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PROCESS PARAMETERS OPTIMIZATION OF CNC TURNING ON AL-6061 USING MULTIPLE CUTTING FLUIDS

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Abstract - *ALUMINIUM-6061 is a widely used alloy material in the production of aerospace, aircraft, gas turbine components. This investigation focuses on the influence of machining parameters, viz., spindle speed, depth of cut and feed rate on the surface finish obtained in Lathe operation of Al6061 alloy. In the present study, experiments are conducted for twenty-seven different Al6061 work piece materials to see the effect of work piece material variation in this respect. Five roughness parameters, viz., Centre line average roughness, root mean square roughness; skewness, kurtosis and mean line peak spacing have been considered. The roughness models as well as the significance of the machining parameters have been validated with analysis of variance. In addition, a good agreement between the predicted and measured surface roughness was observed. Therefore, the developed model can be effectively used to predict the surface roughness on the machining of Al6061 within 95% confidence intervals ranges of parameters studied.*

Key Words: CNC Lathe Process, Aluminium-6061, Surface Roughness, Machining Parameters

1. INTRODUCTION

Machinability studies are also important in the process of developing an understanding of the machining parameters that influence the quality of surface finish. Surface finish represents the Quality of the surfaces obtained through the machining processes. With the more precise demands of modern engineering products, the control of surface texture together with dimensional accuracy has become more important. It has been investigated that surface texture greatly influences the functioning of the machined parts. Manufacturing involves various processes to turn raw materials to finished products to be used for a variety of purposes. Whatever may be the manufacturing process used, it is not possible to produce perfectly smooth surface. Hence, the improved qualities of product and the economics of the manufacturing operation are very important consideration to produce product having the functional and visual appeal. Although the aim of all the process is to obtain the desired shape, size and finish. The selection of a particular process depends on several factors, which includes the shape and size of the finished component, precision required in the volume of production, cost of material and process and its availability. The commonly used method for obtaining the desired shape, size, and finish is machining, which involves removal of excess material in the form of chips. Machining is one of the most versatile manufacturing processes. Popularity of turning for machining application is increasing mainly due to the introduction of High Speed Machining (HSM), made possible by improvements in the design and operation of turning machines and tools. Most frequently, turning involves the generation of flat faces and slots. However, its application for contour turning is growing with the availability of CNC turning machines. With the introduction of high speed machining (HSM), the scope of application of Lathe is continuously expanding.

The Current investigation has been carried out on Aluminium-6061 as the basic raw material. Aluminium alloy is widely preferred material for the manufacture of Turbine Blades.

1.1 Surface Roughness

Response surface method proposes a holistic view of quality, which relates quality to cost, not just to the manufacturer at the time of production, but to the customer and society as a whole. It defines quality as, "The quality of a product is the (minimum) loss imparted by the product to the society from the time product is shipped." This economic loss is associated with losses due to rework, waste of resources during manufacture, warranty costs, customer complaints and dissatisfaction, time and money spent by customers on failing products, and eventual loss of market share.

The variables that influence the economics of machining operations are numerous. Some of the important ones are machine tool capacity, work piece material and its geometry, tool geometry, vibrations, cutting parameters such as speed, feed, depth of cut and types of coolant used etc. The cutting parameters affect the production rate. The surface roughness, surface texture, and dimensional deviations are also affected by the cutting conditions. Ultimately, it has overall impact on the product quality as well as the unit cost of component and productivity. The principal reasons for controlling the surface roughness is essential to enhance the service life of the components, as it improves the fatigue resistance; and reduces corrosion and initial wear due to lack of irregularities and closer dimensional tolerances. The economic selection of cutting conditions requires knowledge of technical aspects and cost aspects, which are not easily available in many cases.

Surface roughness (R_a) in machining is a measure of micro-geometrical technological quality errors occurred in a product and a factor that greatly influence manufacturing cost. It describes the geometry of the machined surface texture, which is entirely process dependent. The prescribed sampling length as per IS: 2073 150 is 0.8mm for majority of the machining processes and in case of turning operation the Roughness value is 0.32µ to 25µ. Therefore, this may be the basis of optimizing the operational characteristic of the processes.

