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Experimental Investigations to Determine Optimal Cutting Parameters in Grinding Operations by Design of Experiments

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ABSTRACT

Grinding is one of the important metal cutting processes used extensively in the finishing operations. Grinding machines are generally used for achieving of high dimensional accuracy surfaces and good surface finish. In most cases, the grinding is the final processing operation. A large amount of coolant is needed to achieve the grinding performance in terms of grinding forces, metal removal rate; temperature developed in grinding zone, Specific energy and better work piece surface finish.

The surface roughness and material removal rates are determined by performing different experiments on grinding of Aluminum alloy 6082 pieces is done in this thesis. This is done by varying the cutting parameters table feed, depth of cut and speed for minimum surface roughness and maximum material removal rates. The parameters considered for experimentation are feed rate 11mm/min, 19mm/min and 28mm/min, the Spindle speed 1100rpm, 1200rpm, 1400rpm, the depth of cut 0.01mm, 0.05mm and 0.1mm. L9 orthogonal array is taken and experimentation is done. The optimization is carried out by using Taguchi Method and regression analysis in Minitab software

INTRODUCTION

THE GRINDING PROCESS

Grinding is the process of removing metal by the application of abrasives which are bonded to form a rotating wheel. When the moving abrasive particles contact the work piece, they act as tiny cutting tools, each particle cutting a tiny chip from the work piece. The grinding

Machine supports and rotates the grinding abrasive wheel and often supports and positions the work piece in proper relation to the wheel.

The grinding machine is used for roughing and finishing flat, cylindrical, and conical

Surfaces; finishing internal cylinders or bores; forming and sharpening cutting toolssnagging or removing rough projections from castings and stampings; and cleaning, polishing, and buffing surfaces. Once strictly a finishing machine, modern production grinding machines are used for complete roughing and finishing of certain classes of work. Various types of grinding machines used for finishing processes are explained below.

Shaping and finishing of components made of metals and other materials is done by surface generation and material removal method that is done by grinding process. When comparing with that of either milling or turning the surface finish and precision obtained through grinding may be up to 10 times.

BASICS OF GRINDING

Pore density or structure of wheels is one of the main aspects that refer to the porosity between individual grains. Chips are formed in the areas and coolant retention provision is done by spaces between the grains which are created by pore structure. For hard materials dense wheels are good, for soft metals w more open densities are good.

The performance of a wheel is dependent on the three factors of pore structure, bond type and structure of grain that are closely related .Suspected damaged or damaged wheels should not be used.

For this purpose truing and wheel dressing and truing is done with special tools. The dressing task is performed automatically by some grinding machines but for some dressing is done manually between work cycles.

The coolants application to the grinding process is important. Work quality is maintained, power requirements for grinding machine are reduced, longer life of wheel is ensured and part dimensions are stabilized when coolants are used. Coolants are emulsions, synthetic lubricants or special grinding oils. Either by jet streams of high pressure or by flooding area coolants is applied.

TYPES OF GRINDING

The major four grinding processes are:

• Cylindrical grinding machine
• Internal grinding machine
• Center less grinding machine
• Surface grinding machine

Cylindrical Grinding machine

Cylindrical grinder is a type of grinding machine used to shape the outside of an object. The cylindrical grinder can work on a variety of shapes, however the object must have a central axis of rotation. This includes but is not limited to such shapes as a cylinder, an ellipse, a cam, or a crankshaft.

Cylindrical grinding is defined as having four essential actions:

- The work (object) must be constantly rotating
- The grinding wheel must be constantly rotating
- The grinding wheel is fed towards and away from the work
- Either the work or the grinding wheel is traversed with respect to the other.

Cylindrical grinding machine is used to produce external cylindrical surface. The surfaces
maybe straight, tapered, steps or profiled. Broadly there are three different types of Cylindrical grinding machine as follows:

1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centre less cylindrical surface grinder

LITERATURE SURVEY

INTRODUCTION

Many researcher works on grinding machine, but only few works are done on cylindrical Grinding from the literature survey. So my present work is based on cylindrical grinding machine.

