EFFECT OF MACHINING PARAMETER ON SURFACE ROUGHNESS IN ROLLER BURNISHING OF ALUMINIUM ALLOY

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Abstract: In today's time, the manufacturing of machines and other components with highly furnished surfaces are becoming more and more important. Surface finishing is the mandatory characteristic of any produces machine. Burnishing operation is getting evolved very frequently and it helps to improve surface roughness of machinery part easily. It basically involved plastic deformation of the material. It is cold rolling process without any removal of metal from the work piece. Peaks get changed into valleys and at last a highly polished mirror like surface is obtained. In case of sliding surfaces it enhances the life of the material. This paper explains the effect of machine parameters on a surface roughness in roller burnishing of aluminium alloy. In Experimentation, design of experiments (DOE) is applied to study various burnishing parameters on surface roughness**.**

***Keywords* - Aluminium Alloy, Surface Roughness, Response Surface Methodology, Scanning Electron Microscopy, Roller Burnishing Process.**

I. INTRODUCTION

There is a large significance of alternate energy sources like solar and wind. In real time of globalization and modernalization, the performance of the machine is highly dependent on dimensional accuracy, geometrical tolerance and surface finish of the component. Lots of emphasis is given on the quality of surface for getting desired physical and mechanical properties. Over the span of last few years a lot of research is being done on metal surface finishing increasing the surface properties of the machinery parts. There are several finishing processes used to produce surfaces with desired quality properties. These processes might be divided into chip removal processes, such as reaming, grinding or lapping, and chip less processes, such as burnishing. Burnishing is a cold working process, which deforms the material plastically for improving the surface characteristics. Surface characteristics affect by burnishing operation in particular rolling

- Improves surface roughness parameter
- Increases surface hardness.
- Increases wear and corrosion resistance

1.1 WORKING PRINCIPLE OF BURNISHING OPERATION

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 during burnishing operation. It basically helps in minimizing the distance of peaks from its mean and ultimately decreases the roughness of surface. It reduces the machinery cost, human effort and time required for remounting of components. This tool is mounted on the tool post of the lathe. When the tool gets pressed against the rotating work piece, the frictional force comes in picture between the roller and the work piece. The direction of the rotation of the work piece is always opposite to that of the tool. Burnishing process is sometimes also known as cold working process.

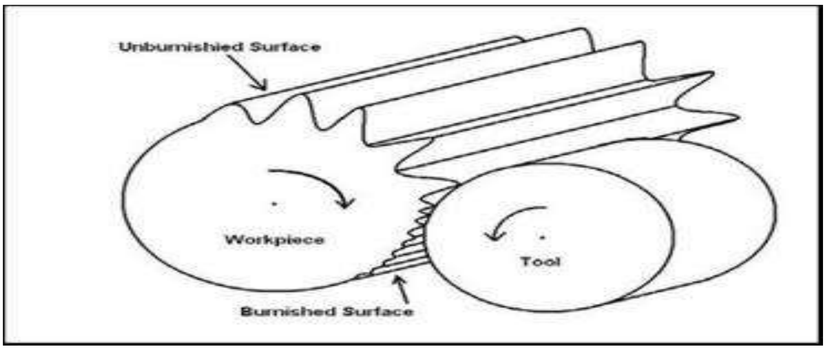


Figure 1.1 Basic operation of burnishing

1.2 PROCESS PARAMETERS OF BURNISHING OPERATION

All burnishing parameters need to control and optimize to get the best results. The various process parameters are as follows:

- Burnishing speed
- Feed Rate
- Depth of penetration
- Number of Passes

1.3 SURFACE ROUGHNESS

Surface roughness is many times used as roughness and it is major part of surface texture. Deviation of real surface from its ideal form in the direction of applied normal vector is surface roughness. If this deviation from the ideal surface is too large then the surface is very rough and if it is small then the surface is very smooth. The roughness plays very important role in deciding the behavior of the real surface when it is comes in contact with environment. The rough surface usually have high co-efficient of friction than the smooth surface and normally wear out rapidly as compare to smooth surface [1].