1.2 CNC Turning Machine

Computer numerical controlled (CNC) lathes are rapidly replacing the older production lathes (multi-spindle, etc.) due to their ease of setting, operation, repeatability and accuracy. They are designed to use modern carbide tooling and fully use modern processes. The part may be designed and the tool paths programmed by the CAD/CAM process or manually by the programmer and the resulting file uploaded to the machine, and once set and trialed the machine will continue to turn out parts under the occasional supervision of an operator.

The machine is controlled electronically via a computer menu style interface; the program may be modified and displayed at the machine, along with a simulated view of the process. The setter/operator needs a high level of skill to perform the process, however the knowledge base is broader compared to the older production machines where intimate knowledge of each machine was considered essential. These machines are often set and operated by the same person, where the operator will supervise a small number of machines (cell).

1.3 Aluminium-6061

Aluminium-6061 is a precipitation hardened alloy, containing magnesium and silicon as its major alloying elements. Originally called Alloy 61S. It has good mechanical properties, exhibits good weldability and is very commonly extruded. It is one of the most common alloys of aluminium for general purpose use.

The alloy composition of 6061 is:

- ✓ Silicon minimum 0.4%, maximum 0.8% by weight
- ✓ Iron no minimum, maximum 0.7%
- ✓ Copper minimum 0.15%, maximum 0.4%
- ✓ Manganese no minimum, maximum 0.15%
- ✓ Magnesium minimum 0.8%, maximum 1.2%
- ✓ Chromium minimum 0.04%, maximum 0.35%
- ✓ Zinc no minimum, maximum 0.25%
- ✓ Titanium no minimum, maximum 0.15%
- ✓ Other elements no more than 0.05% each, 0.15% total
- ✓ Remainder aluminum (95.85–98.56%)

1.4 Literature Survey

Some survey on research papers require to deliberate in this chapter connected towards CNC Turning Machine. From the readings out in these papers and thesis is mostly concerned through the CNC Lathe settings such as the feed, depth of cut, cooling medium, spindle speed etc. and in what way these parameter will affect the machining outputs like MRR, R_a, TWR etc.

N.zeelanbasha et al. [1] have analyzed the effect of process parameter in turning operation to predict surface roughness and to predict the surface roughness on aluminum 6061, by optimizing the input parameters such as spindle speed, feed rate and depth of cut by using coated carbide tool and a second order mathematical model has been developed using regression technique and optimization is carried out using Box-Behnken of response surface methodology. The paper is focused to find the optimal solution of the cutting conditions for giving the minimum value of surface roughness using design- expert 8.0 software.

Jasvir Singh et al. [2] have experimentally observed the effects of various machining parameters such as feed rate, cutting speed, and depth of cut on surface roughness during dry turning process. Aluminium 6061 alloy is machined using CNMG 120408 EN-TM (H20TI) CNC turning inserts. Response Surface Methodology (RSM) is used to design the experiment, to get regression equation and for optimization of the input parameters. Surface plots and Contour plots were generated by using RSM to check the interaction of input parameters on the surface roughness of the component. The result suggests that feed rate has maximum effect on surface roughness and cutting speed and depth of cut has minimum effect on surface roughness.

Himanshu Sonar et al. [3] have studied and implemented for system design and process parameters design such as selecting depth of cut, feed rate and speed of CNC turning machine for aluminum alloy using Taguchi method. Four parameters with three different suitable levels and based on this the orthogonal array were selected (L9). Nine runs were carried out using three different cutting tool insert with reference to the orthogonal array selected. The target material used in this paper was Al6061 T6. Result and analysis was carried out using regression modeling and polynomial equations were generated and optimum machining parameters were determined. Using this polynomial equation the surface roughness and material removing rate were predicted.

Naveen Kumar Nayak et al. [4] has studied the present manufacturing scenario, focus of all manufacturing organizations, is to produce good quality product with a minimum cost. CNC turning process is the most common machining process that is used in now days. Present work has been done, to optimize the machining parameters, for material AL 6061 like, depth of cut, feed rate and cutting speed. MINITAB software is used for formulating the matrix and, for the analysis of regression and response surface methodology.

Y. Mustafa & T. Ali. [5] had conducted experiments on aluminum alloy work piece to analyze geometric tolerance and surface roughness by turning. The effect of the length and diameter of working piece, depth of cut and feed were also investigated. They used Taguchi and ANOVA approach to analyze the data. They found from the experiments: (i) The minimum surface roughness value was 0.831 μm, (ii) The minimum cutting force was 94 N, (iii) The minimum workpiece cylindricity error was 0.019 mm. They also concluded from these number of experiments that : (1)cylindrical error the workpiece length and feed are the most significant factor, (ii) Surface roughness, the feed and work piece diameter are the most significant parameters & (iii) for force the most significant parameters are DOC and feed.

