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Using Design of Experiments to Optimize Machining Parameters in Turning Operation

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ABSTRACT

Most industrial applications of machining are in metals. Turning is a process of machining to create external surfaces of rotation by means of a cutting tool on a rotating part, usually in a lathe. Lathe is a machine that rotates the workpiece on its axis for various operations such as cutting, knurling, drilling, threading, etc. with tools that are applied to the workpiece, to create an object that has symmetry around the axis rotation. Aluminum alloys can be processed quickly and economically due of their metallurgical structure. In the present study investigated the influence of all cutting parameters, such as feed rate, cutting speed, cutting depth, tool radius and angle of rotation on machinability factors when aluminium alloys such as Al6063T6 and to develop of an experimental approach with using Taguchi method. The orthogonal matrix L9 is used for turning of aluminium Al6063T6. To optimization of process parameters of lathe machine and to obtain best response variables for surface finish, material removal rate and machining time.

Keywords : Turning, Cutting, Metallurgical Structure, Machinability, Orthogonal

I. INTRODUCTION

Turning is a process of machining to create external surfaces of rotation by means of a cutting tool on a rotating part, usually in a lathe. The lathe is a machine that rotates the workpiece on its axis for various operations such as cutting, knurling, drilling, threading, etc. with tools that are applied to the workpiece, to create an object that has symmetry around the axis rotation. Aluminum alloys can be processed quickly and economically due of their metallurgical structure. The influence of all cutting parameters, such as feed rate, cutting speed, cutting depth, tool radius and angle of rotation on machinability factors when aluminium alloys such as Al6063T6. Processing is large collection of manufacturing processes designed to remove unwanted material. Machining is used to convert castings, forgings with dimensions that meet the design requirements. Every product manufactured has components that require machining. The application of these processes in the industrial world is widespread. The machine operator has direct control of the input variables and selects them at processing process. The selection of the processes necessary to convert the source material to the finished product based on the geometry of the size and shape of the part, rotational or non-rotational, the required finish and tolerances and the quantity of the product to be manufactured. Dependent variables are defined by a process based on the preliminary selection of input variables. Important dependent variables are the cutting force, the size of the finished product, tool wears etc. The lathe is a machine tool that rotates the workpiece on its axis for various operations such as cutting, knurling, drilling, cutting threads, etc. With tools that are applied to the workpiece, to create an object that has symmetry relative to the axis of rotation. Lathes are used in woodworking, metalworking, metal spinning, part regeneration. The automatic lathe machine controls the tools through all stages of the cycle without the operator after the machine has been set up. The workpiece rotates between the centers. The tools are placed on the blocks on the front and rear slides. The front self moves along the bed. And the tools make straight cuts along the workpiece removed at the end of the cut and taken original position. The rear tool slides to the center of the workpiece for lining but lateral movement can be given at the end of the cut. Cutting tool is used to remove material from a workpiece by means of shear deformation. Cutting can be done using single-point or multi-point tools. Single point tools are used for turning, forming, trimming for removing material with a single cutting edge. Cutting tools must be made of a material that is more rigid than the material to be cut and the tool withstand the heat generated during the cutting process.

Process Parameters: The following are the different types of cutting process parameters which are discuss below as:

Cutting Speed: The cutting speed should be as high as necessary to save time and minimize temperature. As the cutting speed increases, the probability of forming a built-up edge on the cutter decreases, the chips break more easily and the finish improves. The cutting speed has the greatest influence on the service life of the tool.

Depth of cut: The depth of the cut must be as large as possible within the strength of the part, the power of the machine and the amount of stock to be removed in order to minimize the number of cuts. As the cutting depth increase, the cutting force increases.

Feed: Feed is the movement of the tool parallel to the axis of work. It is define as the ratio of the distance travelled by time. It is usually given in units of mm/min. Feed is the most important factor that affects surface roughness. As the feed increases, the quality of the surface roughness improves.

Tool nose radius: The nose radius of a cutting tool as the durability of the tool point and along with feed rate defines the part of finishing. The nose radius having more effect on the surface roughness and cutting force.

