OPTIMIZATION OF SURFACE TEXTURE IN DIAMOND TOOL BURNISHING PROCESS USING RSM AND ANOVA

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Abstract:Burnishing is considered as a cold-working finishing process, differing from other cold-working, surface treatment processes such as shot peening and sand blasting, etc. In that it produces a good surface finish and also induces residual compressive stresses at the metallic surface layers. The changes in surface characteristics due to burnishing will cause improvements in surface hardness, wear resistance, fatigue resistance, yield and tensile strength and corrosion resistance. The ball or roller rotates by the effect of frictional engagement between the surface of the ball or roller and the surface of the work piece.In this research paper theoptimization of surface texture in diamond tool burnishing process is done by using RSM and ANOVA methods. In which we have determined the surface roughness value which is measured on mild steel work pieces by changing the different parameter such as number of pass, speed and feed with the use of diamond burnishing tool. We will make the jobs of mild steel and will do diamond burnishing process on that job and after that by using RSM and ANOVA method we will compare the results of surface roughness value.

***IndexTerms* - Burnishing, RSM, Anova.**

1.INTRODUCTION

Surface modifications and surface treatments play vital role in enhancing service life of many critical parts of materials and devices that are used for engineering and/or structural applications. Modern technologies employ advanced surface modification techniques, such as laser treatment and coatings to enhance service life. However, most of these advanced technologies are prohibitively expensive and economically unviable for simple to moderate critical applications such as those for automobiles and machine parts. In these circumstances, traditional surface modifications that result in surface roughness values of the order of 0.1 to 0.2 µm are desirable. Numerous past studies have indicated that post-machining and metal-finishing operations have become attractive one such process is 'Burnishing' which improves surface characteristics by plastically deforming the surface layers. Though burnishing has been widely employed, no systematic studies have been conducted or reported till date, which elucidate the effects of all burnishing processing parameters on the surface finish, surface residual stress, micro structure and micro hardness. Burnishing is considered as cold-working finishing process which produces good surface finish and residual compressive stresses at metallic surface layers. It distinguishes itself from chip-forming finishing processes such as grinding, honing, lapping and super finishing, which induce residual tensile stresses at the surface, while burnishing results in residual compressive stresses. Moreover, burnishing is economical and requires less time and skill to obtain a high quality surface finish. The study of surface finish that results from burnishing is very much essential because the fatigue life, bearing properties and lubrication of a part depends largely on the appropriate surface finish which ultimately decides the effectiveness of burnishing process. If the surface finish is high, then seizure would occur due to difficulty of maintaining the lubricating oil film. On the other hand, if the surface finish is low, the hills in irregular surface reduce the metal to metal contact and valleys help to retain the film of lubricating oil; but, cannot as low surface finish leads to high wear and fatigue resistance. In order to increase the life of any part which is subjected to repeated reversals of stress, the working and non-working surfaces of that part must be given good surface finish as economically as possible. Constant surface roughness, a desirable feature can be achieved over a wide range of process conditions through hard roller burnishing. The present research aims at arriving optimum burnishing parameters for a variety of materials with characteristic strength level (in the present case varied average micro hardness) the materials considered are EN series steels, AA6061 alloy, alpha–beta brass and the burnishing parameters evaluated include burnishing force, burnishing feed, burnishing speed and number of passes. Systematic experiments have been conducted based on a 2 and 3 level Taguchi's design experiment method. Unlike many investigations reported in the open literature, the present paper also addresses the variation of micro hardness with radial distance and depth of burnishing obtained using optical microscope. Based on these data, an attempt has been made for the first time to report the 'burnishing maps' considering average micro hardness of the un-burnished materials and optimized values of burnishing volumes that has resulted in highest surface finish and highest compressive residual stresses.

2 INTRODUCTION TO PROCESS

Burnishing is the plastic deformation of a surface due to sliding contact with another object. Visually, burnishing smears the texture of a rough surface and makes it shinier. Burnishing may occur on any sliding surface if the contact stress locally exceeds the yield strength of the material.