REVIEW OF RESEARCH PAPERS

The following works are done by some authors on grinding operations

B. Dasthagiri, Dr. E. VenugopalGoud [1], focused on empirical models development using RSM technique for MRR and surface roughness by considering control parameters as depth of cut, table speed and wheel speed. Optimizing machining parameters for minimizing surface roughness and maximizing MRR on surface grinding EN8 steel are the main objectives of RSM. For surface roughness and metal removal rates (MRR) based on results of experiments 2ndorder mathematical models were developed and the validation with F – Test is done for models are validated with F-est.

On the basis of model output responses adequacy of models was found by using Analysis of variance (ANNOVA). Utilizing RSM with multi objective characteristics this paper attempted in optimizing cutting parameters.

Kundan Kumar, SomnathChattopadhyaya, Hari Singh[2], This research outlines the Taguchi's Parameter Design Approach, which has applied to optimize machining parameters in Cylindrical Grinding Process. The grinding parameters evaluated are cutting speed and depth of cut. An orthogonal array, signal-to-noise (S/N) ratio and analysis of variance (ANOVA) are employed to analyze the effect of these grinding parameters. An orthogonal array has used to plan the experiments. The raw data analysis and signal-to-noise ratio analysis have employed to analyze the influence of grinding parameters on material removal rate during grinding process. The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This procedure eliminates the need for repeated experiments, saves time and conserves the material as opposed by the conventional procedure. Experimental results are provided to confirm the effectiveness of this approach.

Sandeep Kumar, Onkar Singh Bhatia[3], Taguchi method or Design of experiments has been used to optimize the effect of cylindrical grinding parameters such as wheel speed (rpm), work speed, feed (mm/min.), depth of cut and cutting fluid on the Material Removal Rate of EN15AM steel. Material removal rate measurements were carried out during the machining process on the work piece. EN15AM steel is generally known as free cutting steel and consists of higher machinability. It has several industrial applications in manufacturing of engine shafts, connecting rods, spindles, connecting components etc. The results indicated that grinding wheel speed, work piece speed, table feed rate and depth of cut were the significant factors for the material removal rate. The optimized parameters for material removal rate are grinding wheel speed 1800 rpm, work piece speed 155 rpm, feed rate 275 mm/min. and depth of cut 0.04 mm.

M.MelwinJagadeesh Sridhar ,M. Manickam, V.Kalaiyarasan[4], Surface quality of OHNS steel after cylindrical grinding process is proposed to be studied in this experimental work using L9 orthogonal array selected for three levels and three input parameters. The inputs parameters are considered in this Experimental study are work speed, depth of cut and number of passes and response parameter is metal removal rate (MRR) during cylindrical grinding process. Higher metal removal rate is the main objectives of this machining process.

The different machining parameters of OHNS steel of cylindrical grinding process are optimized by Signal to noise ratio and analyzed by Analysis of variance (ANOVA's).

Renaldo YoshinobuFusse [5], the application of cutting fluid in a deep grinding process is becoming more and more important, mainly where the cutting fluids are used as an "external" agent to the grinding conditions. The role of the fluid in grinding operations is in refrigeration of the work piece, removal of the shavings, lubrication of the grinding zone, and refrigeration and cleaning of the wheel. The efficiency of a cutting fluid will depend mainly of the type of fluid that will be used. In this work, the influences of the type of cutting fluid used in a deep grinding process of the steel VC131 using CBN grinding wheel are analyzed. Three different types of cutting fluids were used: a vegetable emulsion, a synthetic solution and a integral oil. The variables analyzed during and after the grinding process were the grinding force, the superficial roughness, the acoustic emission (EA), the temperature of the piece and the G ratio (relationship between the volume of material removed from the piece and the volume worn off the grinding wheel). The integral oil showed the best performance relative to the following output variables: EA, cutting force and G ratio. The vegetal emulsion was the fluid that best dissipated heat from the cutting region.