II. LITERATURE REVIEW

Surface treatment is one of the most important characteristics in the manufacturing industry which affect the characteristics of mechanical parts as well as cost price. In order to improve the quality and efficiency of products during turning processes. A good turning surface can lead to improved strength properties such as fatigue strength, corrosion resistance and heat resistance. The right choice of tool geometry and cutting parameters that affect surface roughness are important factors. Surface roughness increases with feed. With increase in cutting speed, the surface roughness of the of the parts increases due to increase friction between the workpiece and the tool interface. As the depth of cut change, the rate of material removal changes continuously during the process. So, the amount of material removed depends on the speed, feed rate and depth of cut. There have been numerous researches that had been performed in this field. The most relevant of those studies have been discussed as. **F. Tsang Xue et al.** studied the influence of the rotation parameters on the surface roughness that influence of feed, speed and depth of cutting, the radius of the nose of the tool and the working material on the roughness of the working material on the roughness of the working material surface. **Manu Garg et al.** have studied to optimize the effects of cutting parameters on surface finish and MRR of EN24 by using Taguchi techniques. **P. Sharma et al.** have optimization of two response parameters (surface roughness and material removal rate) three machining parameters (cutting speed, feed rate and depth of cut) is investigated in high speed turning of H13 in dry conditions. **L B Abhang et al.** have to find the optimal combination of process parameters based on S/N ratio and to know the significance of each parameter by performing ANOVA analysis. **R Davis et al.** have concerned with the optimization of cutting parameters(depth of cut, feed rate, spindle speed) in turning of EN24 steel with hardness. **A K Mathew et al.** The process parameters influencing the roughness of the surface of the machine roughness with emphasis of the feed rate and improving the quality of the surface. **Wang et al.** have the orthogonal array of the taguchi method is used in combination with a gray relational analysis taking four parameters speed cutting depth, feed rate, nose for the tool etc. to optimize surface roughness, tool wear and material removal. **Md Nasimuddin et. al.** have investigates the effect of turning parameters such as rotational speed, feed rate and depth of cut on surface roughness of high carbon steel. **P. Chenneswari et. al.** have carried out orthogonal array design for turning operation on Al 7175 using tungsten carbide tool with three input process parameters cutting speed, feed and depth of cut and effect of surface roughness reduced increasing spindle speed and MRR **N. D. Patel et al.** has shown three cutting parameters affect the surface roughness: Cutting speed, feed rate and cutting depth and found that the cutting speed has a maximum effect on the surface roughness. **T. Ganapathy et al.** have to optimise machining and geometrical parameters in turning process. cutting speed, feed rate, depth of cut, material type, cutting-insert-shape, relief angle and nose radius is use and to ensure minimum flank-wear and surface roughness. **M. Murthy et al.** have studied the effect of various cutting parameters on the surface finish of Al6061 aluminium alloy was investigated. **S. Jaiswal et al.** have obtain the optimal value of turning process parameters in order to reduce the rejection rate during machining. **T. Rajmohan et al.** have optimization of material removal rate in turning operation is done by using nanoparticle.

III. Methodology

Material: Al6063T6 alloy was used as work piece material to study machinability in this investigation. The size of the work pieces used in the present investigation 25 mm diameter and 50 mm length. Aluminium alloy 6063 is an alloy of medium strength commonly referred to as an architectural alloy, usually it is used in complex extrudes. It is good surface finish, high corrosion resistance, easily suitable for welding and good formability.

Table 1: Chemical Composition of Al6063T6 alloy

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.2-0.6	0.35	0.1	0.1	0.45-0.9	0.1	0.1	0.1	Balance

Table 2: Composition of HSS cutting tool

C	Cr	W	V	Mn	Si	Fe
0.65-0.80	3.75-4.0	1.7-2.5	0.9-1.3	0.1-0.4	0.2-0.4	Balance

Experimental Setup: Machinability of Al6063T6 aluminium alloy is conducted by CNC lathe machine using various process parameters like feed, depth of cut, speed and turning spindle on/off etc. depending on type of job and controls the slide movements by hand. It performs several operations on different surfaces of the workpiece in which nine workpiece make through CNC lathe machine.

