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Investigation on Aluminium Alloy 1100 Using Taguchi Design Methodology on CNC Milling

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ABSTRACT

The machining procedure depends on material properties and machining parameters. This paper summarizes a comprehensive study aimed at improving the effect of shear parameter testing on the surface roughness of 1100 aluminium alloys using the Taguchi design system. Ideal parameter for dealing out i.e. Spindle speeds, feed rate, depth of cut, and coolant's flow. Orthogonal Taguchi Matrix is considered with three destructive levels of machining parameter, tests are performed using Orthogonal Group L9 (34) with nine columns, and nine unique by mixing nine specific parameters. Tests were processed and each estimate was collected. Work After heavy machining, each part of the material determines its surface roughness. The estimated surface/noise ratio (S/N) is close to the ideal quality of the test. The goal of the work is done by estimating the signal-to-noise ratio of the assertion. The test was within the expected limits.

Keywords: - 1100 aluminium alloy, taguchi method, feed rate, spindle speed, depth of cut, coolant flow

1. Introduction:-

Milling is one of the most convenient machining operations and one of the most convenient. Grinding is one of the most common and basic raw material removal processes in manufacturing industries such as the automotive and aerospace industries, where quality is an impotant consideration in slot, bag and mussel / mussel manufacturing. When a router uses a multi-tooth rotary cutter to remove metal, each tooth has a cutting edge to remove metal from the work piece. In milling, parts are generally sent to a rotary cutting tool called a milling cutter. The uniformly spaced peripheral teeth of the tool are in discontinuous contact with the work-pieces and the work-pieces. Milling machenis are used to produce parts with flat and curved contours. You can use the milling macheni to create complex shapes that other macheni tools cannot create. This macheni is probably close to the big turning point [1]. Milling tools are a very important and complex part of manufacturing. Many researchers have done a lot of research and experimentation on milling tool design and are still working on its. Many aspects such as tool properties, surface roughness, edge radius, resistance to cutting, vibration, abrasion, etc. I am involved in the design of milling tools. Milling is the process of creating complex, flat shapes using a multi-tooth cutting tool (multi-point cutter) called a milling cutter, and the cutting edge called a tooth. The axis of rotation of the cutting tool is parallel or perpendicular to the work surface and is perpendicular to the feed direction. Traditionally, this milling macheni was called a milling macheni. The most common cutting tool used in vertical milling is an end mill. It looks like a thick twist drill with a flat end instead of a pointed one. The cutter can cut Part 2 vertically, like a drill bit, or horizontally using the face of the cutter. This transverse movement exerts a strong lateral force on the tool and the cutter, both of which require rigidity. By making a series of horizontal cuts across the surface of the work- piece, Paver removes a layer of metal to a precisely controlled depth of approximately 1/1000 inch (0.001 inch). High Speed Milling (HSM) has become increasingly important in recent years due to the increasing demand for quality, productivity and cost savings in production. The HSM can be used primarily for the production of relatively soft materials and large components. The CNC vertical milling macheni has been greatly improved to meet the advanced requirements of various manufacturing fields, especially the precision metal cutting industry. High quality and high production rates are required to maintain material properties. The surface finish of the product affects the appearance, function and reliability of the product, so the surface finish of the machined surface is more important. For these reasons, it is important to maintain consistent surface finishes and tolerances. A higher production rate is also desirable without sacrificing material properties.

1.1 Process parameters

1. Cuttings speed: The cutting speeds (Vc) of milling is defined as the tangential speed of the tool (tool). The cutting speed is given by the subsequent formula: $\boldsymbol{Vc} = \boldsymbol{\pi DN1000m}$ / $\boldsymbol{m}$ Cutter (mm.) and N is the cutter speeds (r.).

The choice of cutting speed baseds on the subsequent factors:

a) Characteristics of the materials to be cut;

b) Diameters along with useful life of the cutter;

c) Number of cutter teeths;

d) Advance;

e) Depth of cuts and width’s of cut

f) Used of coolants.