Jae-SeobKwak[6], deals with study on effect of grinding process parameters on metal removal rate (MRR) and surface roughness on surface grinding of Al6061-SiC composites using Taguchi's design of Experiments. Further by Analysis of Variance, a complete realization of the grinding parameters and their effects were achieved. The variation of metal removal rate and surface roughness with grinding process parameters was mathematically modelled using response surface methodology. Finally the developed model is validated with the set of experiments. It is observed that developed model is in close agreement with the experimental results.

NitinSohal, Charanjeet Singh Sandhu, Bidyut Kumar Panda[7], the various parameters of machining were studied and optimized to obtain the quality finish upon the surface of machined surface. After an exhaustive literature survey, two different types of EN range of steels have been selected for the examination in terms of surface roughness and material removal rate. The above parameters were examined and the experiment has been conducted high precision 2 axes hydraulic CNC surface grinding machine The machining parameters such as Grinding Table speed, Depth of cut and Feed rate were analyzed and found that best results of percentage improvement in surface roughness as 0.39 and 0.47 for EN24 and EN353 at a table speed of14m/min keeping feed rate and depth of cut constant and MRR as 1.05 and 1.16 for EN24 and EN353 keeping the feedrate and depth of cut constant at table speed of 14m/min. The best value for the surface roughness keeping the table speed and depth of cut constant at feed rate 2 mm/stroke for EN24 and EN353 comes out to be 0.47 and 0.44 and the best value for MRR as 1.05 and 1.14 keeping the table speed and depth of cut constant at a feed rate of 6mm/stroke. The best value for the surface roughness keeping the table speed and feed rate constant at depth of cut 0.10 microns forEN24 and EN353 comes out to be 0.38 and 0.42 and the best value for MRR as 1.05 and 1.14 for EN24 and EN353keeping the table speed and feed rate constant at depth of cut 0.20 microns.

Sudheesh P K &GovindanP [8], an evaluation of the jig grinding process using a comprehensive experimentation is performed. There are several factors influencing the performance of the grinding performance. The performance of the process was measured in terms of MRR and Ra. The experiments were conducted based on Taguchi L9 orthogonal array with the chosen three parameters at three levels. The statistical analysis using ANOVA indicates that none of the parameters are significant at95% confidence level. It was observed that speed followed by depth of cut and feed influence the roughness of the ground
Surfaces . The MRR was influenced by feed followed by speed and depth. The AOM analysis was performed for MRR and Ra at all processing conditions. The response graphs for means and S/N rations were generated for each of the chosen input parameters. Regression equations were developed corresponding to each of these

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processing conditions. This comprehensive analysis has helped characterize jog grinding at an experimental level.

Dilbag Singh, P. VenkateswaraRao[9], this study deals with an investigation of molybdenum disulphide as a solid lubricant as an alternative to the cutting fluids to reduce friction and thereby improve the surface finish of bearing steels .Experiments have been conducted using central composite rotatable design, to study the effect of molybdenum disulphide lubricant on surface roughness while hard turning bearing steel. Results indicate that there is a considerable improvement in the performance of hard turning of bearing steels using molybdenum disulphide as a solid lubricant when compared with dry hard turning in terms of surface roughness.

R. R. Chakule [10], the main objective is to achieve good surface finish by optimizing parameters and analyze the process using CFD by constructing the 3-D model which gives simulation of grinding process. Distribution of temperatures, pressures, velocities and flow

Pattern in and around the grinding region are obtained in more detail. Such results are helpful to obtain optimized grinding process. In this study the Taguchi method that is a powerful tool to design optimization for quality is used to find the optimum surface roughness in grinding operation. An orthogonal array, a signal-to-noise (S/N)ratio and an analysis of variance (ANOVA) are employed to investigate the surface roughness characteristic for grinding operations. The material hardness and microstructure are examined and optimum grinding parameters are found out for better surface roughness. The experimental results of this study shows that coolant flow rate and table speed have significant effects on the surface roughness while depth of cut has a lower effect on it.