Fig.1: Experimental Setup

Four factors like feed rate, speed, depth of cut and tool nose radius and three levels for L_9 orthogonal array of Al6063T6.

Table 3: Process Parameter for turning operation

Cutting Parameters	**Unit**	**Notation**	**Limits**		
			Level 1	**Level 2**	**Level 3**
Feed rate(A)	mm/min.	F	10	40	70
Speed(B)	RPM	V	500	1000	1500
Depth of Cut(C)	Mm	D	0.3	0.5	0.8
Tool nose radius(D)	Mm	R	0.4	0.6	0.8

The value obtained from the experimentation using orthogonal array is given in the following tables.

Table 4: Results of Turning of Al6063T6

Exp No.	**Surface Roughness(μM)**	**Material Removal Rate (mm³/min.)**	**Machining Time(min.)**
1	2.023	235.619	11.475
2	7.141	392.699	6.602
3	7.682	628.319	4.421
4	1.765	1570.796	1.792
5	7.027	2513.274	1.208
6	7.214	942.478	2.476
7	1.581	4398.230	0.640

8	4.927	1649.336	1.954
9	7.649	2748.894	0.849

Results and Discussion:

Effect of Cutting parameters on surface roughness: The work piece made of Al6063T6 was machined using the CNC lathe machine. Cutting parameters employed and observed values of machinability factors are tabulated. Surface roughness of the work material is measured using Profilometer and the values are recorded. The effect of cutting parameters employed on surface roughness is discussed below as fig.

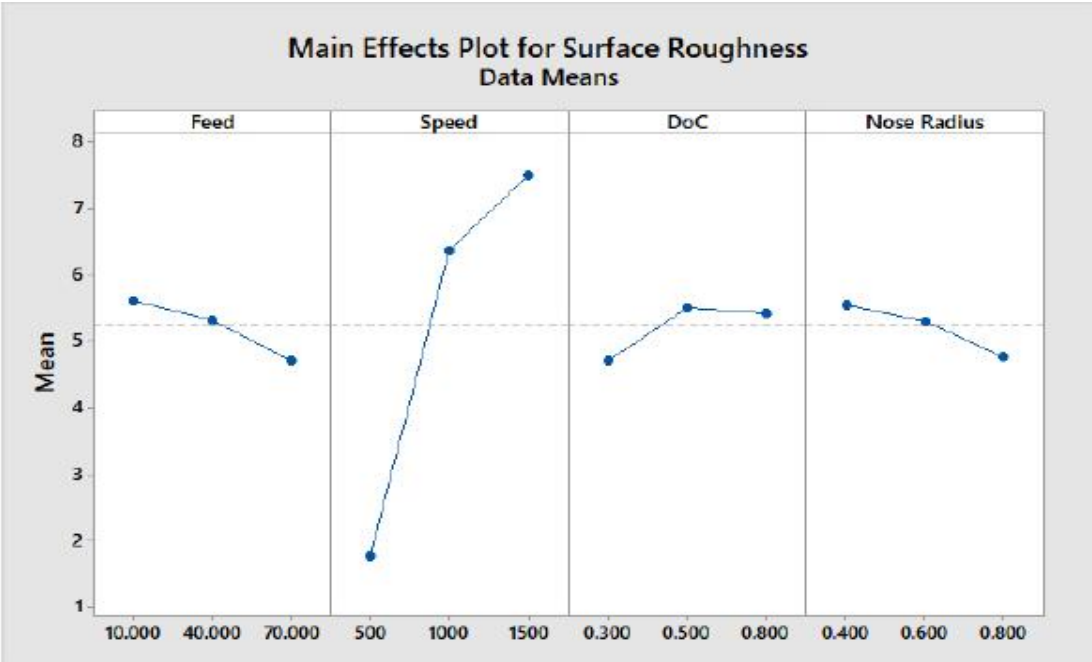

Fig.2: Main effect plot for surface roughness of Al6063T6 turning operation

It can be seen from figure that increases in speed with increases the surface roughness of the work piece. The surface roughness value decreases with increase in feed rate and Nose radius of the tool. The surface roughness increases till a certain value of depth of cut and then decreases. From figure we can see that higher feed rate, lower speed, low depth of cut and high nose radius are required to obtain the lowest surface roughness.

