Experimental Investigation of Mild Steel Components by Roller Burnishing Process and its Mechanical Properties by Taguchi Method

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Abstract – *Roller burnishing is cold working process used to improve surface structure it produces a fine surface finish by planetary rotation of hard rollers over bored or turned metal surface it compresses projection(peaks) into indentations(valleys) thus forming smooth mirror finished surface in the burnishing process at point of contact. The pressure generated by rollers exceed the yield point of material, the surface is plastically deformed by cold flowing of subsurface material the result is mirror like finish tough and hardened surface. The pressure required for roller pressure is applied and burnishing operation is performed in this research project. The burnishing process is used to analyze the effect on hardness and tensile test of mild steel material using lathe machine. The Taguchi method is used to obtain main effect plots of hardness and tensile strength of the specimen*

Key Words: Burnishing process, Roller burnishing, burnishing tool, Lathe Machine, hardness, tensile strength Universal testing machine, Brinell hardness testing machine, Taguchi method.

1. INTRODUCTION

Roller burnishing helps users to eliminate secondary operations for substantial time and cost savings, while at the same time improving the quality of their product. Roller burnishing is a method of producing an accurately sized, finely finished and densely compacted surface that resists wear. Hardened and highly polished steel rollers are brought into pressure contact with a softer work piece. As the pressure exceeds the yield point of the workpiece material, the surface is plastically deformed by cold flowing of subsurface material. A burnished surface is actually smoother than an abrasively finished surface of the same profilometer reading. Profilometers measure roughness height. Abrasive metal removal methods lower the roughness height. But, they leave sharp projections in the contact plane of the machined surface. Roller burnishing is a metal displacement process. Microscopic “peaks” on the machined surface are caused to cold flow into the “valleys”, creating a plateau like contact plane. The burnished surface will therefore resist wear better than the abraded surface in metal to metal contact, as when a shaft is rotating in a bushing. Roller Burnishing is a Super-finishing process. It is a Cold Working process which produces a fine surface finish by the planetary rotation of hardened rollers over a bored or turned metal surface. Since all machined surfaces consist of a series of peaks and valleys of irregular height and spacing, the plastic deformation created by roller burnishing is a displacement of the material in the peaks which cold flows under pressure into the valleys. The result is a mirror-like finish with a tough, work hardened, wear and corrosion resistant surface. Lapping and Honing is eliminated. Roller burnishing is cold working the surface of the work piece to improve surface structure .it produces a fine surface finish by the planetary rotation of harden rollers over a bored or turned metal surface. The roller burnishing operation compresses the projection (peaks) into the indentations (valleys) thus forming a smooth mirror finished surface in the burnishing process at the point of contact, the pressure generated by the rollers exceeds the yield point of the piece-part materiel, the surface is plastically deformed by cold flowing of subsurface material the result is mirror like finish and tough, hardened surface. The pressure required for roller burnishing depends on various factors like tensile strength of the material, surface toughness before and after roller burnishing, ductility, shape of the rolls and diameters. Roller burnishing is used on cylindrical, conical, or disk shaped workpieces. The tool resembles a roller bearing, but the rollers are fixed so they slide against the workpiece surface instead of rolling. It is simultaneously rotated and pressed into the workpiece. Typical applications for roller burnishing include hydraulic system components, shaft fillets, and sealing surfaces. Burnishing Balls also occurs to some extent in machining processes. In turning, burnishing occurs if the cutting tool is not sharp, if a large negative rake angle is used, if a very small depth of cut is used, or if the workpiece material is gummy. As a cutting tool wears, it becomes blunter and the burnishing effect becomes more pronounced. In grinding, since the abrasive grains are randomly oriented and some are not sharp, there is always some amount of burnishing. This is one reason the grinding is less efficient and generates more heat than turning.

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods, and more recently also applied to engineering, biotechnology, marketing and advertising. Professional statisticians have welcomed the goals and improvements brought about by Taguchi methods, particularly by Taguchi's development of designs for studying variation, but have criticized the inefficiency of some of Taguchi's proposals. Taguchi's work includes three principal contributions to statistics:

- A specific loss function — see Taguchi loss function;
- The philosophy of *off-line quality control*; and
- Innovations in the design of experiments.

2. EXPERIMENTAL PLAN

Specimen preparation:

MS rod of length 200mm and 14 mm diameter was cut according to the dimensions.

