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A Study of Effect of Burnishing Pressure on Surface Finish, Surface Hardness and Case Depth in Twin Roller External Burnishing of EN24 Steel

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ABSTRACT

Burnishing is a very simple and effective method for improvement in surface finish and can be carried out using existing machines, such as lathe. On account of its high productivity, it also saves more on production costs than other conventional processes such as super finishing, honing and grinding. Moreover, the burnished surface has a high wear resistance and better fatigue life. Project work has been carried out in two parts , namely the design development of twin roller system for roller burnishing made of HCHCR material where as the tool holder is made of EN(9) material. The Pressure application is done using an hydraulic pressure adjuster mechanism where in the pressure is applied through an hydraulic pump . The project work has been designed to be operated on alloy steel EN24 material which is normally used for spindles , shafts gears etc, which are highly stressed parts and require maximum surface integrity.The basic aim of the project work is to apply the optimization techniques to the available experimental data in effect of burnishing pressure on surface finish, surface hardness and case depth in twin roller burnishing of EN24 steel. The goal of this work is to determine the possible effects of machining parameters on EN24 steel. The hydraulic pressure is varied to change the surface conditions obtained on the work piece material. variation in process parameters such as Speed, Feed, Burnishing pressure and corresponding output parameters like surface finish, surface hardness and case depth. Optimized the process parameters by using Taguchi analysis using MiniTab 17.0.

This study demonstrates the use of optimization techniques in twin roller burnishing of EN24 steel processes, which help to improve surface finish drastically and positively, increase in Case depth and surface hardness. Optimization techniques help to take decision in many fields and that also effect the growth of manufacturing sector as well as other so many sectors.

Keywords- Roller burnishing, Burnishing pressure, Ra, Case depth, Surface hardness.

I. INTRODUCTION

The main goal of roller burnishing is to achieve high-quality smooth surfaces or surfaces with pre-defined surface finish. One or more rollers or balls plastify and deform the workpiece's surface layer. This process is used when the goal is to either achieve a high-quality surface finish or when a pre-defined surface finish cannot be achieved by machining. At the contact point, the burnishing force generates contact stresses in the material's edge zone. If this stress is higher than the material's yield strength, the material near the surface starts to flow. As the ball or roller moves across the workpiece surface, the surface's peaks are pressed down, almost vertically, into the surface and the material then flows into the valleys between the peaks (Fig. 1.1). The resulting smooth surface occurs not because the peaks are bent into the surface (a widely held, but false assumption), but because the material flows, eliminating surface roughness. Almost all processes for the manufacturing of high-quality surfaces can be replaced by roller burnishing (e.g. grinding, super finishing, lap grinding, galling, honing, polishing, rubbing, fine ROLLER BURNISHING etc.). This proven process entails considerable technological and economic advantages for surfaces in the roughness area $R_z < 10$ µm.

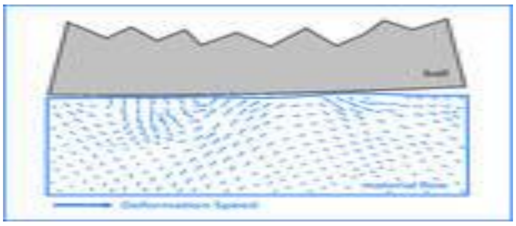

Figure 1.1 : Material flow

1.2 Ball Burnishing

In this method, machined surfaces are burnished by a ball burnishing tool. The experimental work is carried out on a lathe machine or milling machine. The ball burnishing process is done to improve the surface finish of work pieces that have been previously

In case of ball burnishing process best roughness values are also obtained on the surface of smaller radius and in case of higher feed rates. In the case of the direction of burnishing, the measurements in the parallel direction to the milling feed rates are smaller for the perpendicular burnishing and in the perpendicular direction to the milling process. The lower roughness values were obtained in the burnishing parallel to the milling feed rates.

1.3 Roller Burnishing

Roller burnishing is a cold working process which produces a fine surface finish by the planetary rotation of hardened roils over a bored or turned metal surface. Roller burnishing involves cold working the surface of the work piece to improve surface structure.

As all machined surfaces have series of peaks and valleys of irregular height and spacing, the plastic deformation created by roller burnishing is a displacement of the materials in the peaks in which cold flows

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under pressure into the valleys. This results in a mirror-like finish with a tough, work hardened, wear and corrosion resistant surface.