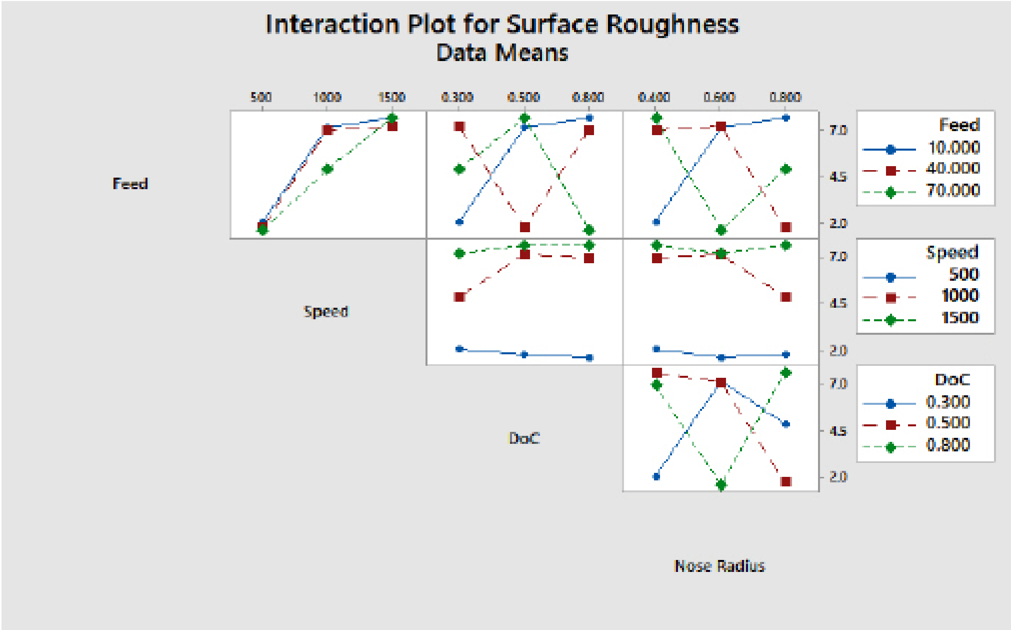

Fig.3: Interaction effect plot for surface roughness of Al6063T6 turning operation

Above figure gives the interaction effect of two factors on the surface roughness of aluminium alloy under turning operation using L_9 orthogonal array. Based on the results obtained, it can be said that the interaction between high feed rate of 70 mm/min, low speed of 500 RPM, high depth of cut of 0.8 mm and average nose radius of 0.6 mm gives the lowest surface roughness and better surface finish of value 1.581 μm.

Effect of cutting Parameters on material removal rate:

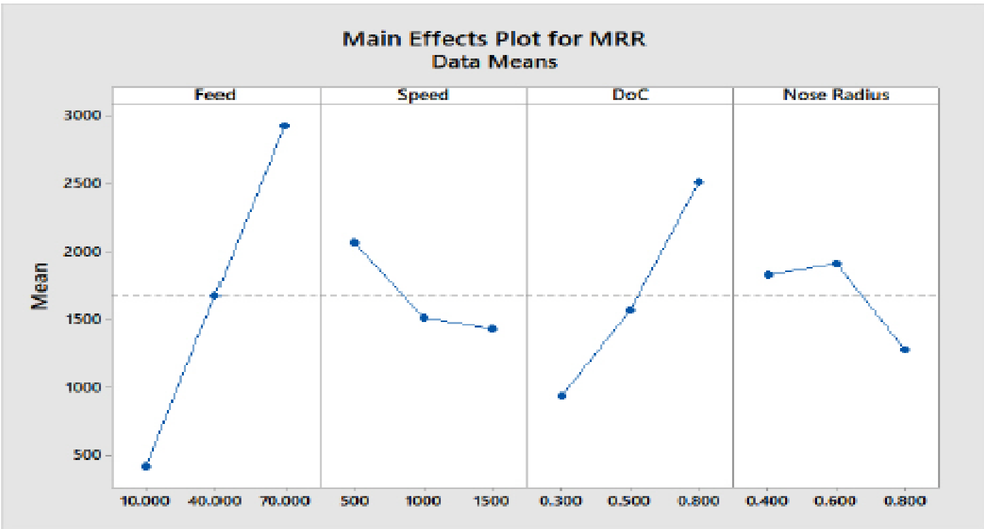

Fig.4: Main effect plot for material removal rate of Al6063T6 turning operation

It can be seen from figure that the increase in speed decreases the material removal rate of the work piece. The material removal rate value increases with increase in feed and depth of cut of the tool. The material removal rate increases till a certain value of nose radius and then decreases. From figure we can see that higher feed rate, higher speed, large depth of cut and high nose radius are required to obtain the maximum material removal rate.

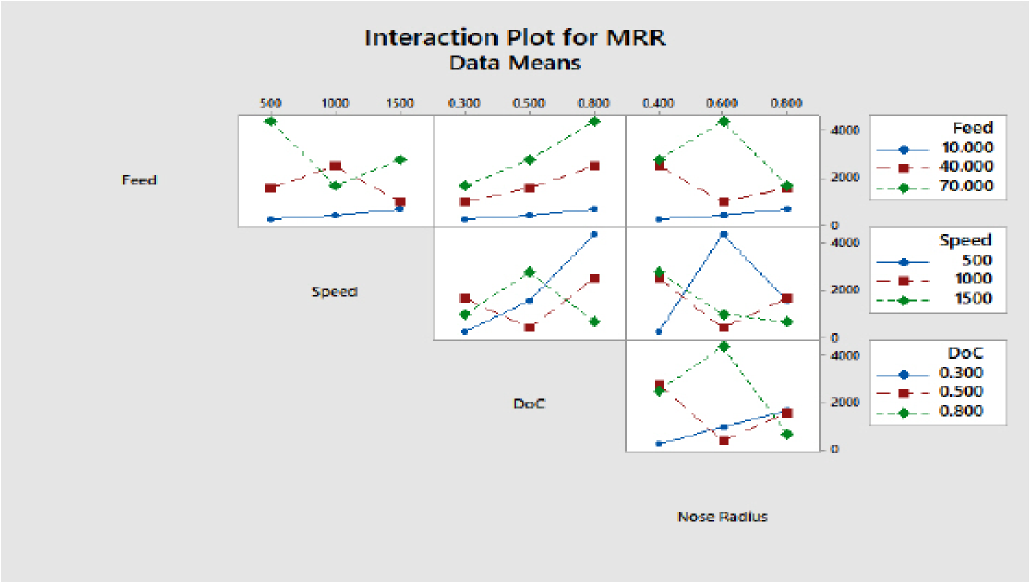

Fig.5: Interaction effect plot for material removal rate of Al6063T6 turning operation

It can be seen from figure that the increase in speed decreases the material removal rate of the work piece. The material removal rate value increases with increase in feed and depth of cut of the tool. The material removal rate increases till a certain value of nose radius and then decreases. From figure we can see that higher feed rate, higher speed, large depth of cut and high nose radius are required to obtain the maximum material removal rate.