Ali Abdallah et al. [6] had optimized cutting parameters for the surface roughness in CNC turning machining with aluminum alloy 6061 material. They had applied 'response surface methodology' on the most effective process parameters, namely, feed, cutting speed, and depth of cut, and optimized considering the surface roughness and material removal rate for turning process. Based on the results of surface roughness it was analyzed that feed rate affects both MRR and surface roughness. The effect of cutting speed in the cutting process is more significant on surface roughness than on MRR. Higher the cutting speed results in better surface roughness, and this finding can be explained along with other significant parameters. The depth of cut also influences both MRR and surface roughness in the cutting process.

2. EXPERIMENTAL PROCEDURE

2.1. Investigational Setup:

The experimentations be there performed by operating on CNC Lathe whose polarization on the electrode be located as negative whereas that of work piece be located as positive. The dielectric liquid recycled was deionized water. The EDM machine contains with the following measures:

(a) For circulation of dielectric there is reservoir at base, pump and valves for passage.

(b) Power supply unit and CNC functions.

(c) Leak-proof tank along with tool fixing chuck.

(d) Two-dimension movable table by lever.

(e) Tool holding device.

(f) Servo control unit for vertical movement of the tool.

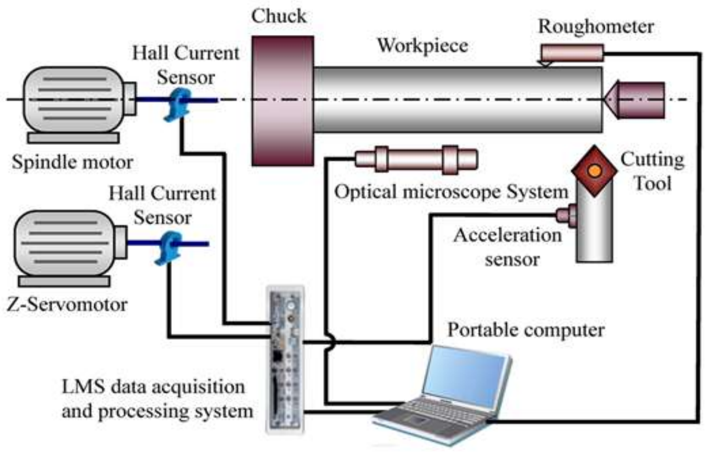

Fig 1.Investigational Setup

Table -1: **Selection of Process Parameter**			
Spindle Speed	500	1000	1500
Feed Rate	50	75	100
Depth of Cut	0.5	1	1.5
Coolant	Water	Coconut Oil	Mustard Oil

2.2. Selection of work piece

Aluminium Al6061 T6 was used as the target material in this paper. The work piece was of dimensions, 26 mm diameter and total length of 80 mm out of which 60mm was machining length and rest was used for holding for holding the work piece.

2.3. Selection of tool material:

Principal categories of cutting tools include single point lathe tools, multi-point milling tools, drills, reamers, and taps. All of these tools may be standard catalog items or tooling designed and custom-built for a specific manufacturing need.

The number one error when selecting tooling is calculating monetary savings based on lowest cost per tool, rather than on maximized productivity and extended tool life. To effectively select tools for machining, a machinist or engineer must have specific information about:

- ✓ the starting and finished part shape
- ✓ the work piece hardness
- ✓ the material's tensile strength

- ✓ the material's abrasiveness
- ✓ the type of chip generated
- ✓ the work holding setup
- ✓ the power and speed capacity of the machine tool

Changes in any of these conditions may require a thorough review of any cutting tool selection. Different machining applications require different cutting tool materials. The ideal cutting tool material should have all of the following characteristics:

- ✓ harder than the work it is cutting
- ✓ high temperature stability
- ✓ resists wear and thermal shock
- ✓ impact resistant
- ✓ Chemically inert to the work material and cutting fluid.