2**. Feed rate**: The feed rate (f) during milling is defined as the movement of the part with respect to the tool axis. This is the speed at which the work-piece is sent to the tool. The best possible feed is used for roughing, but the finish is limited by the specified surface finish. When milling mild steel, the feed rate ranges from 0.03 mm / tooths to 0.For 25 mm milling / hardened steel, the recommended feed rate is one third to one half of these values

3. Cutting depth: During milling, the cutting depth (d) is the cutting thickness. The layers of material are immediately removed from the work piece under the milling cutter (tool). The milling cutter is mounted on the vertical axis of the milling groove and the lifting of the table determines the depth of the cut. Rough cuts typically have a depth of cut between 3mm and 8mm and finished cuts less than 1.5mm

2. **Problem formulations:-**

On the basis of literature study constraints Spindle speeds, feed rates (f) along with depth of cut (DOC), coolant flows are picked for this present work. The experimental work is performed to study the material surface roughness using machining parameters selected as spindle speed speed, feed rate (f) as well as depth of cut, coolant’s flow using Taguchi L9 orthogonal array

- To discover influence on surface roughness with Cutting’s Speed, Feed furthermore Depth’s of Cut, coolant’s flow
- To find optimal parameters by ANOVA method influence on Surface Roughness of Aluminium Alloy 1100.

3. **EXPERIMENTAL SETUP**

In present investigation, the experiments are conducted on a Vertical Milling macheni of model BFW Agni+BMV 45 + tc24 manufactured by BFW. The macheni specifications are shown in the table 4.1 below. Milling is the second most used macheni after lathe macheni. The material is removed in form of chips from the work-piece by the facilitate of rotary cutter tool rotating at high velocity. The macheni was accessible at Central

Institute of Plastic Engineering and Technology, Lucknow. Figure 4.1 on the next page shows the BFW Agni+BMV 45 + tc24.

3.1 Materials properties of Aluminium alloy-1100:-

(Cu) Copper.	0.04-0.25%
(Fe) Iron.	0.96Max
Manganese.	0.04%
(Si).Silicon.	0.94%
(Zn).Zinc.	0.12%
Density (x1000 kg/m2).	2.80
Residual.	0.16%
Poisson's Ratio(μ)	0.34
Elastic Modulus (E) (GPa).	68-80
Tensile Strengths (Mpa).	112
Yield Strengths (Mpa).	106

Table 3.1 Materials properties of AL-1100

3.2 **CNC Milling Macheni (BFW Agni+BMV 45 + tc24),**

Height/Stroke Length	450.0 mm
Length of the bed	600.0 mm
Clamps use	Hydraulic vice
coolant	Diesel Engine Oil

Table 3.2 CNC milling mchine

3.3 Tool details: - Mill Cutter

Materials	Carbide.
Diameter	55.0mm.

Table 3.3 Tool details

3.4. Surface roughness Equipment details; - Mitutoyo Surf test SJ-301

Tip Material	Diamond
Traverse length of tip	8mm

Table 3.4 Surface roughness Equipment details

Figure 3.1: BFW Agni+BMV 45 + tc24

3.5 Surface Roughness:-

Surface roughness indicates the quality of the machining or work. When the plane roughness of the work is reduced, the surface finish of the work is improved and the machining quality is improved, so it is desirable to reduce the surface roughness of the work. Plane roughness is measured with a Mitutoyo 178602 plane roughness meter. The figure below is a Mitutoyo 178602 plane roughness meter and Table 4 shows the specifications for plane roughness adjustment. Surface quality plays an important role in the performance of machined surfaces. A good quality floor plane improves fatigue resistance, corrosion resistance and service life. plane roughness also affects many functional properties of parts, such as wear resistance, surface friction, lubricant distribution and retention, and coating retention. The irregularities caused by the cutting action of the cutting edge and the abrasive grains and the advancement of the macheni tool due to the machining and action of the abrasive grains are called plane roughness, called texture irregularity, and the roughness is considered to overlap fundamentally be finished On wavy surfaces**.** The upper limit of height or the roughness form created by a single point cutting tool is given by

$$\mathbf{Hmax = f^2 / 8R}$$

Where f is feed and R is nose radius.