Effect of Cutting Parameters on machining Time:

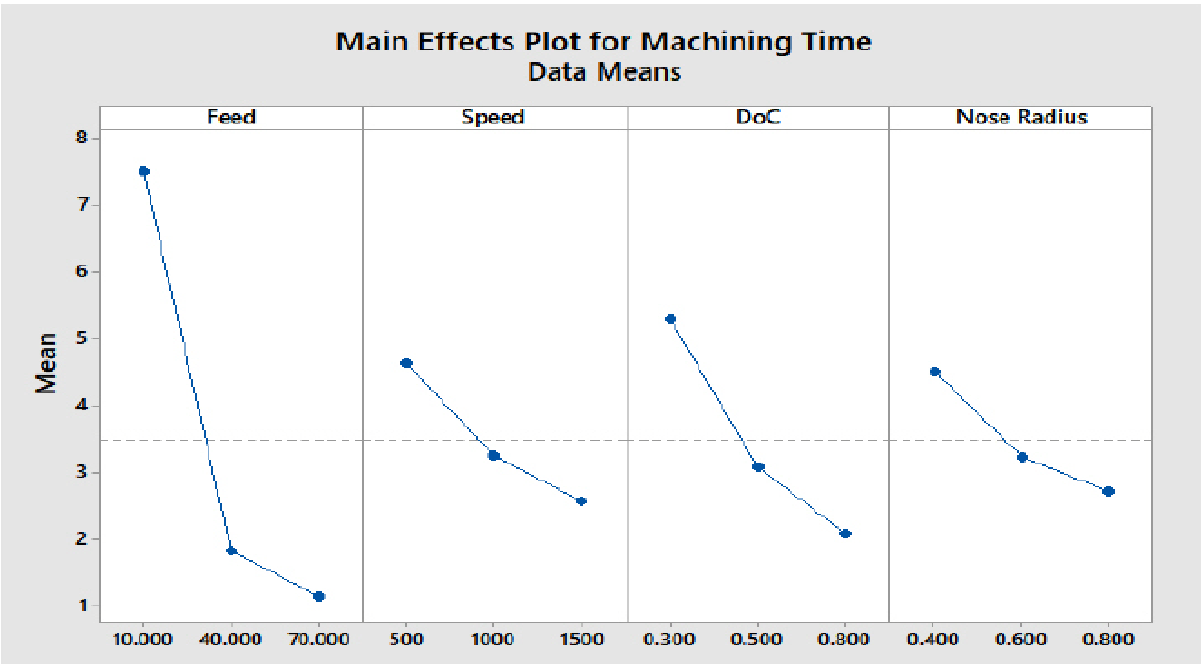

Fig.6: Main effect Plot for machining time of Al6063T6 turning operation

It can be seen from figure that the increase in speed decreases the machining time of the work piece. The machining time value decreases with increase in feed and depth of cut of the tool. The machining time decreases with increase in nose radius. From above figure we can see that higher feed rate, higher speed, large depth of cut and high nose radius are required to obtain the lowest machining time.