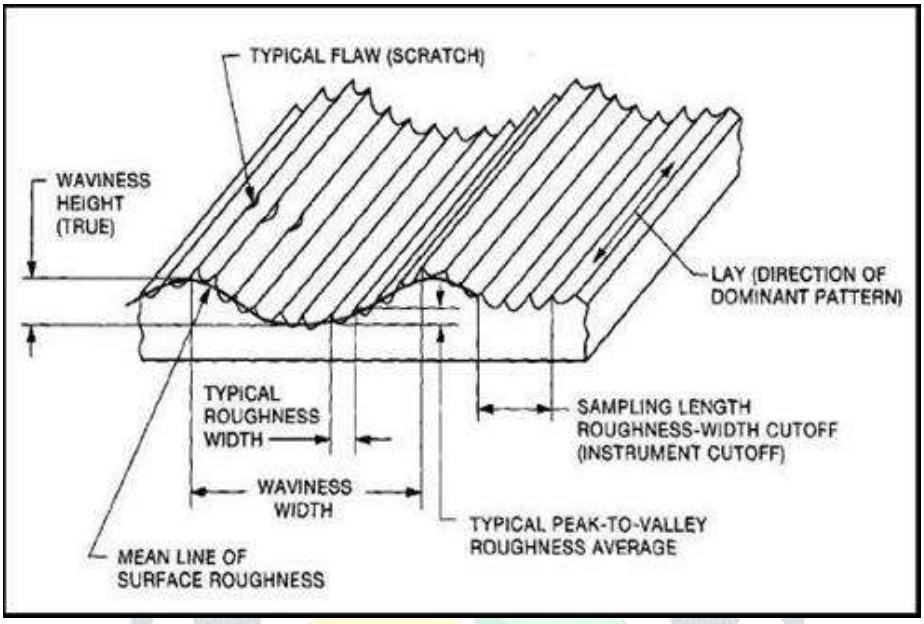


Figure 1.2 Surface profile

Advantages of Good surface finish are:

- Excellent surface finish increases the wear resistance of the work piece in contact.
- It reduces the friction between two work pieces.
- Good surface finishes result in high cosmetic effect and also increases the load carrying capacity. It also decreases the corrosion and fatigue life of components.

II. WORKPIECE AND EQUIPMENTS

2.1 WORKPIECE MATERIAL

Aluminum has the second largest quantity of elements that are available in the earth's crust. Aluminum alloy is very light in weight. This property of aluminum makes it widely suitable for manufacturing of components which are used in transportation industries. Almost all parts of aero planes are manufactured from aluminum alloys. Aluminum also has huge applications in robotics and engine devices. High electrical conductivity and thermal conductivity makes aluminum fusible to use in the electrical and electronics devices. Aluminum alloy has following properties - the Young's modulus is 70 GPA. Density of aluminium is 2700 kg/m3, Poisson's ratio is 0.35. Aluminum is a reactive in nature so it form an aluminium oxide when comes in contact with air which protect aluminium from corrosion in any environment.

Table 1 Chemical composition of the Al 63400 Grade

Sr. No.	Sample Identification	Chemical Composition (%)							
		Si	Cu	Fe	Zn	Mn	Mg	Pb	Al
1	Aluminum sample	0.349	0.07	0.367	0.057	0.067	0.4	0.064	98.54

2.2 EQUIPMENTS

There are major two equipments which have been used in the experimentation:-

- Roller Burnishing tool
- Surface Roughness Tester

2.2.1 Roller burnishing tool

The single roller burnishing tool which is used during experimentation is shown in figure. It has following main components:

- Hard roller
- Shank
- High stiffness spring

To improve its hardness heat treated shank is made of mild steel. The shank of roller burnishing tool has square cross section (30mm * 30mm) which is hold in the tool holder. Using a bolt and nut assembly is use provision to fix the roller at the end of the square shank which looks similar to a fork.

Figure 2.1 Single roller burnishing tool

2.2.2 Surface roughness tester

As a stylus instrument, we used surface roughness tester (MITUTOYO Model -SJ211). Roughness tester has its working principle as moving the probe of tester on surface whose roughness is to be measure. Basically, hard material used to make probe to resist the wear as it is continuously in contact with surface whose roughness is to measure.