Figure 3.2: MITUTOYO 178-602 Surface Roughness tester measuring the roughness of surface machined by milling macheni

Roughness is an impotant parameter in determining whether a plane is suitable for a particular use. Rough planes frequently wear out faster than smooth surfaces. Rough planes are often susceptible to corrosion and cracking, although they also contribute to adhesion. Roughness meters are used to rapidly and precisely find out the plane texture or plane roughness of a material. The roughness meter displays the determined roughness depth (Rz) and the average roughness value (Ra) in micrometers or micrometers (μm).To measure surface roughness; you need to apply a roughness filter. Different international standards and specifications for texture or plane finish recommend the use of different roughness filters. Example, the ISO standard habitually recommends a Gaussian filter

4. **RESULTS AND DISCUSSION**

4.1 CALCULATION FOR PLANE ROUGHNESS

Surface roughness is a calculation of the relative smoothness of a plane profile. In this case, numeric parameters are used. The Ra surface texture graph shows the arithmetic mean of the surface height. As already mentioned, the surface has three basic components.These include roughness, the waviness, and the lay. Therefore, several factors influence the shape characteristics of the surface.

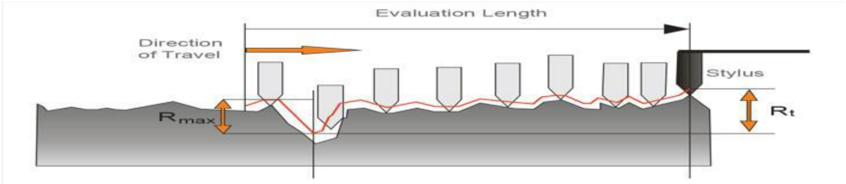


Fig.4.1 Different factors are affecting the characteristics of surface geometry.

1. Direct measuring methods.
2. Non Contact method,
3. Comparison method,
4. In-process method,

The direct measurement method uses a pencil to measure the roughness of the surface, so the pencil should be drawn perpendicular to the surface. The machinist then uses the saved profile to determine the roughness parameters. White light and confocal light replace the pencil.These instruments use different measuring principles. The physical probe can be modified with an optical sensor or a microscope. First, the apparatus is used to send an ultrasonic pulse to the surface. Then there are the changes and reflections of the sound waves. You can then evaluate the reflected wave to determine the roughness parameters. On the other hand, the comparison method uses a surface texture pattern. These patterns are generated by the device or process. The manufacturer then uses visual and tactile sensations to compare the results. The results are compared with known surface roughness parameters. Current engineering is inductance.This method is useful for evaluating surface roughness with magnetic materials. Here, the inductive receiver uses electromagnetic energy and uses the energy to measure the distance to the surface. The defined parameter values will help you find comparative roughness parameters.

Iterations Numbers	Control Factors				Surface roughness
	Spindle**’s** Speed(rpm)	Feed’s rate (mm/min)	Depth of Cut(mm**)**	Coolant’s Flow(Lt/min)	
1	1500	1200	0.50	80	0.61650
2	1500	840	1.00	100	0.60300
3	1500	600	1.50	120	0.41750
4	2500	1200	1.00	120	0.67550
5	2500	840	1.50	80	0.41500
6	2500	600	0.50	100	0.38900
7	3500	1200	1.50	100	0.38150
8	3500	840	0.50	120	0.45200
9	3500	600	1.00	80	0.41500

Table 4.1: Calculations for surface roughness

4.2 Investigational results of plane roughness & computed S/N Ratios:-

The S/N ratio, which condenses the various data points within a examination, depends on the type of attributes being estimated. For estimate of S/N ratio for surface roughness LARGER IS BETTER situation is opted.

The equation for the computation of S/N ratio for material removal rate is:

$$S/N_{LB} = -10 \log (\Sigma (1/y_i^2))$$

Iterations Numbers	Control Factors				Surface roughness	S/N Ratio
	Spindle**'s** Speed(rpm)	Feed rates (mm/min)	Depth of Cut(mm**)**	Coolant's Flow(Lt/min)		
1	1500	1200	0.50	80	0.61650	**4.20133**
2	1500	840	1.00	100	0.60300	**4.39365**
3	1500	600	1.50	120	0.41750	**7.58687**
4	2500	1200	1.00	120	0.67550	**3.40749**
5	2500	840	1.50	80	0.41500	**7.63903**
6	2500	600	0.50	100	0.38900	**8.20100**
7	3500	1200	1.50	100	0.38150	**8.37010**
8	3500	840	0.50	120	0.45200	**6.89723**
9	3500	600	1.00	80	0.41500	**7.63903**