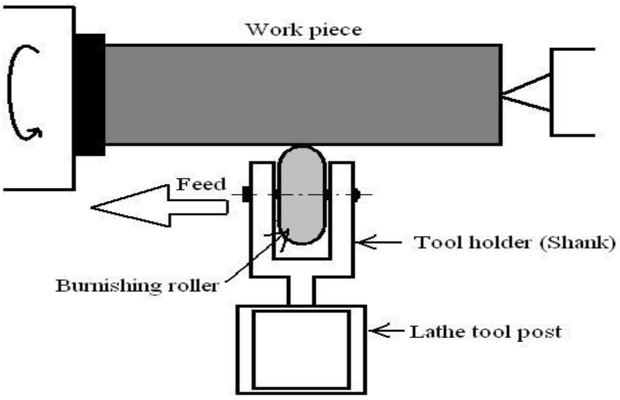

Figure 1.2 : Conventional Roller Burnishing Process

1.4 Pre-machining of the work piece

The work piece must be prepared for the roller burnishing with the right stock allowance and the right surface finishing rate. The amount of the stock allowance depends from the job conditions, the material properties, the wall thickness of the part, the type of the machined surface and the quality of the desired surface finishing. The following chart shows typical stock allowances for internal and external burnishing. However, because of the number of variables involved, these references should be considered only not binding. An exact stock allowance can be established by tests. It is important never to burnish parts with too much stock allowance: a roller burnishing in such conditions reduces the life of the tool but can also produce flaking of the burnishing surface. High ductility materials have an elongation of more than 18% and hardness less than RC 25. They include annealed steel, aluminium, brass, bronze. Low ductility materials have an elongation less that 18% and a hardness of max. RC 45.

Also the internal surface quality plays an important role in the part performance. Internal surfaces of non-ferrous materials are difficult-to-finish due to many problems encountered in grinding which is optimum for ferrous metals. Internal burnishing process is believed to be more suitable since it eliminates sticking, wheel dulling and overheating.

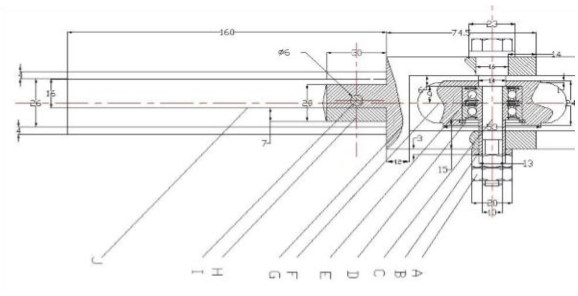

Figure No.- 1.3 General View Of Main Components Of Roller Burnishing Tool

II. MOTIVATION AND OBJECTIVES OF WORK

The existing method uses a single roller design where in the feed force is applied manually , which cannot be accurately controlled resulting in erroneous results. More over the single roller design poses certain problems of lining and irregular finish on job, hence it is required to adopt another approach to the problem .Namely increasing the number of rollers in contact and secondly application of the in-feed force using a hydraulic mechanism.

2.1 Methodology

Thus the project was developed in the above said gap in such manner to design develop and analysis of double roller head hydraulically operated tool head where in Unigraphix software will be used to model the parts of the system and Ansys workbench will be used to do the analysis of the tool head components. Experimental work will be done after manufacturing of the setup on lathe, and the results will be plotted accordingly.

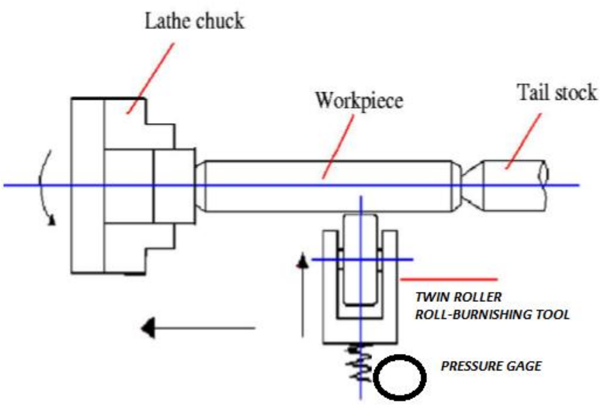

Figure 2.1 Experimental Arrangements (Methodology)

The figure above depicts the process of roller burnishing using twin roller mechanism using a hydraulic feed force adjuster mechanism. The pressure gage indicated in the mechanism will be used to observe and set the desired pressure of roller burnishing

2.2 Design and Development :

1) System design the hydraulic pressure required for the roller burnishing process, selection of and design of the hydraulic cylinder to provide the required force for roller burnishing.
2) Selection and deign of Piston, Piston seal , Cylinder , Oil seal , Piston rod and O-ring for the hydraulic cylinder.
3) Design and analysis of the Rollers , Roller pins, Roller arm , Roller arm hinge pins, roller bracket , Push rod, and the throw arrester linkage using theoretical method, Modelling using Unigraphix and Analysis using Ansys Workbench 16.0 software.