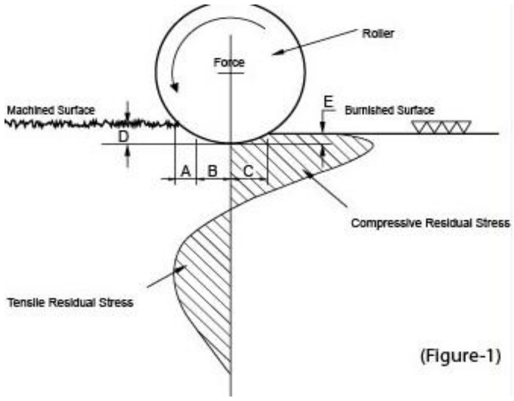


Fig 1: Burnishing Process

To understand burnishing, first look at the simple case of a hardened ball on a flat plate. If the ball is pressed directly into the plate, stresses develop in both objects around the area where they contact. As this normal force increases, both the ball and the plate's surface deform.

The deformation caused by the hardened ball is different depending on the magnitude of the force pressing against it. If the force on it is small, when the force is released both the ball and plate's surface will return to their original, undeformed shape. In this case, the stresses in the plate are always less than the yield strength of the material, so the deformation is purely elastic. Since it was given that the flat plate is softer than the ball, the plate's surface will always deform more. (Note 1: this is not necessarily true. For instance: if both items are steel, hardened steel has the same Young's Modulus as soft steel.)

If a larger force is used, there will also be plastic deformation and the plate's surface will be permanently altered. (Note 2: In this situation, hardness does play a role, as increasing hardness will delay plastic deformation.) A bowl-shaped indentation will be left behind, surrounded by a ring of raised material that was displaced by the ball. The stresses between the ball and the plate are described in more detail by Hertzian stress theory.

Now consider what happens if the external force on the ball drags it across the plate. In this case, the force on the ball can be decomposed into two component forces: one normal to the plate's surface, pressing it in, and the other tangential, dragging it along. As the tangential component is increased, the ball will start to slide along the plate. At the same time, the normal force will deform both objects, just as with the static situation. If the normal force is low, the ball will rub against the plate but not permanently alter its surface. The rubbing action will create friction and heat, but it will not leave a mark on the plate. However, as the normal force increases, eventually the stresses in the plate's surface will exceed its yield strength. When this happens the ball will plow through the surface and create a trough behind it. The plowing action of the ball is burnishing. Burnishing also occurs when the ball can rotate, as would happen in the above scenario if another flat plate was brought down from above to induce downwards loading, and at the same time to cause rotation and translation of the ball, or in the case of a ball bearing

3. **DIAMOND TOOL BURNISHING PROCESS**

Fig: 2 Diamond burnishing tool

As shown in above fig it is diamond tool in this diamond tool burnishing process various parameter are available but we are consider only three speed, feed and No. of pass here also we consider force but it is not measurable because of spring stiffness which is situated near the diamond tip.

4. EFFECTS OF BURNISHING PROCESS ON MECHANICAL COMPONENT

Burnishing is normally undesirable in mechanical components for a variety of reasons, sometimes simply because its effects are unpredictable. Even light burnishing will significantly alter the surface finish of a part. Initially the finish will be smoother, but with repetitive sliding action, grooves will develop on the surface along the sliding direction. The plastic deformation associated with burnishing will harden the surface and generate compressive residual stresses. Although these properties are usually advantageous, excessive burnishing leads to sub-surface cracks which causes palling, a phenomenon where the upper layer of a surface flakes off of the bulk material.

Burnishing may also affect the performance of a machine. The plastic deformation associated with burnishing creates greater heat and friction than from rubbing alone. This reduces the efficiency of the machine and limits its speed. Furthermore, plastic deformation alters the form and geometry of the part. This reduces the precision and accuracy of the machine. The combination of higher friction and degraded form often leads to a runaway situation that continually worsens until the component fails.

A) Burnishing in Manufacturing Process

Burnishing is not always bad. If it occurs in a controlled manner, it can have desirable effects. Burnishing processes are used in manufacturing to improve the size, shape, surface finish, or surface hardness of a work piece. It is essentially a forming operation that occurs on a small scale. The benefits of burnishing often include: Combats fatigue failure, prevents corrosion and stress corrosion, textures surfaces to eliminate visual defects, closes porosity, creates surface compressive residual stress.