Experimentation photos

Fig Work Piece Preparation

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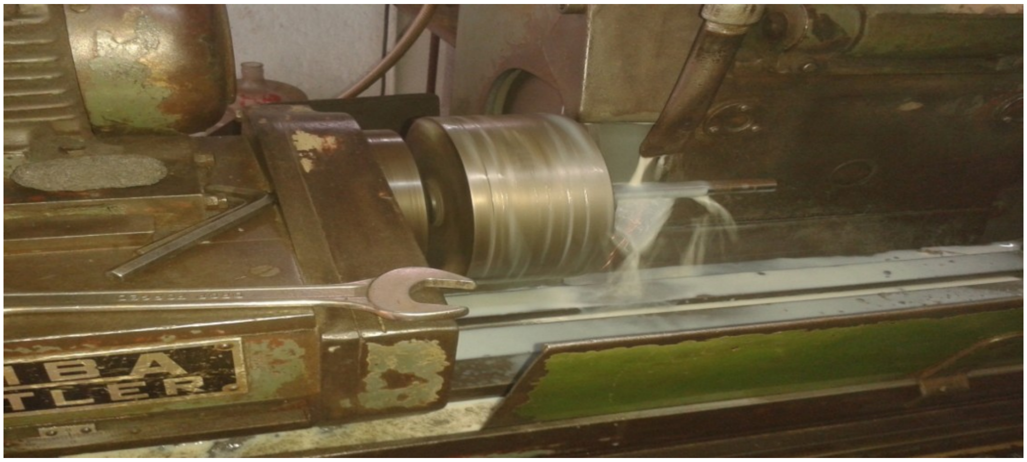

Fig – Grinding of Work Piece

Fig Application of coolant while grinding

Fig – Grinding of Work Piece

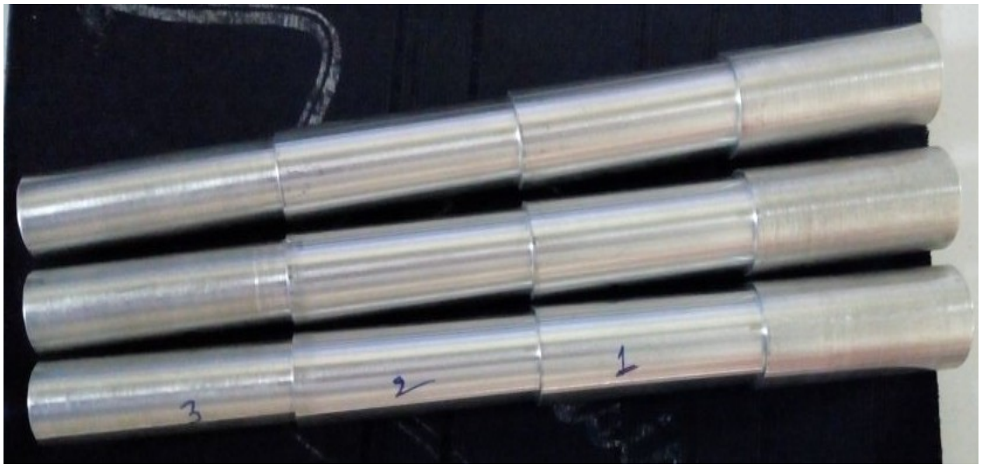

Fig - Prepared Work pieces after cylindrical Grinding Process

RESULTS & DISCUSSIONS

Surface Roughness

After completing the experimental trails using L9 orthogonal array, the surface roughness values are measured using surface roughness tester of model Surf test 211/212 and the results are tabulated.

