OPTIMIZATION OF PROCESS PARAMETERS OF BURNISHING OPERATATION OF EN 31MATERIALUSING TAGUCHI METHOD

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ABSTRACT

Due to development in technology expectation are increased from manufacturing industry. The expected life of any component can be increased without increase its cost. Life of components mainly depends on surface properties such as surface roughness and surface hardness. Also for concurrent manufacturing surface finish plays vital role. Machined surface by conventional process have inherent irregularities and marks .To make the surface smooth conventional finishing processes such as grinding ,honing and lapping have been employed . Burnishing is chipless surface improvement process in which a large contact pressure is applied on the surface of workpiece by a smooth hard roller or a ball burnishing tool to cause plastic deformation of surface irregularities. When high burnishing pressure exceeding the yield strength of workpiece material plastic flow of original asperities takes place which suppress all the texture of the rough surface and peaks are converted into valleys and it leads to smooth the surface. Burnishing process helps to eliminate secondary operations for significant time and cost reducing, while at the similar time improving the excellent quality of the product. Burnishing process changes the properties of the surface, it will cause improvements in surface hardness, wear resistance, fatigue resistance, yield and tensile strength and corrosion resistance. Burnishing can be carried out using conventional machines, such as lathe and CNC machine.

Keyword: - *Surface hardness[1], Burnishing[2], Surface roughness[3], ANOVA[4], Minitab 16[5].*

1. INTRODUCTION

1.1 Burnishing Process

In the burnishing process, the surface properties of the material changes as a result of plastic deformation process, which produces a high surface finish by the rotation of tool over the surface. The tool may further consist of a ball or a roller as per requirement. We know that surface finishing is a process which doesn't involve removal of material. It basically helps in minimizing the distance of peaks from its mean and ultimately decreases the roughness of surface.

1.2 Working Principle of Burnishing

Burnishing process is a highly flexible operation that decreases surface irregularities and improves the dimension of parts without any further requirement of tooling on simply turning the workpiece into convention lathe. It reduces the machinery cost, human effort and time required for remounting of components. The tool used can be a single ruler or multiple roller which are held in tool post. This tool is mounted on the tool post of the lathe. When the tool gets pressed against the rotating workpiece, the frictional force comes in picture between the roller and the workpiece. The direction of the rotation of the workpiece is always opposite to that of the tool. Burnishing process is sometimes also known as cold working process.

1.3 Parameters of Burnishing

Following parameters plays vital role in optimization of burnishing process.

1. Burnishing Speed:
Surface roughness start to decreases with increase in speed due to increases in compressive deforming force and the stability of burnishing tool. But after certain limit it start to decrease.

2. Feed Rate:
The height of surface irregularities and roughness is determined by feed -rate of the ball which is in the general range of 0.1 to 0.2 mm/rev.

3. Number of burnishing passes:
It is responsible to control the surface roughness because more number of passes when used, more surface irregularities

4. Depth of penetration:
If burnishing force increases it increases depth of penetration, the roughness value decreases up to a certain limit and then start to decrease. The force at this point is optimum force and optimum depth of penetration.

5. Ball Material:
Burnishing process is carried out with hard ball and roller. The material of ball/roller have an impact on surface roughness and micro hardness of burnished component. Carbon chromium steel material is used for ball/roller as it is freely available in market.

6. Ball Diameter:
Burnishing process is carried out with hard ball and roller. The material of ball/roller has an impact on surface roughness and micro hardness of burnished component. Radius of 4mm for round diamond sliding burnishing tool to a diameter upto 18mm.

7. Lubrication:
Lubrication are used because of heat is generated due to the high exerting pressure in the process. Lubricants are Kerosene, diesel, soluble oil. Society of Automotive Engineers (SAE) 40 engine oil.

8. Initial Surface Roughness:
Initial surface roughness of work piece plays a vital role in burnishing process. Surface roughness is due to inherent kinematic differences of the cutting process. Various parameters of surface roughness are measured by Surface Roughness Tester.