2.3 Manufacturing of set-up

1) Manufacturing of twin roller head tool set

2) Manufacturing of pressure adjuster and measurement set up

3) Hydraulic circuit implementation

III.TESTING METHODOLOGY

Test will be conducted using twin roller tool head on Lathe for the Burnishing of EN24 material under following conditions

1) Variable pressure (p bar)

2) Variation of cutting speed (v m/min)

3) Variation of feed (f mm/rev)

Machine:

Figure No. 3.1 Actual Image of Lathe machine Set up.

Product details:

Four speed :	Length of Bed 7 Feet
Width of Bed : 15 Inch	Height of Center : 12 Inch
Spindle Bore 80 MM	Distance Of Between Center 1000 MM

In this experimentation twin roller burnishing tool is attached to the tool post of the lathe machine through the hydraulic actuator mechanism for developing variable pressure on the twin roller burnishing tool . Experimentation was carried out for different sets of pressure viz 50 bar, 40 bar, 30 bar and 20 bar. Also the values of Speed Feed combinations was changed for different pressure. The SPEED values are 750 m/min, 500 m/min, 350 m/min, 275 m/min and FEED values are 0.3 mm/rev., 0.25 mm/rev., 0.20 mm/rev., 0.15 mm/rev. respectively. Expected results to study -

1) Theoretical and Ansys analysis of critical parts of the assembly

2) Case hardness & Case depth after roller burnishing process.

3) Surface finish after roller burnishing process.

Graphs

1) Surface finishVs Speed, Feed and Pressure

2) Case Hardness Vs Speed, Feed and Pressure

3) Case Depth Vs Speed, Feed and Pressure

3.1 Document of Analysis

Selection Of Process Parameters Based on the experimental results discussed. important parameters have been selected to analyse their effect on various machining parameters using Taguchi‟ s design ofexperiment technique. In present work, three input parameters namely speed, feed, pressurehave been investigated during Roller Burnishing of EN24 steel. The machining parameters as are as displayed in table below:

Table No. 3.1 Machining Process Parameters and their levels

Parameter	Level-1	Level-2	Level-3	Level-4
SPEED	750	500	350	275
FEED	0.3	0.25	0.20	0.15
PRESSURE	50	40	30	20

3.2 Selection of Orthogonal Array and Parameter Assignment

The orthogonal array forms the basis for the experimental analysis in Taguchi method. The selection of orthogonal array is concerned with the total degree of freedom of process parameters.. The degree of freedom for the orthogonal array should be greater than or at least equal to that of the process parameters. Thereby a L16 orthogonal array having degrees of freedom equal to 15 is considered in present case. The experimental layout is shown in Table.

Table No. 3.2 Orthogonal array for L16

Expt. No.	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2

9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

3.3 Roller Burnishing Test Results Orthogonal Array of L16

Table No. 3.3 Results of experiment with Roller Burnishing

Sr.No.	Speed	Feed	Pressure	Ra	Case Depth	Case Hardness
1	750	0.3	50	1.282	0.154	53.0
2	750	0.25	40	1.036	0.142	54.5
3	750	0.2	30	0.835	0.130	56.8
4	750	0.15	20	0.753	0.118	57.6
5	500	0.3	40	1.190	0.142	61.0
6	500	0.25	50	1.084	0.142	61.3
7	500	0.2	20	1.053	0.124	62.8
8	500	0.15	30	0.923	0.124	67.7
9	350	0.3	30	1.336	0.136	63.1
10	350	0.25	20	1.227	0.130	63.5
11	350	0.2	50	1.254	0.136	62.8
12	350	0.15	40	0.764	0.130	65.4
13	275	0.3	20	2.173	0.124	64.1
14	275	0.25	30	1.139	0.136	63.8
15	275	0.2	40	0.841	0.124	62.2
16	275	0.15	50	1.02600	0.13046	64.4

IV. RESULT ANALYSIS ,DISCUSSIONS

4.1 Taguchi Design for Surface Roughness (Ra)

4.1.1 Taguchi Analysis: Ra_C versus Speed, Feed, Pressure

Taguchi Orthogonal Array Design

L16(4^3)