III. DESIGN OF EXPERIMENTS

Design of experiments (DOE) is procedure for making the plan of experiments for obtaining the expected output in minimum number of trails, which reduce the production cost and production time. The design of experiments plays very important role when there are number of factors and each factor have different levels, then to find out the best possible sets of operation and to find out most significant factor among all factors.

Table 3.1 Factors and their levels for experimentation

Levels	Speed (RPM)	Feed Rate (mm/rev)	Dept of penetration	No. of Pass
1	106	0.4	0.01	1
2	212	0.5	0.02	2
3	318	0.6	0.03	3
4	424	0.7	0.04	4
5	531	0.8	0.05	5

Based on central composite design involves 2^N factorial points, 2N axial points and 7 Central point. Central composite design present an alternative to 3N designs in the construction of Second order models because the number of experiments is reduced as compared to a full factorial design. As per calculation provided in central composite design we have carried out 31 (thirtyone) experiments. Factorial points (2^N = 16) plus Axial points (2N = 8) plus central point (7). All experiments have combination of four factors like different speed, feed rate, depth of penetration and number of passes.

IV. EXPERIMENTAL SETUP

In experiment, we don't want to remove material from work piece, and this can be achieved using super finishing process, hence we have selected burnishing process. Due to inherent flaws like scaling, out of roundness, irregular diameter etc. Component cannot be suitable to be burnished directly. The wok piece needs to pass through various different machining process, to make material free from surface imperfections. Before burnished work piece by using single roller burnishing tool, there are some operations like facing and turning operations are carried out.

Figure 2.2: Experimental Setup

V. ANALYSIS

Mathematical and statistical techniques have been considered by Response surface methodology to create robust model building. The objective is to optimize a response which is prejudiced by several self-governing variables. In experiment, during the number of runs, changes are made in the input variables in order to identify the reasons for changes in the output response. Find the levels of temperature (x1) and pressure (x2) to maximize the yield (y) of a process.

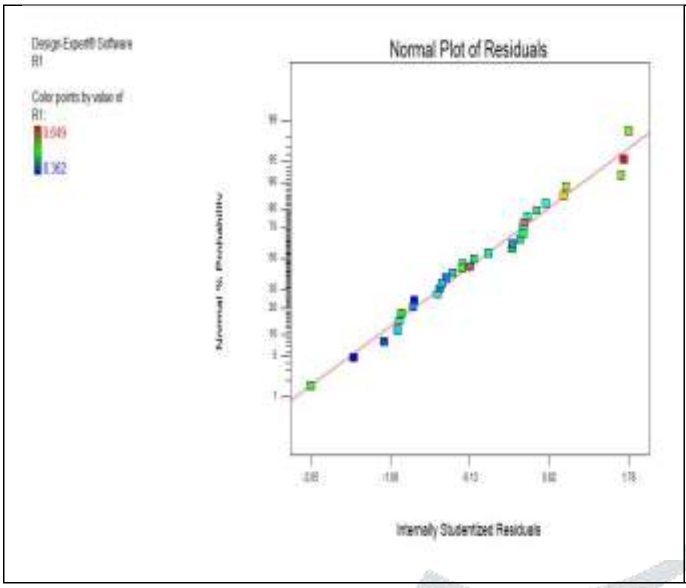
$$y = f(x_1, x_2) + \varepsilon$$

Approximate the true relationship between y and the independent variables by the lower-order polynomial model

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$
$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

5.1 Diagnostic with the help of design expert tool

We have diagnostics all experiments with the help of diagnostic tool and collected output results in term of graphical format. While doing the diagnostics we have selected particular criteria which has mentioned in below section.