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface Roughness (R_a) µm
1	1100	11	0.1	0.34
2	1100	19	0.05	0.52
3	1100	28	0.01	0.61
4	1200	11	0.05	0.47
5	1200	19	0.01	0.29
6	1200	28	0.1	0.43
7	1400	11	0.01	0.25
8	1400	19	0.05	0.34
9	1400	28	0.1	0.72

Fig. Measured Surface Roughness Values

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OPTIMIZATION OF PROCESS PARAMETERS THROUGH TAGUCHI TECHINQUE

OPTIMIZATION OF PARAMETERS FOR LESSER SURFACE ROUGHNESS VALUE

Enter Surface Roughness Values in the table

Worksheet 1 ***

↓	C1	C2	C3	C4
	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Surface Roughness
1	1100	11	0.10	0.34
2	1100	19	0.05	0.52
3	1100	28	0.01	0.61
4	1200	11	0.05	0.47
5	1200	19	0.01	0.29
6	1200	28	0.10	0.43
7	1400	11	0.01	0.25
8	1400	19	0.10	0.34
9	1400	28	0.05	0.72

Table.Observed Surface Roughness values from experimentation

S/N Graph

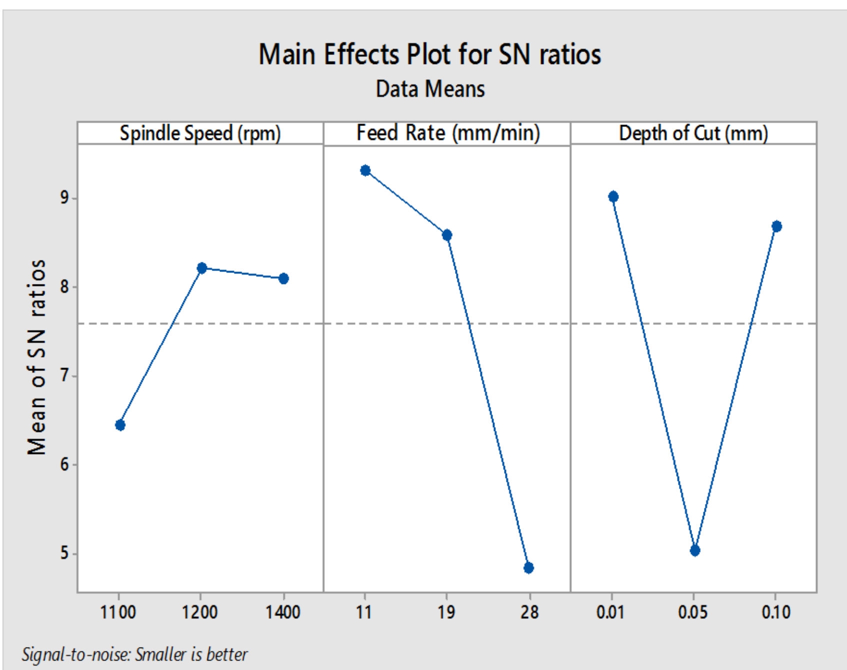

Fig .Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

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OPTIMIZATION USING REGRESSION ANALYSIS

Enter Process Parameters Spindle Speed, Feed Rate and Depth of Cut and Results Surface Roughness and MRR in the table.