There are several forms of burnishing processes, the most common are roller burnishing and ball burnishing (a subset of which is also referred to as ballizing). In both cases, a burnishing tool runs against the work piece and plastically deforms its surface. In some instances of the latter case (and always in ballizing), it rubs, in the former it generally rotates and rolls. The work piece may be at ambient temperature, or heated to reduce the forces and wear on the tool. The tool is usually hardened and coated with special materials to increase its life.

Burnishing 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 work piece material is gummy. As a cutting tool wears, it becomes more blunt 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. In drilling, burnishing occurs with drills that have lands to burnish the material as it drills into it. Regular twist drills or straight fluted drills have 2 lands to guide them through the hole. On burnishing drills there are 4 or more lands, similar to reamers.

B) Work piece Specification for experiment

The work piece of 24 mm outer diameter and 65 mm length is used in this experiment. The selected work piece material for this experiment is Mild steel (AISI 1020) due to its high machinability index and commercial availability.

AISI 1020 provides high machinability, high strength, high ductility and good weldability. Mild steel (AISI 1020) can be largely utilized in all industrial sectors. It is used in a variety of applications due to its cold drawn or turned and polished finished property. It can also be used in components like axles, spindles, machinery parts, shafts, camshafts, ratchets, light duty gears, worm gears and general engineering parts and components.

MILD STEEL PROPERTIES

The chemical, physical and mechanical properties for M.S. AISI 1020 are shown in tables below. Chemical composition of AISI 1020

TABLE 1

Component	Amount (wt. %)
Carbon, C	0.17-0.23
Sulpher, S	0.05 Max
Iron, Fe	99.08-99.53
Phosphorus, p	0.04 Max
Manganese, Mn	0.30-0.60

TABLE 2

Physical properties of AISI 1020

Density	7.87 Kg/m^3

Mechanical properties of AISI 1020

TABLE 3

Hardness	Above 18 HRC
Ultimate Tensile Strength	394.72 MPa
Ield Tensile Strength	294.74 MPa
Modulus of Elasticity	200 Gpa
Bulk Modulus	140 GPa
Poissons Ratio	0.290

Shear Modulus	80 GPa
Hardness	18 HRC

C) SELECTION OF PARAMETERS IN BURNISHING PROCESS

The process parameters that are affecting the characteristics of burnishing parts are (1).Cutting tool parameters- tool geometry and tool material. (2).Work piece parameters –hardness. (3).Cutting parameters –cutting speed, feed, no of pass. 4).Environmental parameters-dry cutting. Feed, speed, and no of pass have a direct effect on productivity, tool life, and machine requirements. Therefore, these elements must be carefully chosen for each operation. Whether the objective is rough cutting or finishing will have a great influence on the cutting conditions selected.

CUTTING SPEED

For our experiment speed range is 300 to 400 rpm. Effects of Cutting Speed. Increase in cutting speed increases temperature and results in shortening of tool life. Cutting speed variation depends on the type and hardness of the work material. Cutting at low cutting speed (20-40 m/min) tends to cause chattering. Thus, tool life is shortened.

FEED

The feed of a cutting tool in a machine work is the distance the tool advances for each revolution of the work. Feed is expressed in millimeter per revolution. Feed range 0.075 to 0.1 mm/rev.Effects of Feed: Decreasing rate results in flank wear and shortens tool life. Increasing feed rate increases cutting temperature and flank wear. However, an effect on the tool life is minimal compared to cutting speed. Increasing feed rate improves machining efficiency.

NO OF PASS

It is third factor which effects on the surface roughness. Range of number of pass is 1 to 3.

D) PARAMETERS THAT AFFECT BURNISHING PROCESS:

•Roughness: It consists of relatively closely-spaced or fine surface irregularities, mainly in the form of feed marks left by the cutting tool on the machined surface. The mean height or depth of irregularities is measured over a relatively small length called the roughness sampling length.