Fig-2: MS rod specimens before burnishing

2.1 MACHINE AND TOOL USED

- Centre Lathe Machine
- Roller Burnishing Tool

Fig-2.2: Centre Lathe Machine

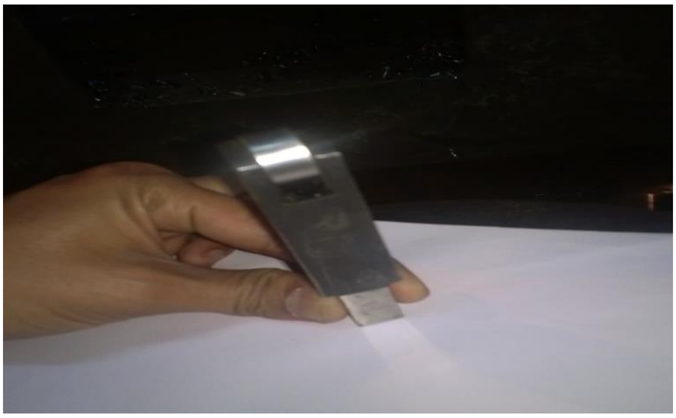

Fig-2.1: Single Roller Burnishing Tool

2.2 PROCEDURE

1. Bars were cut to proper length by sawing machine.

2. Nine specimens were prepared to required length and diameter by performing facing and turning operations on lathe machine.

3. Burnishing was performed on each of the specimen using roller burnishing tool at the specified parameters.

4. The burnished specimens were now tested for hardness and tensile loads.

5. The values were tabulated and compared and graphs were plotted.

Fig-2.3: Fixing specimen

Fig-2.4: Performing Burnishing

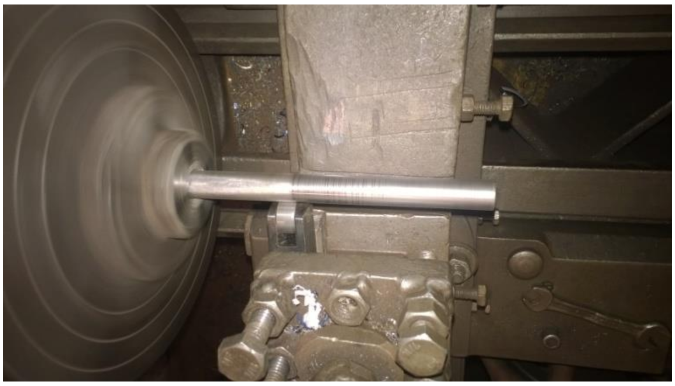

Fig-2.5: Performing Burnishing top view

Fig-2.6: Specimens after Burnishing

3. BRINELL HARDNESS TEST

In the Brinell hardness tests, the specimen is mounted on the anvil of the machine and a load of 6620 lb (3003 kg) is applied against a hardened steel ball which is in contact with the surface of the specimen being tested. The steel ball is 0.4 in. (10.2 mm) in diameter. The load is allowed to remain 1/2 minute and is then released, and the depth of the depression made by the ball on the specimen is measured. The resultant Brinell hardness number is obtained by formula shown in figure-7.

$$Bhn = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

Bhn: Brinell hardness number
P: applied load in kilograms
D: diameter of steel ball in millimeters
d: diameter of impression in millimeters

Fig-2.7: Formula for Brinell hardness No

It should be noted that, in order to facilitate the determination of Brinell hardness, the diameter of the depression rather than the depth is actually measured. Charts of Brinell hardness numbers have been prepared for a range of impression diameters. These charts are commonly used to determine Brinell numbers. To find the Brinell hardness number of the given specimen. Justy's Brinell hardness testing machine, microscope and specimen. Hardness of a material is defined as the resistance it offers to indentation by another body. The purpose of the determining hardness number is

- To have quality control over materials.
- To grade materials.
- To have rough idea of tensile strength of material this has some relationship with hardness number.

Hardness tests are mainly of three types:

- Brinell test
- Rockwell test
- Vickers test

Brinell hardness test is based upon pressing a steel sphere of known dimensions into material under test. The hardness can be determined from the size of indentation made for a known load.

B.H No= load/spherical area of indentation

= 2F/3.14(D-d)

F= Load in Kg

D= Diameter of Steel Ball in mm

d= Diameter of Indentation

Ball Diameter and Loads: The standard ball diameter is 10mm, but ball of size 1, 2,5mm, are also available. The ideal value for the ratio of indentation diameter to ball diameter is 0.375 for a realistic hardness no. to be obtained and should not be outside the range (0.25 to 0.50). To achieve an acceptable value of d/D the relationship between loads F/D2 for various metals are shown in table 3.