Factors: 3

Runs: 16

Columns of L16(4^5) Array

1 2 3

Table No. 4.1 Response Table for Signal to Noise Ratios

Larger is better

Level	Speed	Feed	Pressure
1	1.6501	-1.3147	1.6291
2	0.9841	-0.1609	0.3483
3	0.4955	0.9823	-0.5005
4	-0.3884	3.2346	1.2645
Delta	2.0386	4.5494	2.1296
Rank	3	1	2

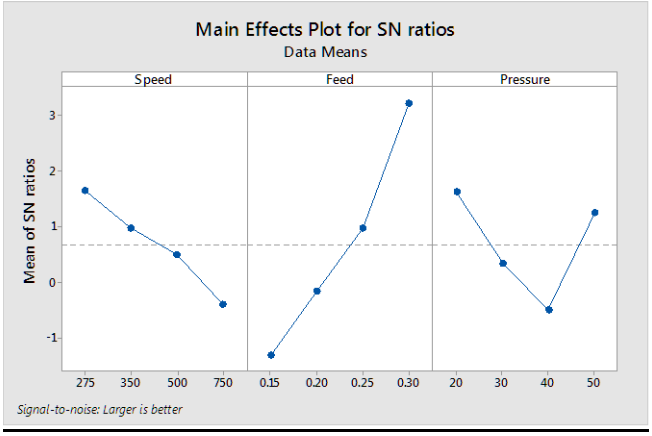

Figure No.-4.1 Main Effects Plot for SN ratios

Table No. 4.2 Response Table for Means

Level	Speed	Feed	Pressure
1	1.2951	0.8669	1.3020
2	1.1457	0.9961	1.0585
3	1.0631	1.1220	0.9583
4	0.9768	1.4958	1.1619
Delta	0.3182	0.6289	0.3437

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Rank	3	1	2

Figure No.-4.2 Main Effects Plot for Means

4.1.2 Selection of Optimum Level of Parameters

The least variation and the optimal design are obtained by means of the S/N ratio. Lower the S/N ratio, more stable the achievable quality (Tosun et al., 2004). Figure 5.1 shows the S/N ratio plots for Ra. It is clear from Figure 5.1, lowest S/N ratio first level of SPEED (750), Fourth level of FEED (0.15 mm/rev), third level of Pressure (40 bar).

4.2 Taguchi Design for Case Depth

4.2.1 Taguchi Analysis: Case Depth versus Speed, Feed, Pressure

Taguchi Orthogonal Array Design

L16(4^3)

Factors: 3

Runs: 16

Columns of L16(4^5) Array

1 2 3

Table No. 4.3 Response Table for Signal to Noise Ratios

Larger is better

Level	Speed	Feed	Pressure
1	-17.80	-18.00	-18.10
2	-17.50	-17.80	-17.60

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3	-17.51	-17.22	-17.41
4	-17.35	-17.14	-17.04
Delta	0.45	0.86	1.06
Rank	3	2	1

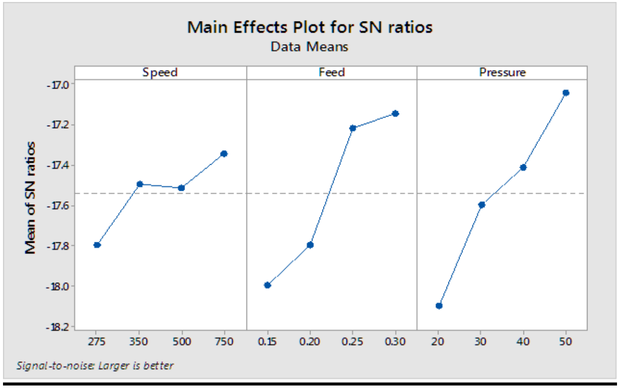

Figure No. 4.3 Main Effects Plot for SN ratios

Table No. 4.4 Response Table for Means

Level	Speed	Feed	Pressure
1	0.1290	0.1260	0.1245
2	0.1334	0.1290	0.1319
3	0.1334	0.1379	0.1349
4	0.1364	0.1394	0.1408
Delta	0.0074	0.0133	0.0163
Rank	3	2	1

As per above Response Table for Means following plot of main effects can be drawn.