•Waviness: It consists of all surface irregularities whose spacing is greater than the roughness sampling length (about 1mm). Waviness may be caused by vibration, chatter, and tool and work piece deflections due to cutting loads and cutting temperature.

•Lay: It denotes the predominant direction of the surface irregularities. The lay is usually specified with respect to an edge called the reference edge of the work piece. The lay depends upon the orientation of the work piece and the cutting tool on the machine as well as the nature of the relative motion between the two.

•Surface flaws: Flaws could be due to inherent defects, such as inclusions, cracks, blow-holes, etc. in the work piece that get exposed on machining, or they could arise from the machining process.

Job Preparation before Burnishing Process:

•Turning

•Cutting

•Grinding(Centre less grinder)

•Diamond tool Burnishing

5) RSM METHOD

Burnishing process parameter optimization

Burnishing process parameters value under experiment trial:

•Speed: 300-400 RPM

•Feed: 0.075-0.1

•No. of pass:1- 3

Above three parameter we use in RSM method

A) INTRODUCTION TO RSM

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. Response surface method are used to examine relationship between one or more response variables and the set of quantitative experimental variables or factors .This method is often employed after you have identified a “vital few” controllable factors and you want find the factor setting that optimize the response .Design of this type are usually chosen when you suspect curvature in the response surface .By using Minitab software we get the 20 No. of results..

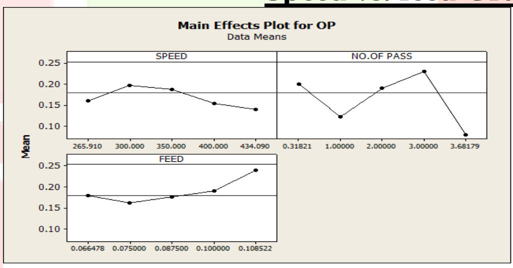
Why RSM?

RSM not only gives the effect of parameter on response but it also gives effect of machine repeatability on response.RSM also generates some important combination for experimental trial.By the end of experiment it also gives the significant of each parameter on response by help of different interaction plot.

RSM OBSERVATION TABLE 4

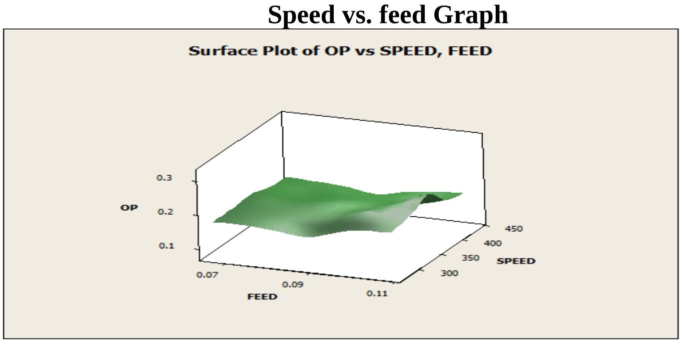
Sr.No	Run order	Blocks	Speed	Feed	No. of pass	O/P
1	1	1	350	0.0875	2	0.22
2	2	1	265.9	0.0875	2	0.16
3	3	1	400	0.100	1	0.11
4	4	1	300	0.100	1	0.12
5	5	1	300	0.075	3	0.19
6	6	1	300	0.075	1	0.16
7	7	1	350	0.0875	2	0.27
8	8	1	350	0.0875	2	0.25
9	9	1	350	0.0664	2	0.18
10	10	1	400	0.100	3	0.21
11	11	1	350	0.0875	2	0.12
12	12	1	434.1	0.0875	2	0.14
13	13	1	400	0.075	3	0.20
14	14	1	300	0.100	3	0.32
15	15	1	350	0.0875	2	0.21
16	16	1	350	0.0875	3	0.08
17	17	1	350	0.1085	2	0.24
18	18	1	400	0.075	1	0.10
19	19	1	350	0.0875	2	0.11
20	20	1	350	0.0875	1	0.20