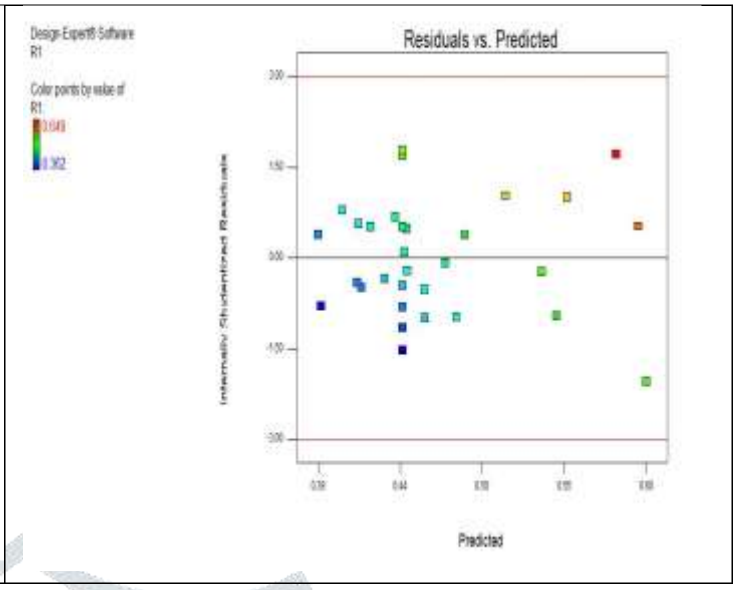
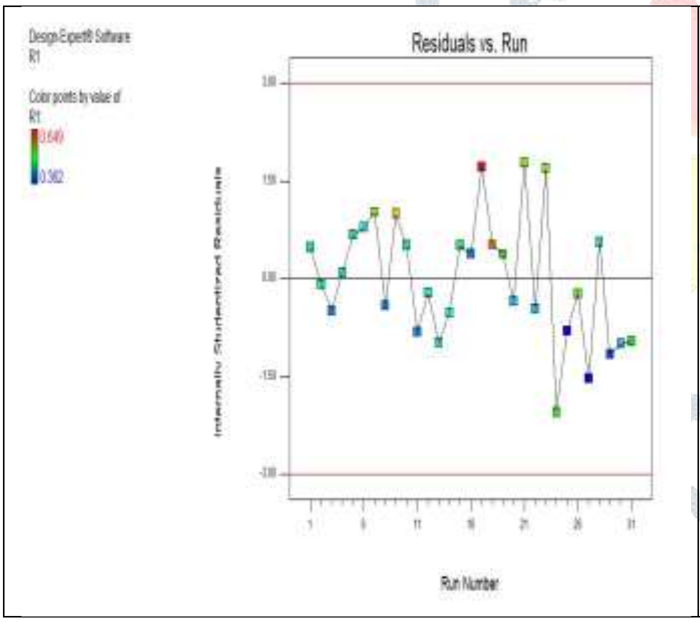


Figure 5.1 Normal probability of residuals **Figure 5.2 Residuals versus predicted**

Normal probabilities of residuals are presented in Figure 5.1. It represents the normal of the offense since each point in the plot pursues a straight line pattern. The normal probability plot is used to verify the normality assumption. Figure 5.2 display the studentized residuals versus predicted values to investigate for constant error. Residuals versus predicted values should be distributed at irregular intervals. In a linear regression investigation it is expected that the scattering of residuals is in the population (total number of testing data). Here is a plot of the residuals versus predicted.