From literature it is observed that very less work has been carried out on surface roughness and surface hardness of burnishing process. The main objective of this project work is to Design such a tool which is suitable for burnishing process and also to investigate surface roughness and Micro hardness of EN31 with various burnishing parameters. In this experiment orthogonal array is used with four controllable factors like Feed , force, ball diameter & number of passes with three levels of each to find out optimum level of process parameters for burnishing operation. The ANOVA results used to find out significant factor and percentage contribution of individual factor.

2. EXPERIMENTAL METHODOLOGY

2.1 Experimental Design

In the current research, four control factors such as Feed, Burnishing force, Ball diameter and Number of passes were considered based on author's preliminary investigation. Each factor was examined at three level to explore the non-linearity effects. The selected control parameters and their levels are illustrated in table .According to Taguchi method, L9 orthogonal array with 4 columns and 9 rows was selected, each control factor is assigned to a column and 9 distinct factor combinations are offered. Thus 9 experiments are enough to analyze the entire burnishing experimental design space using L9 orthogonal array.

Table -1: Control factors and their levels

Level of Experiment	Control Factors and their Code			
	Feed (A) (mm/rev)	Force (B)	Ball Diameter (C) (mm)	Number of passes (D)
1	0.035	17.00	9	1
2	0.07	29.75	10	2
3	0.105	42.50	11	3

The FANUC CNC was used to perform the burnishing experiments. The CNC is equipped with maximum Speed of 2000rpm and 3.5KW spindle power. The work material used in this study is an EN31, in the form of work bars of 20.00mm diameter and its chemical composition is given in table. Initially EN31 bars were turned under minimum quantity lubrication (MQL) condition, using kerosene with flow rate of 150ml/hr, cutting speed 200rpm, depth of cut 0.55mm and feed of 0.12mm/rev. A polycrystalline diamond (PCD) insert with nose radius 0.8mm was used as cutting tool. The effect of the burnishing process depends on the initial surface roughness i.e workpiece condition due to previous machining. The bars were finish turned because the lowest burnishing surface roughness is proportional to initial surface roughness.The pre-machined average roughness was found to be in the range of 0.355µm to 1.5µm, hardness obtained was around 250Hv. In the present investigations, external ball burnishing tests were performed as per the experimental plan under lubricated conditions using kerosene. The workpiece to be burnished was clamped by the chuck .Both cutting tool and burnishing tool were mounted on the tool holder. The proper programming was done on CNC. The burnishing process was applied after the turning process to keep the same turning alignment and to overcome the roundness error.The workpieces were prepared by using specifically designed ball burnishing tool. A balls of 9mm, 10mm, 11mm which are made up of tungsten carbide material was used. Preliminary analysis reveals that large diameter balls are found to be more effectual in improving the surface finish, whereas the small diameter balls seem to be more efficient in enhancing the surface hardness.

3. RESULT & DISCUSSION

Orthogonal array is one of the Taguchi tool, which takes out the quantity of test required, decreases the cost, and reduce the time of trials.(5) The Orthogonal array L_9 is shown in Table 2. Taguchi gives three types of quality characteristics Smaller the better, Nominal the better and Larger the better.

Table -2: For feed 0.12mm/rev

Exp. run	**Process parameters**				**Experimental results**					
	feed mm/rev	**Force N**	**Ball Dia. mm**	**No. of passes**	**Surface Roughness**			**Surface Hardness**		
A	A	B	C	D	**(□m)**		**Average**	**HRA**		**Average**
1	0.035	17.00	9	1	0.146	0.195	0.171	58.000	59.000	59
1	0.035	29.75	10	2	0.199	0.21	0.205	59.000	60.000	60
1	0.035	42.50	11	3	0.16	0.175	0.168	59.000	59.000	59
2	0.070	17.00	10	3	0.179	0.185	0.182	59.000	58.000	59
2	0.070	29.75	11	1	0.23	0.225	0.228	56.000	58.000	57
2	0.070	42.50	9	2	0.392	0.386	0.389	59.000	59.000	59
3	0.105	17.00	11	3	0.577	0.517	0.547	49.000	50.000	50
3	0.105	29.75	9	2	0.082	0.092	0.087	57.000	58.000	58
3	0.105	42.50	10	1	0.216	0.224	0.220	59.000	58.000	59

3.1 Taguchi method and signal to noise ratio

Taguchi method is one of the simple and effective solutions for parametrs design and experimental planning. In this method, signal-to-noise (S/N) ratio is used to present a performance characteristics and the largest value of S/N ratio ios required. The subsequent S?N ratios fort each trial of L9 are summarized in table 3.