Cemented Carbide is used in solid round tools or in the form of replaceable inserts. Every manufacturer of carbide tools offers a variety for specific applications. The proper choice can double tool life or double the cutting speed of the same tool. Shock-resistant types are used for interrupted cutting. Harder, chemically-stable types are required for high speed finishing of steel. More heat-resistant tools are needed for machining the superalloys, like Inconel and Hastelloy.

TABLE.2. Properties of Cemented Carbide tool

PROPERTY	UNIT	MATERIAL
Thermal conductivity	W/m-K	110
Electrical resistivity	μ-Ohm-cm	20
Specific heat capacity	J/kg-deg C	150-350
Melting point	Deg C	2870

2.4. Types of Process Parameters:

During the turning operation, the selection of process parameters is very difficult to obtain the high surface finish. The machining operation is used to bring the work piece at the required surface quality and geometry with the use the cutting tool with maximum performance during its lifetime. The performance of the metal cutting operations may be affected from several parameters like geometry of cutting tool, material properties, machine and cutting parameters, vibrations during operation, cutting forces, etc. Among the other parameters, cutting variables can play very important role for obtaining desired quality characteristics like surface roughness. Minimizing surface roughness is of - great importance for any metal cutting industries.

In order to identify the process parameters that effect on performance characteristics like surface roughness, material removal rate, power consumption, vibration etc., the fish bone diagram help to identify which process affect the responding characteristics. So, cause and effect diagram/fish bone diagram/Ishikawa diagram helped for selection of process parameters. Here figure 1 represents the Fishbone diagram with the parameters that affect surface roughness

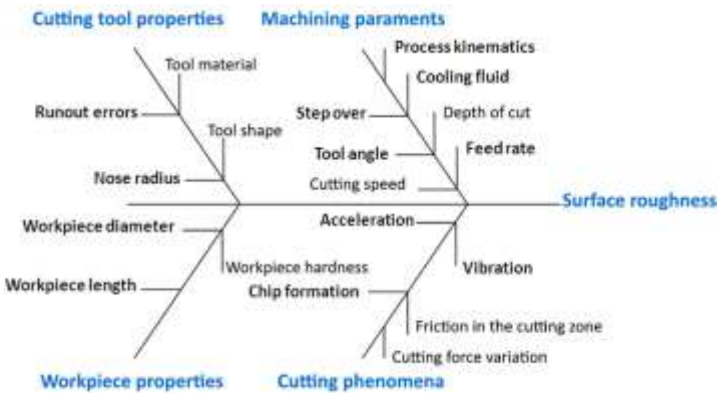

Figure 2. Fishbone diagram with the parameters that affect surface roughness

The main process parameters for turned parts are

1. Cutting parameters: Speed, Feed, Depth of cut
2. Cutting tool parameters: Tool geometry and tool material
3. Work piece material: Hardness, Metallography
4. Cutting environment: Wet, dry

The Process Parameters used as Input are –

1. Feed rate (mm/min)
2. Cutting speed (rpm)
3. Depth of cut (mm)
4. Cutting Fluid

Output Parameters are –

1. Surface Roughness (Ra, Rz)
2. MRR

2.5. Influence of Cooling Medium

The main functions of cutting fluids are:

- ✓ Lubrication at low cutting speeds;
- ✓ Cooling at high cutting speeds;

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And less important:

- ✓ To help the chip removal of the cutting zone.
- ✓ To protect the machine tool and work piece against corrosion.

At low cutting speeds, cooling is not very important, while lubrication is important to reduce friction and avoid the formation of built-up-edge. In this case, an oil based fluid must be used. At high cutting speeds, the conditions are not favorable to fluid penetration, to reach the interface and work as a lubricant. In these conditions cooling becomes more important and a water based fluid must be used.

As lubricant, the cutting fluid works to reduce the contact area between chip and tool and its efficiency depends on the ability of penetrating in the chip-tool interface and to create a thin layer in the short available time. This layer is created by either chemical reaction or physical adsorption and must have a shearing resistance lower than the resistance of the material in the interface. In this way it will also act indirectly as a coolant because it reduces heat generation and therefore cutting temperature.

