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Experimental Investigation of Process Parameters on Material Removal Rate and Surface Roughness in Turning Operation

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Abstract:

Most of the researchers were studied dry and wet machining and compared the dry and wet machining process. MQL technique considerably enhances cutting performance in terms of increasing tool life and improving the quality of the machined parts. Vegetable oils have been used in the food industry, but a recent trend shows they could also use as industrial fluids. Vegetable based lubricants are environmental friendly, less toxicity and easily biodegradable in nature. The aim of the present work is to study the effect of minimum quantity lubrication (MQL) in the turning operation. Cotton seed oil were used in the present work and optimize the process parameters based on the MRR (material removal rate), tool wear and surface roughness. The input parameters were selected as speed, feed, and depth of cut at three different levels for each parameter, L9 orthogonal array were designed by MINITAB software. It was found that the MQL provides better performance.

Keywords: Turning, optimization, MQL, Vegetable oil and tool wear.

1. INTRODUCTION

Material removal is one of the most important processes in the manufacturing industry as it can provide the required surface finish and dimensional tolerances. In this process, plastic deformation uses a hard cutting tool to remove material from the workpiece. All the energy used to compress the workpiece into a chip is converted to heat. Caused internal friction. Most of the heat is generated on the shear plane. The shear plane accounts for about 65-75% of the total heat generated. Next, the friction at the interface between the insert and the tool produces heat in the range of 15-25%, and the friction at the contact between the tool and the workpiece produces heat in the range of 10%. The heat generated is transferred to the cutting tool, workpiece, and surroundings by conduction, convection, or radiation. Radiation is emitted depending on the environmental conditions. The amount of heat generated is determined by the hardness of the work material and the amount of heat supplied. The amount of material removed and the rate at which it was removed. Most of the heat generated is dissipated by the insert and the rest is dissipated to the workpiece and cutting tool [1]. This accelerates tool failure and causes thermal damage to the workpiece. Thermal damage to the workpiece can range from inadequate surface polishing to induced residual stress, microcracks and corrosion. In addition, the higher the temperature in the cutting zone, the more likely it is that a built edge (BUE) will occur at the tool tip. Cutting resistance is variable and the surface finish of the product is inadequate due to BUE [2].

Metalworking fluids (also known as cutting fluids) are widely employed in industrial machining processes to help solve these challenges [3]. Cutting fluids lubricate the machining zone as well as cool it, resulting in lower cutting forces. Cutting fluids also aid in extending tool life and improving product quality [4]. Cutting fluids come in a wide range of options on the market today. Despite this, water miscible oils are employed in more than 70% of applications. Water miscible oils combine the benefits of lubrication and cooling by containing both oil and water. The petroleum-based emulsifier SPS (Sodium petroleum sulfonate) is used to keep the water and oil molecules together [5]. Traditionally, these cutting fluids were used to drain a considerable portion of the heat created during the machining process by flooding enormous amounts of fluid over the backside of the chip [6]. The fluids are recirculated in the system, and any evaporation losses are compensated. The performance of the fluids degrades with time when they are reused. The consequences of the fluids on workers' health, handling and disposal challenges, pollution, and other issues are also key considerations for the industry [7]. Chemically treating and disposing of old cutting fluids costs a lot of money every year. The fluids lose their functionality over time because of regular use, and they must be replaced. Cutting fluids, such as EP additives and emulsifiers, are non-biodegradable due to their constituents. This necessitates special treatment prior to disposal, which raises disposal expenses.

Occupational illnesses are induced by microbiological contamination and hazardous fluid composition in about 80% of cases [8]. Even simple chemicals become poisonous as a result of the chemical processes that occur during the formation. Cutting fluids containing petroleum-based additives, according to the International Agency for Research on Cancer (IARC), cause skin cancer. Cutting fluids may induce a variety of additional ailments, including lung cancer, respiratory issues, and other dermatological diseases [9]. More than 100 million gallons of metalworking fluids were utilized in the United States in 1999, according to reports, and 1.2 million personnel were exposed to the detrimental effects of these cutting fluids, putting their health at risk. The permissible exposure level for metalworking fluid (MWF) aerosol concentration is 0.5 *mg/m3*, while the oil mist level in US automotive parts manufacturing facilities has been estimated to be 20–90 *mg/m3* with the use of conventional lubrication by flood coolant, according to the US National Institute for Occupational Safety and Health (NIOSH).

