aluminium alloy 2014 by ball burnishing process. ELSEVIER , 435-442.

10. Pascale Balland, L. T. (2013). Mechanics of the burnishing process. ELSEVIER , 129-134.

11. Ravi Butola, J. k. (2013). Design and febrication of multi ball burnishing for post machining finishing process. Indian journal of applied research , 202-204.

12. Surface Roughness Tester SJ-20p Manual.

13. Tao Zhang, N. B. (2014). Burnishing of aerospace alloy;A theoretical-experimental approach. ELSEVIER .

14. W Koszela, P. P. (2013). Possible of oil pocket creation by the burnishing technique. ELSEVIER .