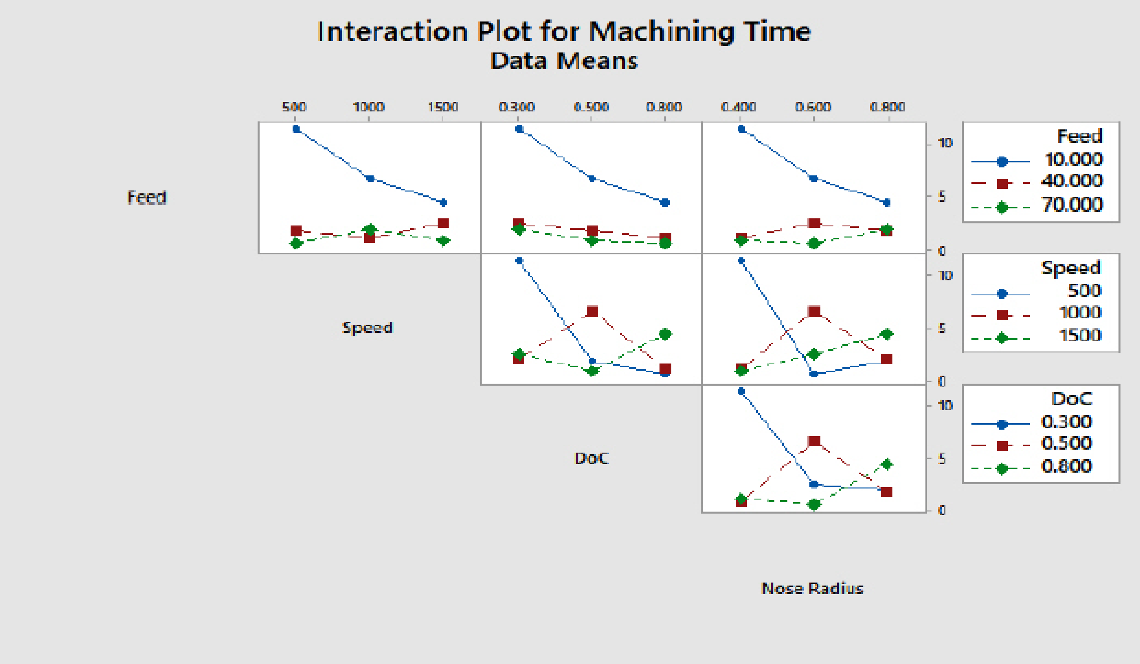

Fig.7: Interaction effect plot for machining time of Al6063T6 turning operation

Above figure gives the interaction effect of two factors on the machining time of aluminium alloy under turning operation using L_9 orthogonal array. Based on the results obtained, it can be said that the interaction between high feed rate of 70 mm / min, low speed of 500 RPM, high depth of cut of 0.8 mm and low nose radius of 0.6 mm gives the lowest machining time of value 0.640 min.

Analysis of Variance:

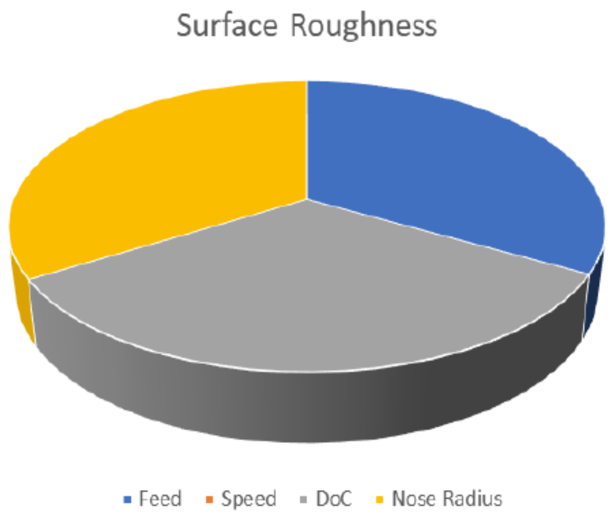

Fig.8: Contribution chart of Al6063T6 for cutting parameters on surface roughness for turning operation

Figure shows the graphical representation of the % contribution of cutting parameters on surface roughness. It can be seen from the table that the % contribution of Nose radius is slightly larger than other parameters followed by depth of cut and feed rate. Speed adds no contribution to the surface roughness of the material during turning operation.

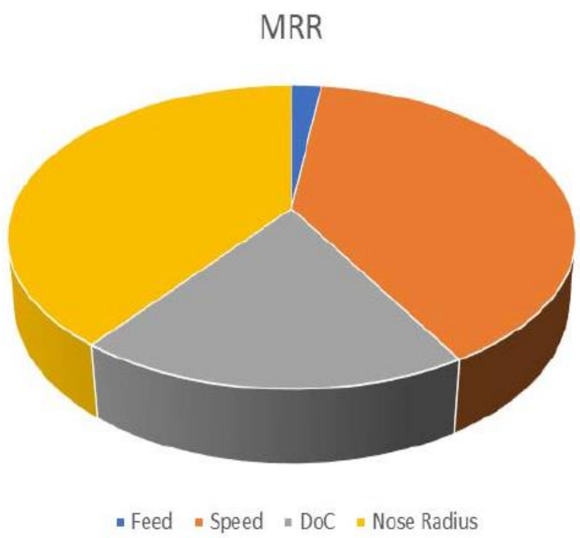

Fig.9: Contribution chart of Al6063T6 for cutting parameters on material removal rate for turning operation

Figure shows the graphical representation of the % contribution of cutting parameters on Material Removal Rate. It can be seen from the table that the % contribution of Speed and Nose radius are larger compared to other parameters whereas Feed has the lowest % contribution.