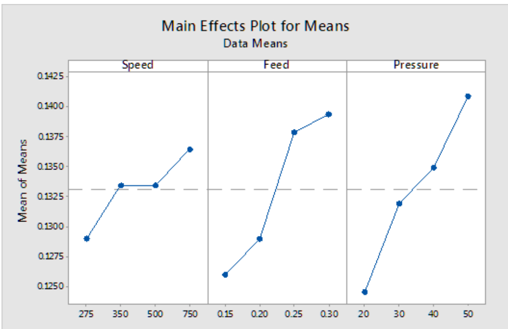

Figure No. 4.4 Main Effects Plot for Means

4.2.2 Selection Of Optimum Level Of Parameters

The least variation and the optimal design are obtained by means of the S/N ratio. Larger the S/N ratio, more stable the achievable quality. Figure 5.3 shows the S/N ratio plots for case depth . It is clear from Figure 5.3, largest S/N ratio fourth level of SPEED (750), Fourth level of FEED (0.3 mm/rev), fourth level of Pressure (50 bar) Therefore, the optimal setting of process parameters which yield maximum Case depth is 0.15418 which is obtained in first combination of experimentation in orthogonal L16 array.

4.3 Taguchi Design for Case Hardness

4.3.1 Taguchi Analysis: Case Hardness versus Speed, Feed, Pressure

Taguchi Orthogonal Array Design
L16(4^3)
Factors: 3
Runs: 16
Columns of L16(4^5) Array
1 2 3

Table No. 4.5 Response Table for Signal to Noise Ratios

Larger is better

Level	Speed	Feed	Pressure
1	36.14	35.91	35.84
2	36.08	35.79	35.78
3	35.84	35.66	35.72
4	34.88	35.58	35.59
Delta	1.26	0.33	0.25
Rank	1	2	3

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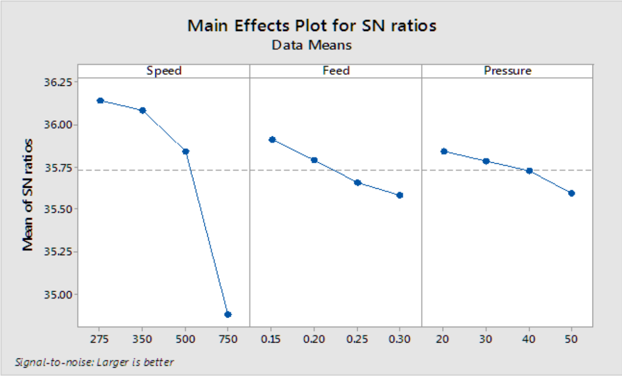

Figure No. 4.5 Main Effects Plot for SN ratios

Table No. 5.6 Response Table for Means

Level	Speed	Feed	Pressure
1	64.13	62.53	62.00
2	63.70	61.65	61.60
3	61.95	60.78	61.28
4	55.48	60.30	60.38
Delta	8.65	2.23	1.63
Rank	1	2	3

Figure No. 4.6 Main Effects Plot for Means

4.3.2 Selection of Optimum Level Of Parameters

The least variation and the optimal design are obtained by means of the S/N ratio. Higher the S/N ratio, more stable the achievable quality. Figure 5.5 shows the S/N ratio plots for case hardness. It is clear from Figure 5.5, largest S/N ratio first level of SPEED (275), First level of FEED (0.15mm/rev), first level of Pressure (20 bar)

Therefore, the optimal setting of process parameters which yield maximum Case hardness is between 61.1 to 61.4 which is obtained in 13, 16 combination of experimentation in orthogonal L16 array.

V. CONCLUSION

No such device is available in market which is so small an offers so high oil saving capacity. Compact size makes it useful in any machine where big tool system is not permitted. Automobile industry can make full use of the technique to bring down the surface finish application overheads in machining.

In this study, Twin roller Burnishing Tool consisting of double roller having material 'HCHC tool steel' is used. The present work has lead to the following conclusions.

1. The Twin roller Burnishing Tool can successfully used to finish operation for outer surface of EN 24T Steel.

2. It has been established that taguchi analysis is an effective optimization technique.

3. Mathematical model for surface finish, burnishing response is identified by taguchi method considering speed, feed and pressure variations.

4. The established model is useful in predicting the response which by selecting proper input parameters that were used in this research work before performing the burnishing process.

5. It has been found that the optimal cutting parameters machining process;

a) The graph of Surface Finish Vs Speed for maximum feed and maximum pressure , it is observed that the speeds of 275 rpm are in the optimal range and the recommended speed for better Surface Finish.

b) The graph Case Depth Vs Speed for maximum feed and maximum pressure , it is observed that the speeds of 275rpm recommended speed for better case hardness

c) The graph Case hardness Vs Speed for maximum feed and maximum pressure , it is observed that the speeds of 750rpm recommended speed for better case hardness

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