Table 4.2 Computation of S/N ratio for surface roughness

4.3 Computation of Mean S/N ratio for surface roughness

Mean S/N ratio is computed by using subsequent formula

$$n_{fi}= (n_{f1}+n_{f2}+n_{f3})/3$$

Anywhere nf is mean S/N ratio for aspects f at the level value i of the choosen factors. nf1, nf2, nf3 are S/N ratio for factors f at level u

The aspects which influence the machining parameters demonstrate in the table as their relevant ranks. Rank of the restrictions depends on the value of delta. If the delta value of one constraint is higher than the other that represents first rank. Superior value of S/N ratio of all aspect shows the best possible level of the factor..

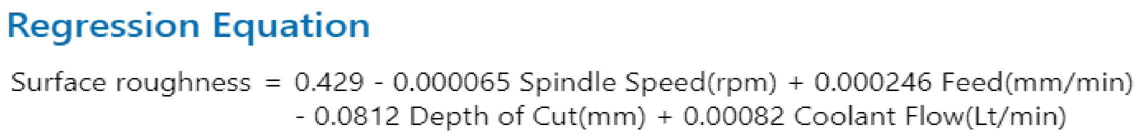
Level	Spindle’s Speed(A)	Feed’s rate (B)	Depth of Cut(C)	Coolant’s Flow (D)
1	5.39395	5.32630	6.43318	6.49313
2	6.41584	6.30997	5.14672	**6.98825**
3	**7.63545**	**7.80896**	**7.86533**	5.96386
Delta	2.2415	2.48266	2.71861	1.02439
Rank	**3**	**2**	**1**	**4**

Table 4.3: Computation of mean S/N ratio for plane roughness

4.3 ANOVA (Analysis of Variance) for surface roughness

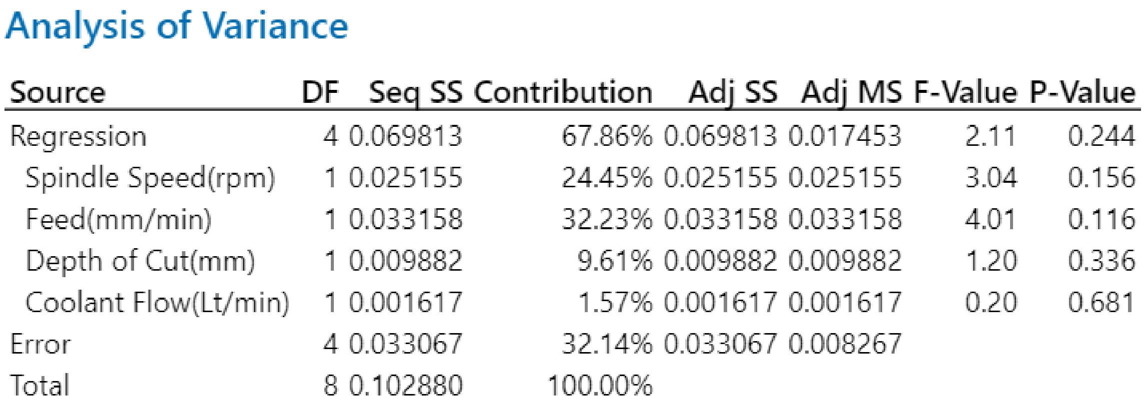
4.3.1 Regression Equation:-

This regression equation we found from **Minitab Software** by using different parameters which affect the surface roughness during milling operation of aluminium alloy 1100.



Regression Equation

Surface roughness = 0.429 - 0.000065 Spindle Speed(rpm) + 0.000246 Feed(mm/min) - 0.0812 Depth of Cut(mm) + 0.00082 Coolant Flow(Lt/min)



Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	4	0.069813	67.86%	0.069813	0.017453	2.11	0.244
Spindle Speed(rpm)	1	0.025155	24.45%	0.025155	0.025155	3.04	0.156
Feed(mm/min)	1	0.033158	32.23%	0.033158	0.033158	4.01	0.116
Depth of Cut(mm)	1	0.009882	9.61%	0.009882	0.009882	1.20	0.336
Coolant Flow(Lt/min)	1	0.001617	1.57%	0.001617	0.001617	0.20	0.681
Error	4	0.033067	32.14%	0.033067	0.008267		
Total	8	0.102880	100.00%				

Table 4.4 ANOVA of surface roughness

4.4 Assortment of most favourable Set of Conditions for plane roughness:

The finest condition for Spindle's Speed aspect is level 3 (3500rpm), for Feed rate is level 3 (600mm/rev), for Depth of Cut level 3 (1.5mm) as well as Coolant's Flow be level 2 (100). Thus, the optimal machining parameters prefer were: A3,B3,C3,D2.