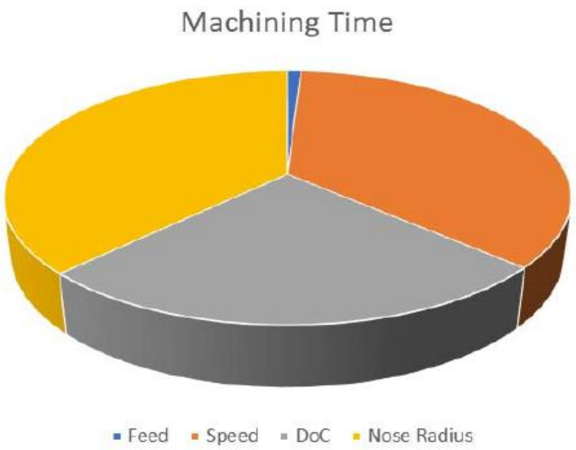

Fig.10: Contribution chart of Al6063T6 for cutting parameters on Machining Time for turning operation

Figure shows the graphical representation of the % contribution of cutting parameters on Machining Time. It can be seen that Nose radius has highest contribution to machining time during turning of the aluminium alloy followed by Speed and depth of cut. Feed rate has the lowest contribution.

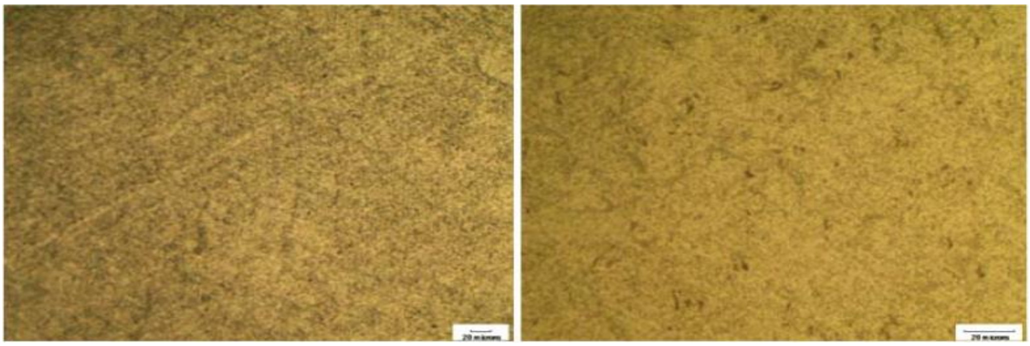

Fig.11: Microstructure of Al6063T6 after turning operation

The images indicate that the microstructure of the aluminium alloy has little or no variation after the machining operations in the structure before the machining operation.

IV. CONCLUSION

The conclusions of this work are presented for its machinability under turning operations using the Taguchi technique. The Taguchi techniques facilitated the use of orthogonal arrays L_9 which used to the cutting parameters for the turning operations. The cutting parameters selected were Feed rate, speed, depth of cut and nose radius for turning operation. Minitab was used to compare the main effect and interaction effect results obtained from the experimentation that discuss as following point:

- Main effect plot for surface roughness during turning operation using L_9 orthogonal array revealed that speed had the highest influence on surface roughness of the material and nose radius had the least influence on surface roughness of the material.
- Main effect plot for material removal rate during turning operation using L_9 orthogonal array revealed that feed rate had the highest influence on material removal rate of the material and nose radius had the least influence on material removal rate of the material.
- Main effect plot for machining time during turning operation using L_9 orthogonal array revealed that feed rate had the highest influence on machining time of the material and nose radius had the least influence on machining time of the material.
- The microstructure studies performed on the machined component indicate a very little to no change in the structural composition of the material during and after the operation. It indicates the aluminium alloy Al6063T6 is safe for machining for turning operation.

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