Table -3: F/D values for various specimens

MATERIAL	SPECIFIED F/D2
Steel	30
Brass & Aluminum Alloys	10
Copper & Aluminum	5
Lead	1

3.1 PROCEDURE

- An anvil most suitable for supporting a particular specimen is selected. The required penetrator is fixed after cleaning it properly, 2.5mm ball penetrator for hard materials such as steel and cast iron under a load of 187.5kgs, and 5mm ball penetrator for copper and copper alloys, aluminum and its alloys etc under a load of 250kgs.

- A major load is selected depending upon the material under test with the help of load selecting disc. The specimen is placed on the anvil and raised by rotating the hand wheel clockwise, until the contact is made with the penetrator.

- The hand wheel is continuously rotated till the main pointer is at set position, zero of 'C' scale and 30 of 'B' scale. The main pointer of dial will automatically stop at this position. This way a minor load of 10kgs is automatically applied.

- For applying the remaining major part of the load, the loading handle is pushed away and kept there for 15 seconds. Within the 15 seconds completion of impression takes place and the major load is removed.

- The specimen is taken out and the diameter of indentation is measured by bringing specimen under the microscope.

- The same procedure is repeated to take a no. of reading and tabulated as shown in table-3.1 to perform the required calculations.

Fig-3: Hardness test

3.2 OBSERVATIONS

Material of test piece: mild steel

Diameter of ball in mm= 10

F/D^2=30kg/mm^2

Load to be applied F=3000kg

Load application time=15 seconds

Table-3.1: Hardness Test

S. No	Impression d_1 in mm	BH.NO
1	4.6	170.59
2	4.6	170.59
3	4.5	180.123
4	4.3	187.32
5	4.3	196.97
6	4.6	170.59
7	4.3	187.32
8	4.5	207.68
9	4.3	180.123

4. TENSILE TEST

The tensile strength of specimens is determined by using Universal Testing Machine. Universal testing machine is primarily intended for tensile tests. It can also be used to carry out with suitable accessories a wide variety of other tests such as bending, shear, compression and hardness.

4.1 PROCEDURE

- The test specimen is fixed between adjustable cross head and the upper tension cross head.

- The load applied to the specimen is noted on the control console. The control console houses the hydraulic drive, load stabilizer, dynamometer and graph recorder. When the load is applied, the wedging action causes these serrated gripping surfaces to bite into and hold firmly the specimen.

- There are four ranges of 10t, 5t, 21/2t, and 1t and the machine can be set for any of these ranges by adjusting the knobs at the dial gauge and weights in the console unit. The recorder consists of a drum on which the graph roll is mounted.

- The test is done till the breaking point of specimens is reached. The breaking point and the tensile strength are noted down shown in table-3.

4.2 OBSERVATIONS

Table-4: Tensile test of burnished MS rod specimen

Length of rod in mm	Diameter of rod in mm	Breaking Point in Mpa	Tensile Strength in Mpa
200	14	101.7	0.65
200	14	55.6	0.35
200	14	104	0.67
200	14	68.7	0.44
200	14	109	0.71
200	14	106	0.68
200	14	108	0.71
200	14	105	0.68
200	14	107	0.69

5. TAGUCHI METHOD

The method explores the concept of quadratic quality loss function and uses a statistical measure of performance called Signal-to-Noise (S/N) ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are as follows: - Nominal is Best (NB), Lower the Better (LB) and Higher the Better (HB). The optimal setting is the parameter combination, which has the highest S/N ratio.

5.1 EXPERIMENTATION

Material used was mild steel. Input and output parameters are considered. Input parameters are R.P.M., feed rate, and number of passes. Output parameter predicting strength of material is tensile strength and hardness.