The bacterial genus discovered in the cutting fluids is extremely dangerous. In both stored and working situations, aerobic bacteria multiply rapidly in cutting fluids. Pseudomonas is the name of the bacterial genus. Because it is an opportunistic bacterium, it becomes more virulent in the event of an injury or burns, which are typical in a machining shop. Pseudomonas is made up of roughly seventy species, the bulk of which can break down oils (which can crucially affect the cutting fluid). The organisms consume the carbon in the oils and decompose them into an inorganic substance. Pseudomonas can thrive in harsh environments and is unaffected by biocides [10]. Furthermore, the use of biocides in cutting fluids is constrained by a number of environmental rules enforced by various organizations [11].

The addition of various chemicals, such as chlorinated paraffin, to boost chemical stability, viscosity, flame resistance, and other properties, exacerbates the disposal problem [12]. When heated, these additives convert to dioxin, which can cause uncontrollable burning. As a result, dangerous substances are assigned to such cutting fluids [13].

Newer cutting fluid mixes were developed to address the difficulties associated with traditional cutting fluids.

It is vital to lower the amount of cutting fluid used while also replacing it with 100 percent biodegradable oil to achieve sustainable machining. eliminating fluid flooding have motivated academics to hunt for alternatives to flooding. The following are a some of the alternatives that were considered, Dry machining, Minimum quantity lubrication (MQL) [14].

1.1 TURNING

Turning is the most common lathe machining operation. During the turning process, a cutting tool removes material from the outer diameter of a rotating workpiece. The main objective of turning is to reduce the workpiece diameter to the desired dimension.

There are two types of turning operations, rough and finish. Rough turning operation aims to machine a piece to within a predefined thickness, by removing the maximum amount of material in the shortest possible time, disregarding the accuracy and surface finish. Finish turning produces a smooth surface finish and the workpiece with final accurate dimensions.

1.2 PARAMETERS OF CONVENTIONAL TURNING MACHINE

Right cutting parameters produces a precise output, which helps in reducing cycle times, and machine costs. The speed and motion of the cutting tool are specified through several parameters that can be modified for different operations Cutting based upon the workpiece material and tool size.

Cutting Speed

The spindle speed is obtained when the cutting speed is divided by the circumference of the work piece in Revolutions Per Minute (R.P.M). The speed varies depending upon several factors like the diameter of the cut or the surface area.

Cutting Feed

This parameter measures the distance undertaken by the cutting tool for every single revolution. It is measured in m per Revolution. Depending upon the mode of operation, the tool is either fed into the workpiece or the workpiece is

Feed Rate

It is defined as the speed of the cutting tool when it cuts through the material. It is the product of the cutting and spindle speed measured in mm per Minute.

1.3 COOLING AND LUBRICATION

Cooling and lubrication (C/L) agents have been used in machining processes for a long time to improve machining results. Improved tribological behavior at the junctions (tool-work chip), for example, is said to have increased tool life, decreased tool wear, improved heat dissipation, reduced cutting force, and improved surface smoothness. These advantages are dependent on the chemical nature of the substance utilized. The mechanical qualities of the tool-work and C/L agents Furthermore, the cutting practice range 3. The selection of C/L agents is influenced by a number of factors. Eco-technical considerations have governed these in recent years choices. The pollution of water, soil, and air caused by the disposal of traditional cutting fluids, for example. Workers' dermatological concerns throughout the process, as well as the separation of cutting fluid into substance. When the machining temperature is raised, there is a lot of focus on the surface.