Speed vs. feed Graph

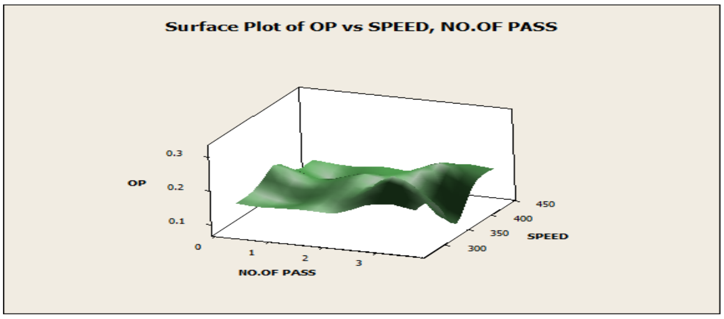


GRAPHS GENERATED BY RSM METHOD
3D Charts Generated in the RSM:

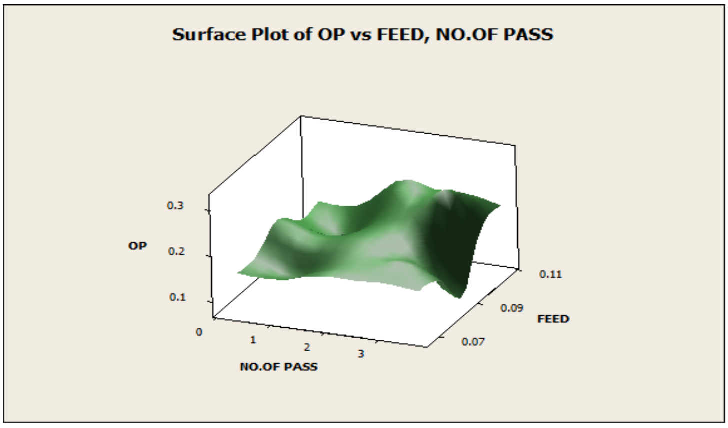
Speed vs. feed Graph



Speed vs no. Of pass



Feed vs. No.of pass



6) ANOVA METHOD

A) INTRODUCTION TO ANOVA

The ANOVA procedure performs analysis of variance (ANOVA) for balanced data from a wide variety of experimental designs. In analysis of variance, a continuous response variable, known as a dependent variable, is measured under experimental conditions identified by classification variables, known as independent variables. The variation in the response is assumed to be due to effects in the classification, with random error accounting for the remaining variation.

The ANOVA procedure is one of several procedures available in SAS/STAT software for analysis of variance. The ANOVA procedure is designed to handle balanced data (that is, data with equal numbers of observations for every combination of the classification factors), whereas the GLM procedure can analyze both balanced and unbalanced data. Because PROC ANOVA takes into account the special structure of a balanced design, it is faster and uses less storage than PROC GLM for balanced data.

Use PROC ANOVA for the analysis of balanced data only, with the following exceptions: one-way analysis of variance, Latin square designs, certain partially balanced incomplete block designs, completely nested (hierarchical) designs, and designs with cell frequencies that are proportional to each other and are also proportional to the background population. These exceptions have designs in which the factors are all orthogonal to each other. For further discussion, refer to Searle (1971, p. 138). PROC ANOVA works for designs with block diagonal X0X matrices where the elements of each block all have the same value.

The procedure partially tests this requirement by checking for equal cell means. However, this test is imperfect: some designs that cannot be analyzed correctly may pass the test, and designs that can be analyzed correctly may not pass. If your design does not pass the test, PROC ANOVA produces a warning message to tell you that the design is unbalanced and that the ANOVA analyses may not be valid; if your design is not one of the special cases described here, then you should use PROC GLM instead. Complete validation of designs is not performed in PROC ANOVA since this would require the whole X0X matrix; if you're unsure about the validity of PROC ANOVA for your design, you should use PROC GLM.