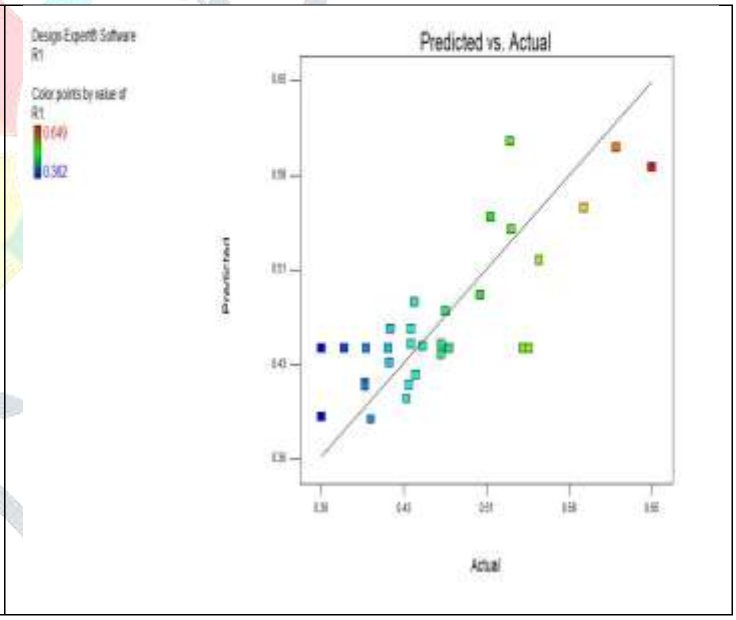


Figure 5.3 Residuals Vs. Run **Figure 5.4 Correlation between the predicted and actual Value**

Figure 5.3 displays the correlation between the residuals and experimental runs. Residuals versus runs should be random scatter and no trends. Figure 5.4 display the interaction between the predicted values and experimental values for surface roughness of Aluminum alloy under roller burnishing. The points should be randomly dispersed along the 45 degree line. Majority of points below or above the line show area of cover or under prediction.

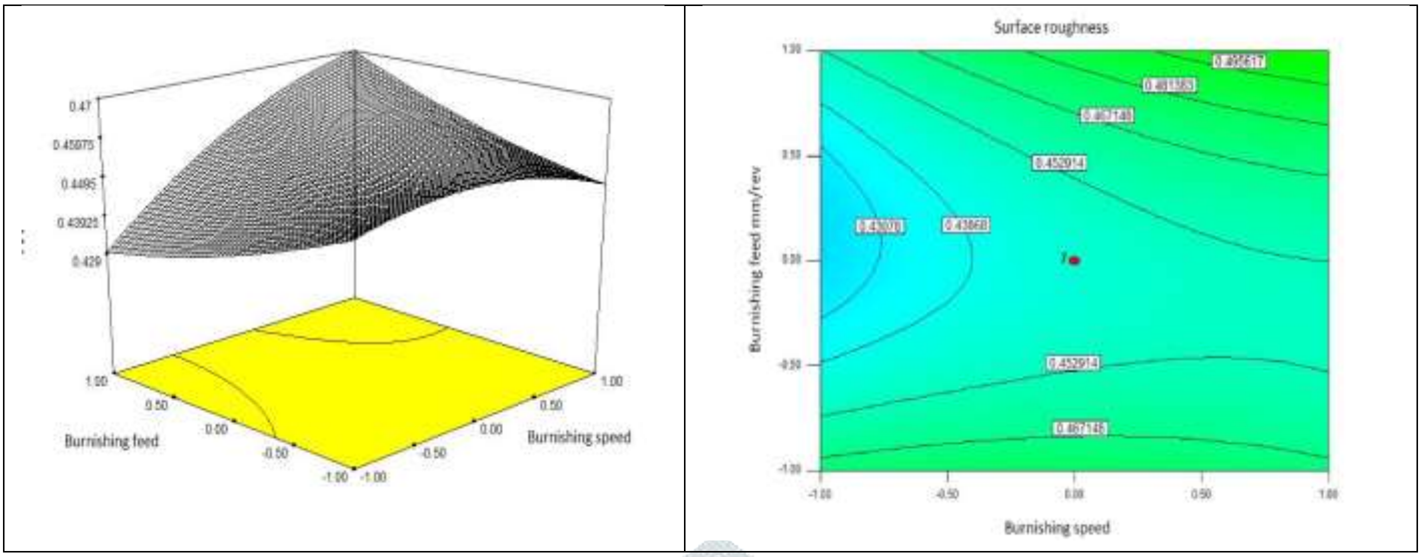


Figure 5.5 3D interaction and contour plot for surface roughness, burnishing speed and No. of passes

We have studied Response Surface Methodology (RSM) is useful for the modeling and analysis of programs in which a response of interest is influenced by several variables. We found that RSM is used for optimization with the help of various variables. We have created design matrix with the help of central composite design. Provides design matrix to tool to calculate the optimized response. ANOVA table is generated to check the accuracy of model. The average feasible predicted is found to be 0.443 micron.