Table -3: Orthogonal array, parameters level and corresponding S/N ratios

Exp. run	Process parameters				Experimental results		S/N Ratio	
	feed mm/rev	Force N	Ball Dia. mm	No. of passes	Surface Roughness	Surface Hardness	Surface Roughness	Surface Hardness
A	A	B	C	D	(□m)	HRA	(□m)	HRA
1	0.035	17.00	9	1	0.171	59	15.365	35.3431
1	0.035	29.75	10	2	0.205	60	13.7861	35.4903
1	0.035	42.50	11	3	0.168	59	15.5197	35.4170
2	0.070	17.00	10	3	0.182	59	14.7986	35.3431
2	0.070	29.75	11	1	0.228	57	12.8604	35.1175
2	0.070	42.50	9	2	0.389	59	8.2010	35.4170
3	0.105	17.00	11	3	0.547	50	5.2403	35.8921
3	0.105	29.75	9	2	0.087	58	21.2096	35.1934
3	0.105	42.50	10	1	0.220	59	13.1515	35.3431

There are 3 types of S/N ratios – the Smaller the better, the Larger the better and the nominal the better. The S/N ratio with the smaller the better characteristics that can be expressed as

$$S/N = -10\log_{10}\left(1/n \sum_{j=1}^{n} y^2\right)$$

The S/N ratio with the higher the better characteristics that can be expressed as

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

The S/N ratio with the nominal the better characteristics that can be expressed as

$$S/N = -10\log_{10}\left(1/ns \sum_{j=1}^{n} y_{ij}^2\right)$$

where y_{ij} is the i^{th} experiment at the j^{th} test, n is the total number of the tests for given (j^{th}) response and s is the standard deviation

3.2 ANOM and ANOVA

The ananlysis of means (ANOM) based on S/N ratio was performed to decide the optimal levels of control factors; the summary is presented in tables. The level of control factor with highest S/N ratio is optimal level

Table -4: ANOM table and ANOVA of surface roughness based on S/N ratio

Factors	Levels			Max	Optimum level	DoF	Sum of Square	Mean Square	F value	% contribution
	1	2	3							
A	**14.8904**	11.9533	13.2005	14.8904	1	2	13.04	6.52	0.21	7.88
B	11.8014	**15.9520**	12.2908	15.9520	2	2	30.87	15.44	0.50	18.67
C	**12.2394**	13.9121	11.2068	13.9121	1	2	49.13	24.57	0.80	29.71
D	13.7925	**14.3989**	11.8528	14.3989	2	2	10.61	5.305	0.17	6.42
Error						2	61.74	30.87	1.00	37.33
Total						8	165.39			

Table 5: ANOM table and ANOVA of surface hardness based on S/N ratio

Factors	Levels			Max	Opt.level	DoF	Sum of Square	Mean Square	% contribution
	1	2	3						
A	**35.4168**	35.2926	34.8095	35.4168	1	2	0.62	0.31	31.66
B	34.8594	35.2671	**35.3924**	35.3924	3	2	0.47	0.23	23.89
C	35.3178	**35.3922**	34.8089	35.3922	2	2	0.60	0.30	30.63
D	35.2679	**35.3669**	34.8841	35.3669	2	2	0.39	0.195	19.99
Error						2	-0.12	-0.06	-6.17
Total						8	1.95		

The Analysis of variance (ANOVA) based on S/N ratio has been performed to know the relative importance of each of the control factors. Tables and present the results of ANOVA for surface roughness and hardness respectively. From ANOVA, it is observed that burnishing speed and burnishing feed plays an important roles in minimizing the surface roughness while burnishing force have least effect.

3.3 Analysis of Surface roughness

The direct effect plots are generated using MINITAB software for investigaring the influence of burnishing process parameters on surface roughness and hardness. Optimum level for surface roughness given by ANOM and ANOVA calculation are A1B2C1D2, that is A is Feed 0.035 mmrev, B is Force 29.75N, C is Ball diameter 9mm and D is number of passes.