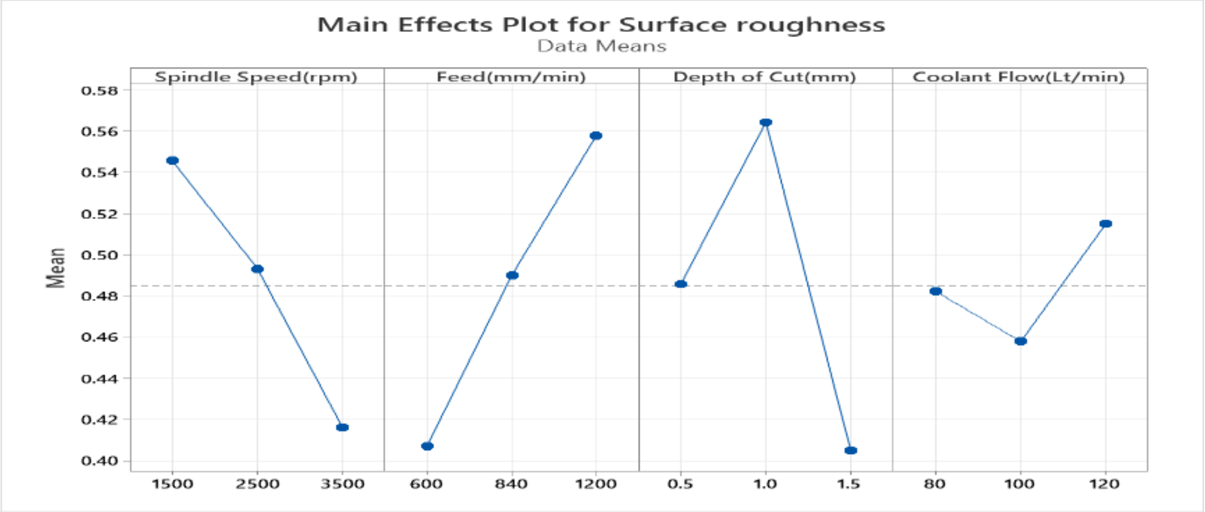


Figure 4.1: Main effect plot for means of surface roughness

The chart above shows the relationship among the plane roughness and the four parameters of a CNC milling machine. Feed rate has a great influence on surface roughness and is the most influential parameter with a contribution rate of 32.23%. It is the most dominant factor for plane roughness. Plane roughness seems to increase as the feed rate boosts. This is because increasing feed reduces vertical removal time, generates heat in the tool and workpiece, and removes material more quickly. As a result, the surface roughness of aluminem 1100 increases at forward speed. The minimum observed surface roughness is 600 mm / min. Spindle speed is the second dominant factor for surface roughness with a contribution of 24.When the spindle speed increases to 45%, the heat from the friction causes the tool and components to heat up. Even at high speed, the material removal rate is high and the material is removed from the surface in the form of chips. High heat rates and large craters increase the roughness of the surface. Minimum surface roughness was observed at 1500 rpm.As can be seen, depth of cut is the third factor that determines plane roughness with a involvement rate of 9.61%. Coolant flow was found to be the smallest surface roughness modifier with a involvement of 1.57%. His influence is negligible compared to that of. Feed speed and cutting speed. There was no significant change in the surface roughness value as the refrigerant flow rate increased.