VI. RESULT AND DISCUSSION

The aim of the present investigation is to analyze the effect of feed, speed, depth of penetration and number of passes in roller burnishing on surface roughness of aluminium alloy. Analysis of response has been completed using design expert software. Analysis of variance (ANOVA) shown in below Table 6.1

Table 6.1 ANOVA Table for surface roughness

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	32.87	14	2.35	4.59	0.0023	significant
A-A	*1.70*	*1*	*1.70*	*3.32*	*0.0873*	
B-B	*5.04*	*1*	*5.04*	*9.86*	*0.0063*	
C-C	*12.44*	*1*	*12.44*	*24.33*	*0.0001*	
D-D	*1.28*	*1*	*1.28*	*2.50*	*0.1334*	
AB	*0.92*	*1*	*0.92*	*1.80*	*0.1982*	
AC	*0.20*	*1*	*0.20*	*0.40*	*0.5380*	
AD	*1.84*	*1*	*1.84*	*3.59*	*0.0763*	
BC	*1.29*	*1*	*1.29*	*2.52*	*0.1320*	
BD	*0.92*	*1*	*0.92*	*1.80*	*0.1982*	
CD	*0.15*	*1*	*0.15*	*0.30*	*0.5930*	
A^2	*1.00*	*1*	*1.00*	*1.96*	*0.1808*	
B^2	*4.86*	*1*	*4.86*	*9.50*	*0.0071*	
C^2	*0.29*	*1*	*0.29*	*0.56*	*0.4637*	
D^2	*1.38*	*1*	*1.38*	*2.70*	*0.1200*	
Residual	8.18	16	0.51			
Lack of Fit	*7.17*	*10*	*0.72*	*4.25*	*0.0451*	*significant*
Pure Error	*1.01*	*6*	*0.17*			
Cor Total	41.05	30	R-Squared		0.8007	

The determination coefficient (R2) was used to check the goodness of fit of the model. The coefficient of determination value (0.8007) was calculated for response. This indicates that 80.07% of experimental data certify the rapport with the data predicted by the model. The R2 value is always between 0 and 1, and its value illustrates correctness of the model. Coefficient of determination value (0.8007) should be close to 1.0 for a good statistical model. F value is defined as ratio of mean square model to mean square error. If P value is less than 0.05 significance of corresponding term is found. Significant P value (P < 0.05) means that the testing sample data are a normal subset of the population data. For lack of fit P value must be greater than 0.05. Based on ANOVA test, the full quadratic model was found to be relevant for surface roughness of aluminium alloy under roller burnishing with regression P value less than 0.05 and lack of fit greater than 0.05. Design matrix table terms burnishing speed, feed, depth of penetration and number of passes, square terms of burnishing speed, feed, and speed, depth of penetration and number of passes and interaction between feed, speed, depth of penetration and number of passes are significant model terms.

5.1 SCANNING ELECTRON MICROSCOPE

To produce image, SEM scans a focused electron beam over a surface. SEM producing a range of signals that can be used to get information about the surface scenery and composition.