ANOVA EXPERIMENTAL TABLE 5

Sr. No	Run Order	Blocks	Speed	Feed	No. Of pass	O/P	EFFECT	COEFFICIENT
1	1	1	300	0.075	1	0.16	-0.0425	0.17625
2	2	1	400	0.075	1	0.10	0.0275	-0.0212
3	3	1	300	0.1	1	0.12	0.1075	0.01375
4	4	1	400	0.1	1	0.11	-0.0175	0.05375

5	5	1	300	0.075	3	0.19	-0.0075	-0.0087
6	6	1	400	0.075	3	0.20	0.0425	-0.00375
7	7	1	300	0.1	3	0.32	-0.0425	0.02125
8	8	1	400	0.1	3	0.21		-0.02125

EXPERIMENTAL RESULTS TABLE 6

SrNo.	**Factors**			**Treatment Combination**	**Response**
	Speed	**Feed**	**No. Of pass**		**Ra value (μm)**
1	300	0.075	1	1	0.16
2	400	0.075	1	A	0.10
3	300	0.100	1	B	0.12
4	400	0.100	1	Ab	0.11
5	300	0.075	3	C	0.19
6	400	0.075	3	Ac	0.20
7	300	0.100	3	Bc	0.32
8	400	0.100	3	Abc	0.21
9	350	0.087500	2	-	0.22
10	350	0.087500	2	-	0.27
11	350	0.087500	2	-	0.21
12	350	0.087500	2	-	0.11

CALCULATION:-

Effects

(1) Effect of A = (a+ab+ac+abc-1-b-c-bc)/4n
= (0.10+0.11+0.20+0.21-0.16-0.12-0.19-0.32)/ 4*1
= -0.0425

(2)Effect of B = (b+BC+ab+abc-1-a-c-ac)
= (0.12+0.32+0.21+0.11-0.16-0.10-0.19-0.20) /4*1
= 0.0275

(3) Effect of C =(c+ac+BC+abc-1-a-b-ab)/4n
= (0.19+0.20+0.32+0.21-0.16-0.10-0.12-0.11)/4*1
= 0.1075

(4)Effect of AB = (ab+ABC+c+1-ac-bc-a-b)/4n
= (0.11+0.21+0.19+0.16-0.20-0.32-0.10-0.12)/4*1
= -0.0175

(5)Effect of BC = (bc+abc+a+1-ab-ac-c-b)/4n
= (0.32+0.21+0.10+0.16-0.11-0.20-0.19-0.12)/4*1
= 0.0425

(6)Effect of AC = (ac+abc+b+1-ab-bc-c-a)/4n
= (0.20+0.21+0.12+0.16-0.11-0.32-0.19-0.10)/4*1
= -0.0075

(7)Effect of ABC = (a+b+c+abc-ab-bc-ac-1)/4n
= (0.10+0.12+0.19+0.21-0.11-0.32-0.20-0.16)/4*1
=-0.0425