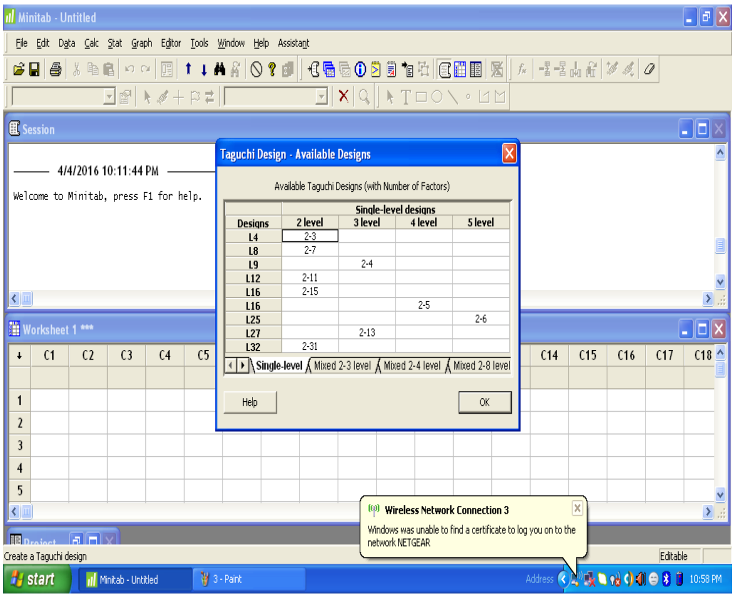

Fig-5: creating Taguchi design

Table-5: The 3 levels of effective factor for exponential variance

Level	Speed in rpm	Feed mm/rev	No of passes
LEVEL 1	800	0.5	1
LEVEL 2	1200	0.7	2
LEVEL 3	1600	0.9	3

5.2 OBSERVATIONS

Process parameters with their values at three levels are shown in Table 5.1. total 9 runs of experiments based on randomized OA were done. R.P.M., feed rate, and number of passes are varied as per values for each level mentioned in table 5.1. Three responses are taken for each setting. Any nonlinear relationship among the process parameters, if it exists can only be revealed if more than two levels of parameters are considered.

Thus each parameter is selected at three levels. According to Taguchi method based on robust design, a L9 orthogonal array is employed for the experimentation.

Table-5.1: Orthogonal array variance

Length of the rod in mm	Diameter of rod in mm	Breaking point in Mpa	Tensile Strength in Mpa
200	14	101.7	0.65
200	14	55.6	0.36
200	14	104	0.67
200	14	68.7	0.44
200	14	109	0.71
200	14	106	0.68
200	14	108	0.71
200	14	105	0.68
200	14	107	0.69

Table-5.2: Results obtained from three levels

Level	Speed (in rpm)	No Of Passes	Feed rate in mm/rev
1	0.5600	0.5967	0.6300
2	0.6100	0.5433	0.4400
3	0.5933	0.6233	0.6933

Table-5.3: Predicting Taguchi results

Speed	1200
No of passes	2
Feed rate	0.9
The highest hardness is	208.3

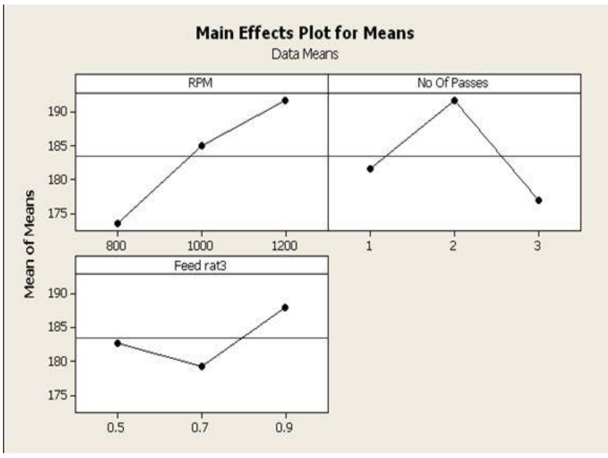

Chart-5: Main effect plot for hardness

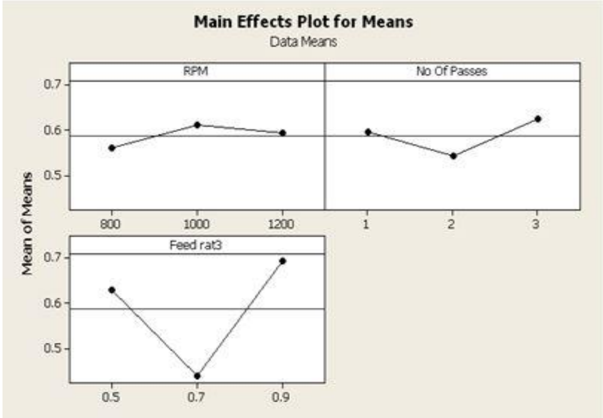

Chart-5.1: Main effect plot for tensile strength

CONCLUSION

There is a considerable increase in hardness and tensile strength of mild steel after roller burnishing Hardness is highest when the speed is 1000 rpm, feed is 0.9 mm/rev and no. of passes is 2. Tensile strength is highest when the rpm is of 1000 rpm and feed is of 0.9mm/rev and no. of passes is 3. The optimal parameters of burnishing have been successfully identified and a confirmation test has proved the parameter levels to be true. The Taguchi design of experiments is suitable to identify the optimal parameters in case of burnishing process.

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