Table 3. Observation Table

WATER

Depth of Cut Vary

Sl. No.	Spindle Speed	Feed Rate	Depth of Cut	MRR	R_a
1	1000	100	0.5	3925	2.741
2	1000	100	1	7222	3.281
3	1000	100	1.5	9655.5	4.959

Feed Rate Vary

Sl. No.	Spindle Speed	Depth of Cut	Feed Rate	MRR	Ra
1	1500	0.5	50	2943.75	4.992
2	1500	0.5	75	4150.68	2.371
3	1500	0.5	100	5298.75	5.697

Spindle Speed Vary

Sl. No.	Feed Rate	Depth of Cut	Spindle Speed	MRR	Ra
1	75	1	500	2884.875	4.296
2	75	1	1000	5181	2.101
3	75	1	1500	7065	3.426

COCONUT OIL

Depth of Cut Vary

Sl. No.	Spindle Speed	Feed Rate	Depth of Cut	MRR	Ra
1	1000	100	0.5	3689.5	2.787
2	1000	100	1	6908	7.624
3	1000	100	1.5	9184.5	4.543

Feed Rate Vary

Sl. No.	Spindle Speed	Depth of Cut	Feed Rate	MRR	Ra
1	1500	0.5	50	2767.12	3.562
2	1500	0.5	75	3974.06	4.818
3	1500	0.5	100	5063.25	3.841

Spindle Speed Vary

Sl. No.	Feed Rate	Depth of Cut	Spindle Speed	MRR	Ra
1	75	1	500	2590.5	7.292
2	75	1	1000	4710	4.054
3	75	1	1500	6358.5	3.503

MUSTURD OIL

Depth of Cut Vary

Sl. No.	Spindle Speed	Feed Rate	Depth of Cut	MRR	Ra
1	1000	100	0.5	3532.5	3.542
2	1000	100	1	6594	2.761
3	1000	100	1.5	8713.5	3.3585

Feed Rate Vary

Sl. No.	Spindle Speed	Depth of Cut	Feed Rate	MRR	Ra
1	1500	0.5	50	2649.37	4.01
2	1500	0.5	75	3797.43	4.06
3	1500	0.5	100	4827.75	3.68

Spindle Speed Vary

Sl. No.	Feed Rate	Depth of Cut	Spindle Speed	MRR	Ra
1	75	1	500	2355	7.4
2	75	1	1000	4239	4.043
3	75	1	1500	5652	3.812

3. RESULT & DISCUSSION

In this chapter, we are discussing about the effects or influence of machining parameter of CNC turning, i.e. Spindle Speed, Feed Rate, Depth of Cut on material removal rate (MRR), surface roughness (SR) of Aluminium6061 machined work piece with cemented carbide tool and find out which parameter is most important during an experiment.

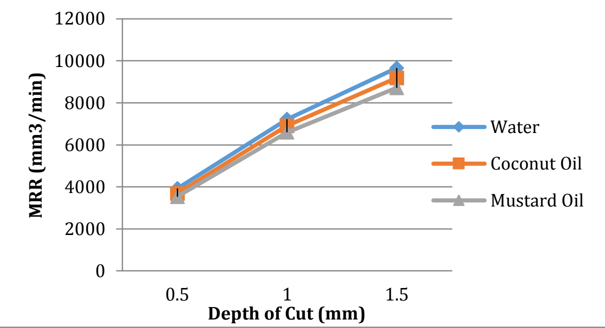


Fig. 3. MRR Vs Depth Of Cut For Constant Spindle Speed & Feed Rate

With the increase in depth of cut, MRR increases for all the cutting fluid. For water MRR is higher as compared to coconut oil & Mustard oil. The trend is somewhat linear.

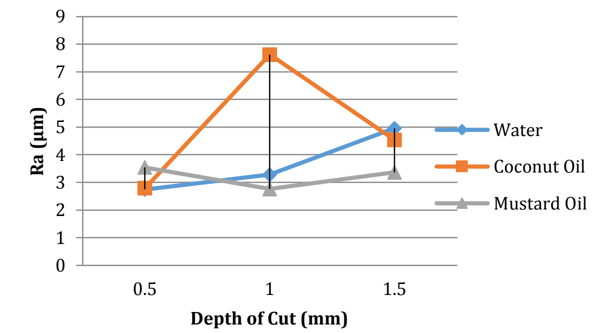


Fig. 4. Ra Vs Depth Of Cut For Constant Spindle Speed & Feed Rate

Surface roughness increases with increase of depth of cut in case of water; first increases and then decreases for coconut oil and first decreases and then increases for mustard oil. Surface roughness is low if the depth of cut is kept low. Lowest Ra is observed for water.