Sum of Squares:-

1.SSA = (Effect of A× 4n)2/(8n)
= (-0.0425×4*1)2/(8*1)
= 0.0036

2. SSB = (Effect of B× 4n)2/(8n)
= (0.0275×4*1)2/(8*1)
= 0.00151

3. SSC = (Effect of C× 4n)2/(8n)
= (0.1075×4*1)2/(8*1)
= 0.02311

4. SSAB = (Effect of AB× 4n)2/(8n)
= (-0.0175×4*1)2/(8*1)
= 0.000625

5. SSAC = (Effect of AC× 4n)2/(8n)
= (-0.0075×4*1)2/(8*1)
= 0.0001125

6. SSBC = (Effect of BC× 4n)2/ (8n)
= (0.0425×4*1)2/(8*1)
= 0.0036

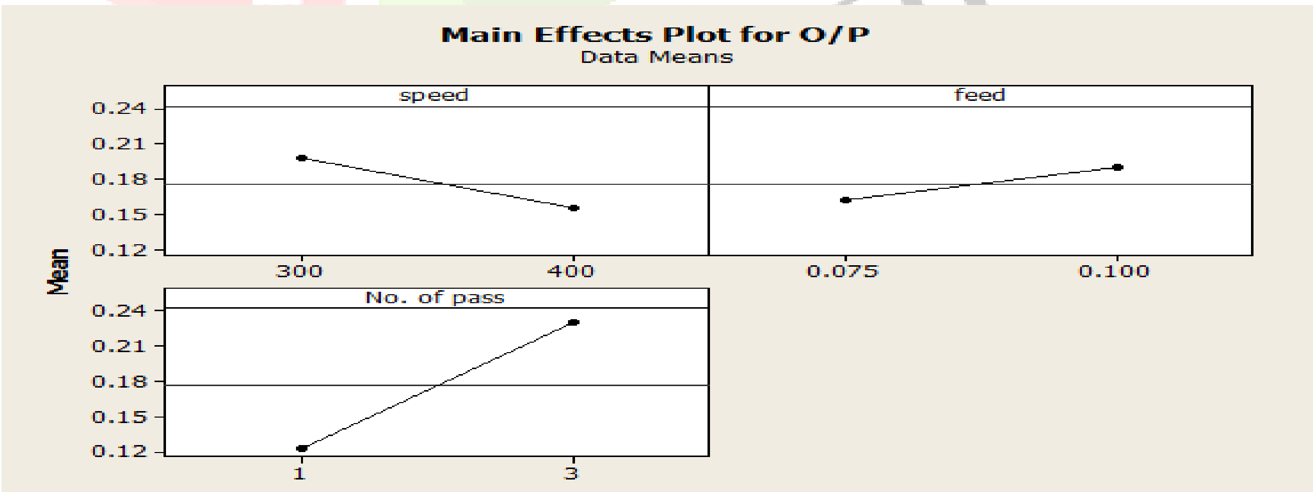
7. SSABC = (Effect of ABC× 4n)2/(8n)
= (-0.0425×4*1)2/(8*1)
= 0.0036125

Percentage Contribution

- Cutting Speed(A) = (0. 0036/0.02821)x100
  = 12.7 6%
- Feed(B) = (0.00151/0.02821)x100
  = 5.35%
- No. of pass (C) = (0.02311/0.02821)x100
  = 81.93%

From ANOVA table, it is clearly understood that, No. of pass has high contribution in Ra value (81.93%) followed by Feed (5.35%) and Cutting speed (12.76%).

Main Effects Plots



Centre Point Calculation :-

(1) y_f = (0.16+0.10+0.12+0.11+0.19+0.20+0.32+0.21)/8
=0.17625

(2) y_c = (0.22+0.27+0.21+0.11)/4 = 0.2025

$SS_{purequadratic} = n_c \times n_f (Y_f - Y_c)^2/(n_c+n_f)$

$= 8*4(0.17625-0.2025)^2/(8+4)$

$= 0.00183$

$SS_{error} = \sum n_c = (Y_i - Y_c)^2$

$= \{(0.22-0.2025)^2+(0.27-0.2025)^2+(0.21-0.2025)^2+(0.11-0.2025)^2\}$

$= 0.01347$

$SS_{total} = SS_A + SS_B + SS_C + SS_{AB} + SS_{BC} + SS_{AC} + SS_{ABC} + SS_E + SS_{Pure\ quadratic}$

$= 0.04964$

2^3 Design model

A 2^3 design model is given by

$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1 x_2 + \beta_5 x_2 x_3 + \beta_6 x_1 x_3 + \beta_7 x_1 x_2 x_3$

$Y=0.17625-0.02125\ X_1+0.01375\ X_2+0.5375\ X_3-0.00875\ X_1\ X_2-0.00375\ X_2\ X_3+0.02125\ X_1\ X_3-0.02125\ X_1\ X_2\ X_3$.

Where y = Function of Model,

x_1, x_2, x_3 = Speed, Feed and no. Of pass respectively.

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$ = Co-efficient

x_1x_2 , x_2x_3 , x_1x_3 = interaction between Speed and Feed, Speed and No. Of pass, Feed and No. Of pass respectively.

$x_1x_2x_3$ =Interaction between Speed, Feed, and no. Of pass

CONCLUSION:

RSM METHOD RESULT:

The surface roughness value increases with increase in speed up to 350 RPM ,decrease with increase in feed up to 0.088 MM/Rev. and decrease with increase in No. of pass up to 2.

For optimum roughness it is suggested that maintain the speed around 350 RPM, feed about 0.09 MM/Rev. and 2 to 3 Number of pass.

ANOVA METHOD RESULT:

The value of surface roughness decreaseswith increase inspeed, decrease in feed and with more number of pass.

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