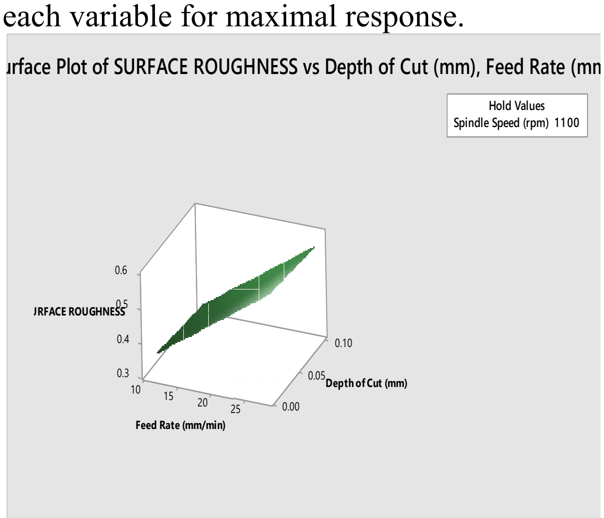
Worksheet 1 ***

↓	C1	C2	C3	C4	C5
	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	SURFACE ROUGHNESS	MRR
1	1100	11	0.10	0.34	0.0083953
2	1100	19	0.05	0.52	0.0045893
3	1100	28	0.01	0.61	0.0027887
4	1200	11	0.05	0.47	0.0046470
5	1200	19	0.01	0.29	0.0052456
6	1200	28	0.10	0.43	0.0069091
7	1400	11	0.01	0.25	0.0062821
8	1400	19	0.10	0.34	0.0055000
9	1400	28	0.05	0.72	0.0079512

Table.Parameters and Responses

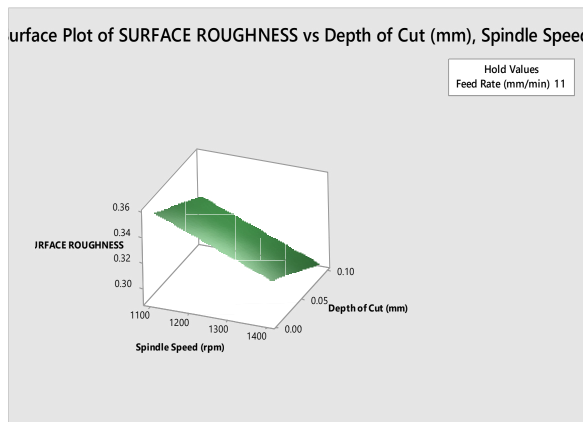
Result and discussions

The 3D response surface plot is a graphical representation of the regression equation. It is plotted to understand the interaction of the variables and locate the optimal level of each variable for maximal response.



Graph – Surface Plot of Surface Roughness vs Depth of cut, Feed Rate

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Depth of cut at 0.1mm.



Graph Surface Plot of Surface Roughness vs Spindle Speed, Depth of cut

By observing above graph, to minimize surface roughness, the Spindle Speed should be set at 1400rpm and Depth of cut at 0.1mm.

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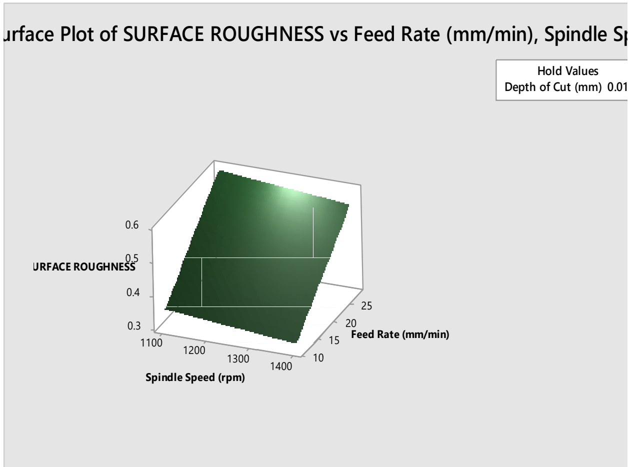
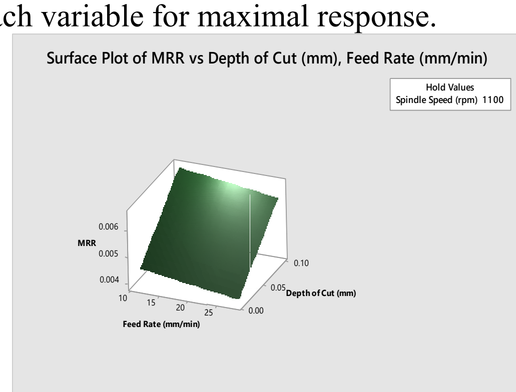


Result and Discussion

The 3D response surface plot is a graphical representation of the regression equation. It is plotted to understand the interaction of the variables and locate the optimal level of each variable for maximal response.