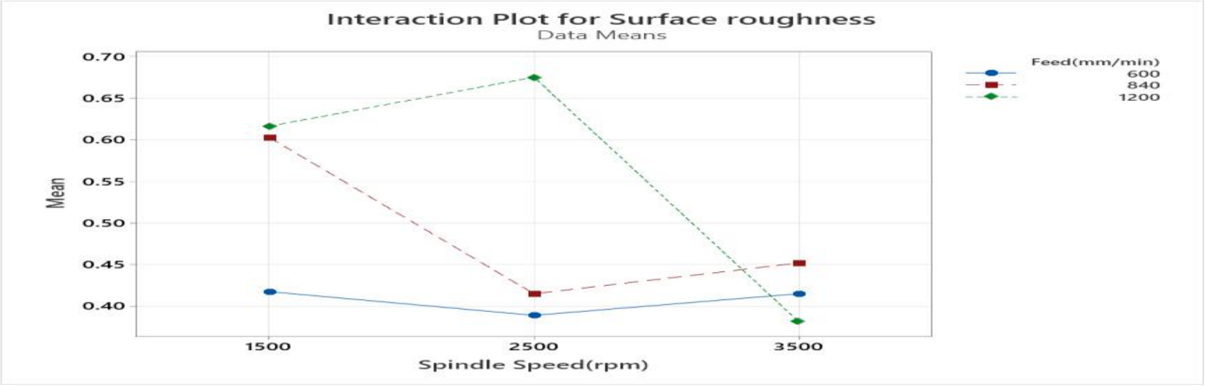


Fig.4.2 Interaction plot between Surface Roughness and Spindle Speed at various levels of Feed

The graph above shows the interaction among plane roughness as well as cutting's speed at dissimilar feed rates given on a CNC milling macheni. The histogram shows that the surface roughness tends to increase as the spindle speed increases at all feeds. The graph shows that the rate of increase in plane roughness boosts as the feed's rate decreases. As the tool feed increases, the surface roughness increases with the cutting speed, but the speed decreases compared to when the tool feed is low. Roughness is observed at the highest levels of spindle and feed speeds.

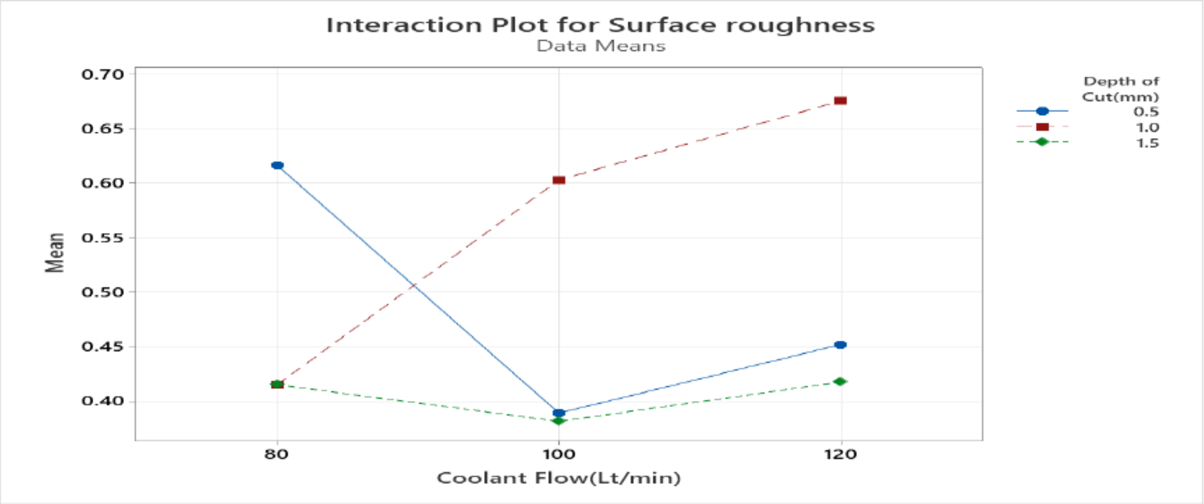


Fig.4.3 Interaction plot between Surface Roughness and Coolant flow at different levels of Depth of cut