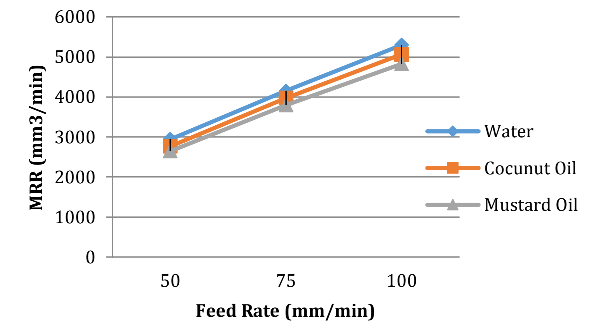


Fig.5. MRR vs Feed Rate for constant spindle speed & Depth of Cut

With the increase in feed rate, MRR increases for all the cutting fluid. For water MRR is higher as compared to coconut oil & Mustard oil. MRR is highest in case of water.

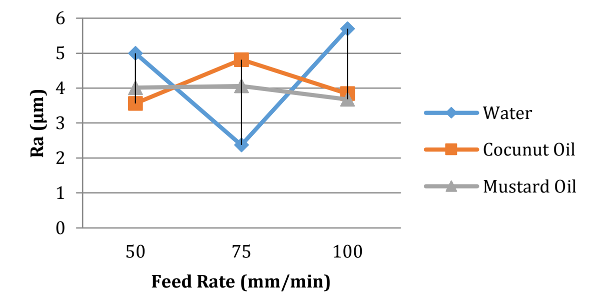


Fig. 6. Ra Vs Feed Rate For Constant Spindle Speed & Depth Of Cut

Surface roughness first decreases and then increases with increase of feed rate in case of water; first increases and then decreases for coconut oil and almost constant for mustard oil. Overall it can be said that surface roughness is lowest in case of water but spindle speed should be kept low to achieve good surface finish.

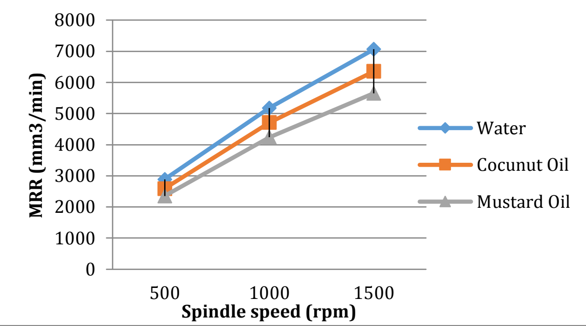
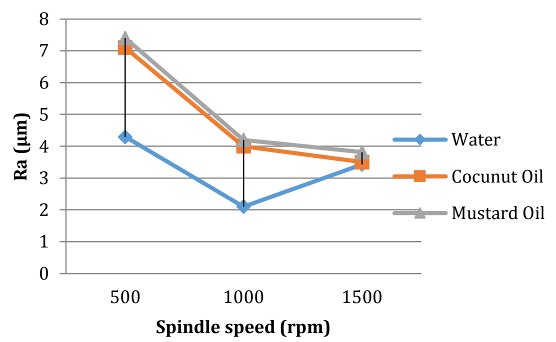


Fig. 7. MRR vs spindle speed for constant feed rate & Depth of Cut

With the increase in spindle speed, MRR increases for all the cutting fluid. For water MRR is higher as compared to coconut oil & Mustard oil. MRR is highest in case of water.

Fig. 8. Ra vs spindle speed for constant feed rate & Depth of Cut



With the increase in spindle speed, surface roughness first decreases and then increases in case of water; and it decreases for both coconut oil and mustard oil. Surface roughness is observed to be lowest in case of water.

3. CONCLUSIONS

1. MRR increases with increases in Depth of cut, Feed Rate & Spindle speed.
2. MRR is highly influenced by depth of cut than Feed Rate & Spindle speed.
3. Water is the best cutting fluid to get high MRR.
4. Surface Roughness is lowest if spindle speed is kept at 1000RPM, feed rate at 75mm/min, depth of cut as low as 0.5mm and water is used as cutting fluid.
5. For aluminium, cutting fluid performs cooling action more as compared to lubricating agent as seen by highest MRR (higher productivity) and hence water acts as the best coolant as compared to coconut oil and mustard oil.

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