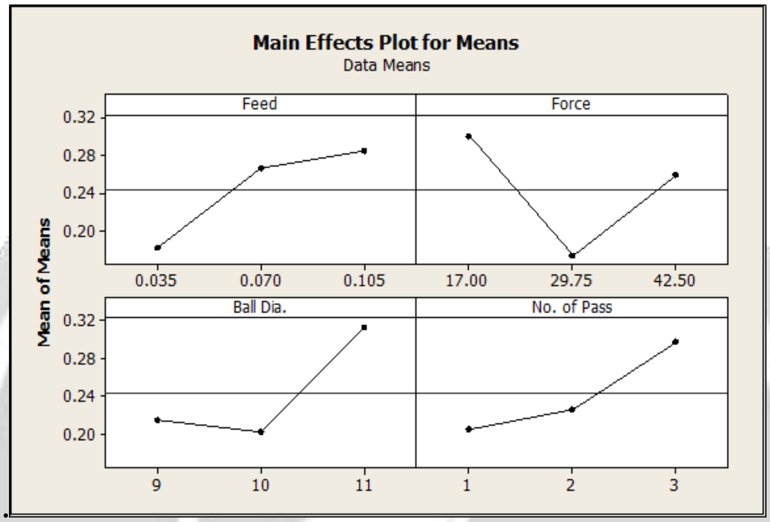

Fig -1: Main effect plot for Means

3.4 Analysis of surface hardness

Optimum level for surface hardness given by ANOM and ANOVA calculation are A1B3C2D2, that is A is Feed 0.035 mmrev, B is Force 42.50N, C is Ball diameter 9mm and D is number of passes

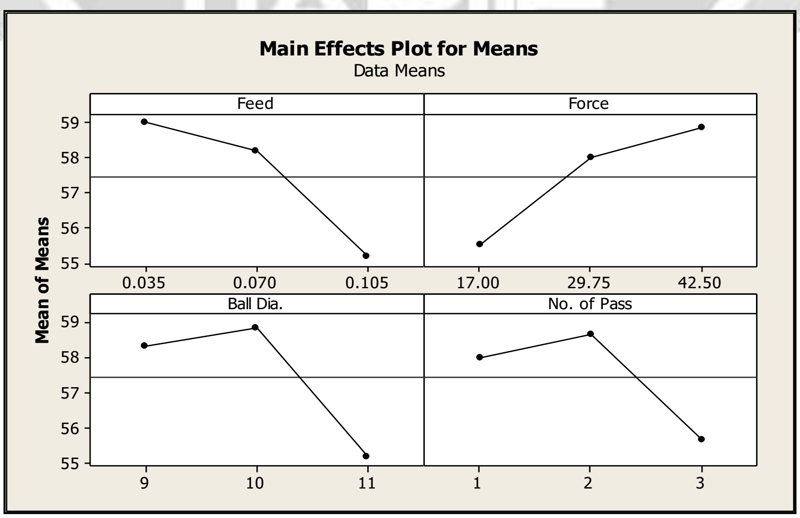

Fig -2: Main effect plot for Means

Table -6: Optimal factor setting and corresponding best combination values of surface roughness and hardness

	Optimum level			
Response	Feed mm/rev	Force N	Ball. Diam. mm	No of passes
Surface Roughness	0.0359(A1)	29.75(B2)	9 (C1)	2(D2)
Hardness	0.0359(A1)	42.50(3)	10 (C2)	2(D2)

Table -7: Confirmatory Experimental Result for A633

Method	Characteristics	Optimal condition	Optimal Experimental Value
Single Response Optimization	Surface roughness	A1B2C1D2	0.04µm
	Surface hardness	A1B3C2D2	62HRA

4. CONCLUSIONS

The experiment was carried out with different feeds, speeds, ball diameter and number of passes to study the effect of this parameter's on surface finish and surface hardness. It is found that,

1. The decrease in surface roughness with increase in burnishing speed
2. Feed has an impact on surface roughness as it increases roughness
3. The surface roughness increases as burnishing force increases and roughness is minimum at minimum burnishing force.

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