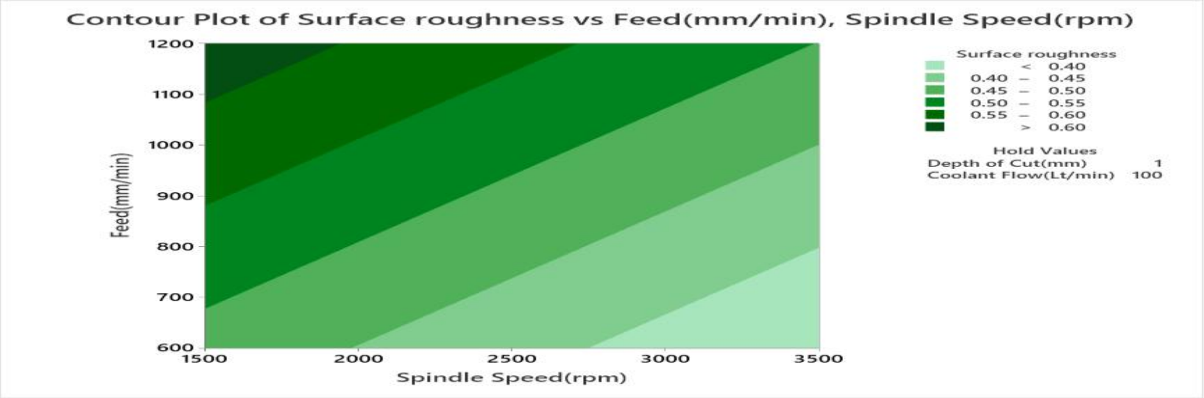


Fig.4.4 Contour plot of plane roughness Vs feed's rate, Spindle's speed

4.5 Predict of process average for optimal situation for surface roughness:-

The complementary counts are done, for all one of the cases the predict esteem figured in a analogous methodology,

$\eta_{\text{predicted}}=Y+(A3-Y)+(B3-Y)+(C3-Y)+(D2-Y)$

=A3. +B3. +C3. +D2.-3Y.

=[**(7.63545)+(7.80896)+(7.86533)+(6.98825)]-[3x(6.48174)]**

=10.85277

Therefore envisaged average for most favourable condition of plane roughness is 10.85277.

Conformation Test

Confirmation tests have been performed for plane Roughness with their optimal levels of course of action variables.

Table 4.5: Confirmation of expected as well as actual values of surface roughness

Exp.No.	optimal Machening Parameters				Surface Roughnes	
	Spindle**'s** Speed(rpm)	Feed's rate(mm/min)	Depth of Cut(mm**)**	Coolant's Flow(Lt/min)	Actual	Expected
1	3500	**600**	1.5	100	**8.37010**	10.85277
					Error (%)	22.64

5. **CONCLUSION**

The present experimental investigation was conducted on **BFW Agni+BMV 45 + tc24** vertical milling macheni using Aluminium alloy 1100 as work piece and HSS as tool to analyze the consequence of process constraints viz. feed rate, spindle's speed, depth of cut and coolant's flow on performance measures plane roughness. The subsequent conclusions were made on the base of investigation:

- Feed's rate has a great impact on plane roughness and is the most influencing parameter with an involvement of 32.23 %. It dominates plane roughness significantly. The plane roughness appears to get increase with the increase in the level of feed rate. This is as when the feed is boost, the time for the length material to be removed diminishes. Surface roughness is minimum at 600mm/min and maximum at 1200mm/min.Due to the induced heat in tool and the work piece and faster material removal, the surface roughness of Aluminium alloy 1100 increases with feed rate.

- Spindle speed is the 2nd most dominating part for surface roughness with a contribution of 24.45 %. As the spindle speed increases, the tool and work piece get heated due to heat produced by the friction. Minimum surface roughness was examined at 3500 RPM.

- Depth of cut is found to be the third domination factor for surface roughness with a contribution of 9.61 %. Its consequence is negligible as compared to the effect of feed rate as well as spindle speed. Coolant flow is to be found least dominating factor for surface roughness only contribution 1.57%. Minimum surface roughness is originated at coolant flow rate 100 Lt/min. No significant variation is getting in the value of surface roughness with increasing levels of coolant flow.

- The most excellent state for Spindle's Speed aspect is level 3 (3500rpm), for Feed rate is level 3 (600mm/rev), for Depth of Cut level 3 (1.5mm) and Coolant's Flow is level 2 (100). Thus, the most favourable machening constraints chosen were: A3, B3, C3, and D2.

- The ANOVA investigation order is examined that subsequent order of consequence on surface roughness is identified: Feed rate> Spindle speed> depth of cut > coolant flow.

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