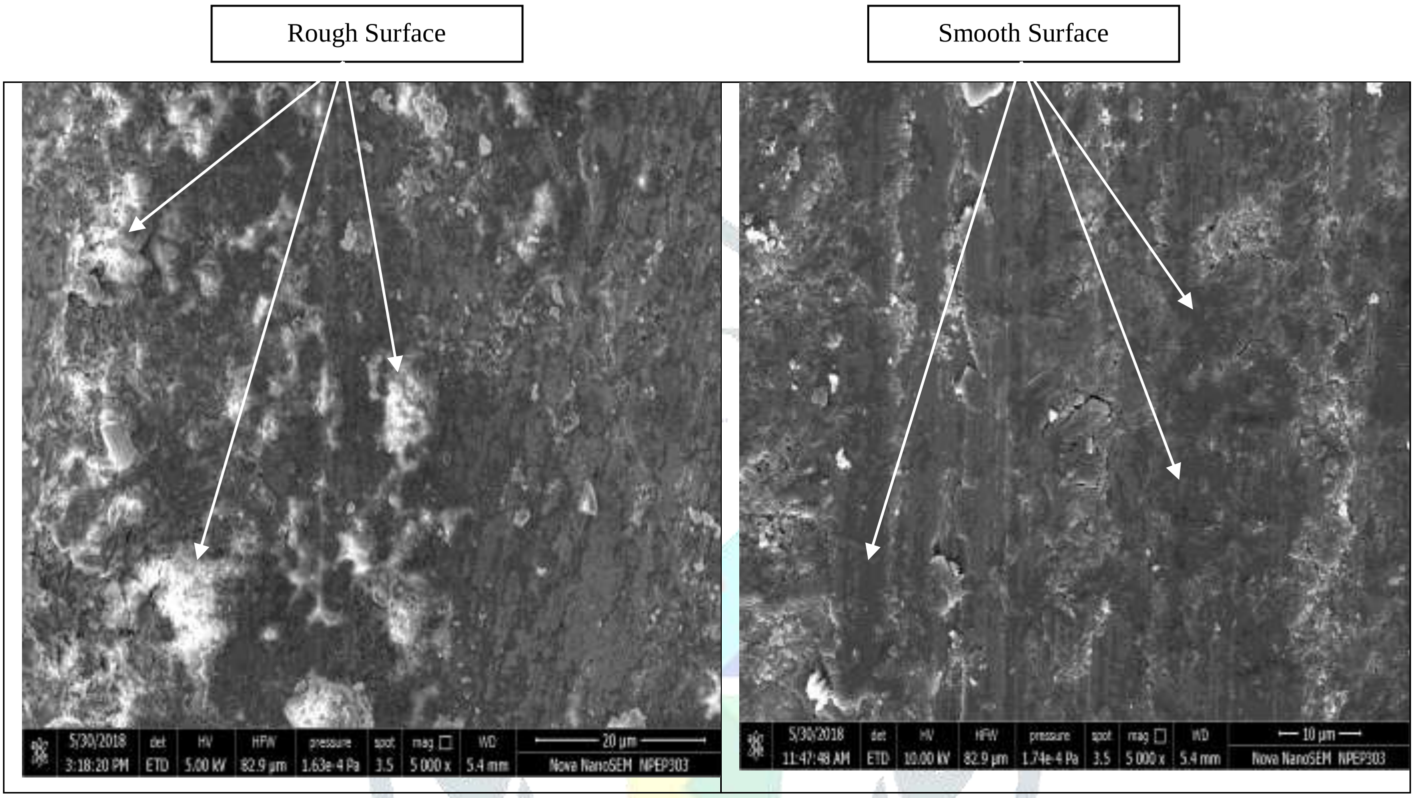


Figure 5.6 SEM micrographs after turning and after burnishing

SEM micrographs of the surfaces of Aluminium alloy in roller burnishing with show much smooth surface as compared to surface generated in turning. Average surface roughness of after turning is 2.9 micron. The average roughness after roller burnishing is obtained 0.445 micron (predicted).

VII. CONCLUSION

SEM micrographs of the surfaces of Aluminium alloy in roller burnishing with show much smooth surface as compared to surface generated in turning. Average surface roughness of after turning is 2.9 micron. The average roughness after roller burnishing is obtained 0.445 micron (predicted). This experimental results show that roller burnishing of aluminium alloy leads to a significant reduction of surface roughness is the burnishing speed. Minimum Ra value of 0.36 micron was obtained at the speed of 106 rpm. Maximum Ra value of 0.67 was obtained at speed of 424 rpm and feed of 0.07 mm/revolution

VIII. ACKNOWLEDGEMENT

It gives me great respect and fulfillment in presenting this inclusive experimental study of “Finite Element Analysis of Roller Burnishing Process”. I will always be thankful to my project guide Prof. V. K. Kurkute for his guidance in this work and his diligent support to make sure its complete within time. I would also like to express my thanks to Mechanical Engineering Department and the faculty members of P.G. (Mechanical Engineering) for their precious support.

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