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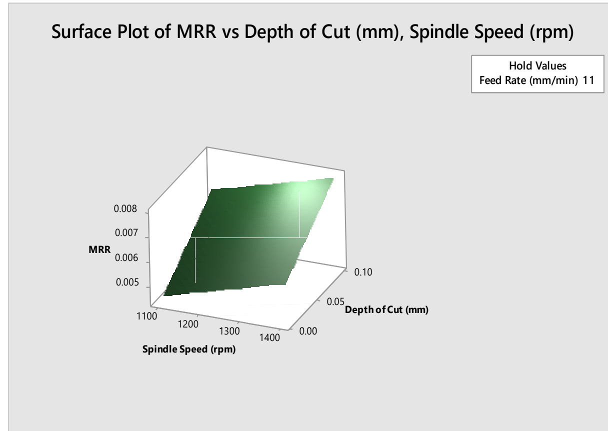
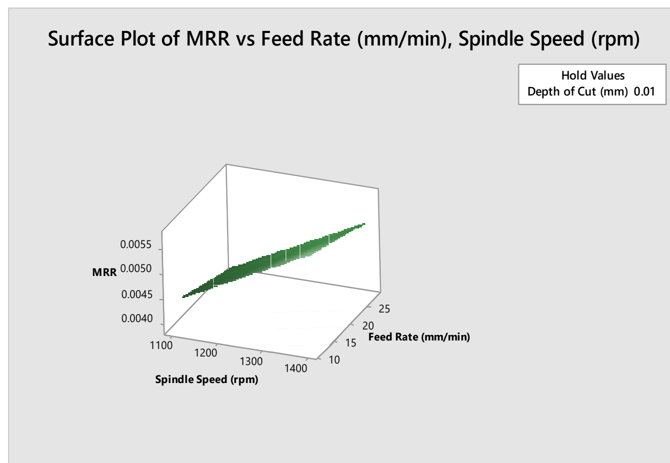
Graph. Surface Plot of MRR vs Depth of cut, Feed Rate

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Depth of cut at 0.1mm.



Graph.Surface Plot of MRR vs Spindle Speed, Depth of cut

By observing above graph, to minimize surface roughness, the Spindle Speed should be set at 1400rpm and Depth of cut at 0.1mm.



Graph.Surface Plot of MRR vs Feed Rate, Spindle Speed

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Spindle Speed to 1400rpm.

CONCLUSION

In this thesis, different experiments are performed on Aluminum alloy 6082 work piece by varying various parameters to determine Material Removal rates and

Surface Roughness. The parameters considered for experimentation are feed 11mm/min, 19mm/min and 28mm/min, the Grinder speeds 1100rpm, 1200rpm and 1400rpm and the depth of cut 0.01mm, 0.05mm and 0.1mm.

Optimization is done using L9 orthogonal array by Taguchi technique and regression analysis to determine better parameters to obtain maximum material removal rates and lesser surface roughness values.

From the **Taguchi Method,** the following conclusions can be made:

- **For better surface finish**, the optimized process parameters are the Feed Rate –11mm/min, Depth of Cut - 0.01mm and Spindle Speed - 1200rpm.
- **For better MRR,** the optimized process parameters are the Feed Rate –11mm/min, Depth of Cut –0.1mm and Spindle Speed - 1400rpm.

From the **Regression analysis,** the following conclusions can be made:

- **For better surface finish**, the optimized process parameters are the Feed Rate –11mm/min and Depth of Cut - 0.1mm and Spindle Speed - 1400rpm.
- **For better MRR,** the optimized process parameters are the Feed Rate –11mm/min and Depth of Cut – 0.1mm and Spindle Speed - 1400rpm.

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