1.4 INFORMATION OF LUBRICATIONS AND LUBRICANT

The primary purpose of lubrication is to reduce wear and heat between contacting surfaces in relative motion, preventing corrosion and reducing between contacting surface in relative motion, acting as a barrier against moisture, dirt, and dust. A Lubricant is a substance that’s helps to reduce friction between surfaces in mutual contact, which ultimately used to reduce the heat generated when the surface move. Lubricant also has the ability to transmit forces, move foreign particles and heat or cool surfaces. Lubricity is a quality that helps to reduce the friction. Lubricants are available in the form of solid, liquid and gas. Lubricants with the following are preferred an elevated boiling point, an elevated viscosity index, thermal steadiness, corrosion protecting ability, lesser freezing point and elevated opposition to oxidation.

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1.5 OPTIMIZATION

In the real world of machining, it is critical to optimize operations because this reduces resource

consumption. Several research have been carried out to improve the system. Machining responses in a variety of machining situations. In the machining, we used response surface methods and particle swarm optimization techniques. Under MQL conditions, a Ti alloy system is used. A desirability-based approach to machining parameter optimization for minimal surface values. Under nanofluid MQL conditions, roughness parameter (Ra, Rq, Rz). The best results were discovered to optimize the values of the parameters are employed; the surface quality improves. Machining reactions were improved.

2. LITERATURE REVIEW

Amini. S et.al., (2015) experiments were performed with different fluid flow rates, frequency, position, and direction of nozzles for determination of optimum parameters. Second, tool life and surface finish were studied. Fluid flow rate, fluid frequency, nozzle position, and distance are effective parameters in MQL machining. Achieved optimum parameters for MQL machining are flow rate of 110 *ml/h*, fluid frequency of 10 *cycles/min*, and nozzle distance of 5 *cm*. Using MQL can increase tool life and surface quality, which means higher cutting speeds can be used by MQL compared with dry machining method.

Fernando. W.L.R et.al., (2019) studied the experiment about novel coconut oil based MWF has shown better heat absorption and lower tool flank wear while machining AISI 304.Optimum parameter settings for turning of AISI 304 with coconut oil based MWF under MQL condition has obtained. However, it has shown better surface finish in Mild Steel. Surface roughness depends on other factors like tool nose wear (feed marks) and built-up edges. Therefore, as future work the surface roughness needs to be studied more giving consideration to above factors too. Further novel coconut oil based MWF to be tested under different flowrates for different work materials.

Ganesan. K et.at., (2018) conducted experimental investigation on copper nanofluid based minimum quantity lubrication in turning of H 11 steel surface roughness is decreased by 40% while machining with copper nano fluids with optimal settings of feed = 0.1 *mm/rev* and cutting speed = 209 *m/min*. The penetrating ability of nano fluids in the machining zone direct to good cooling and efficient lubrication causing a reduction in surface roughness. The tool wear was minimized by 66% due to copper nano fluids. The excellent conduction and convection properties of copper nano fluids provide a good lubrication to the cutting tool and reduce the flank wear.

Gurpreet Singh et.al., (2013) compare the performance of Vegetable and Mineral performance in terms of Surface roughness by using Different cutting environments and different cutting inserts at different cutting parameters. The effect of nose radius on surface roughness in dry and MQL cutting environment has also been presented in this study. The results of Surface roughness obtained during dry and MQL cutting has also been compared for exploring the role of MQL. In surface roughness, cutting speed, and Noise Radius.

Huseyin Cetin .M et.al., (2011) conducted the experiments on canola based cutting fluids with 12% of EP additive is more influence than the other cutting fluids on surface roughness. And sunflower based cutting fluids has negative effects on surface roughness when the ep ratio is increases to 8% to 12% in cutting fluids. Canola based cutting fluids with 50% of EI improve surface roughness by 5.51%. Performance of vegetables based cutting fluids and commercial cutting fluids are also compared and then the sunflower and canola based cutting fluids better than other fluids.

Mukesh Gan chi et.al., (2018) studied the experiments about Surface roughness and cutting parameters (i.e., SS and FR) have high non-linear relationships among them for all cutting environments. Amongst the cutting parameters, feed rate affects the surface roughness to greatly extent while the spindle speed has least effect on surface roughness.

Neetu Upadhyay et.al., (2015) studied the effectiveness of machining AISI 316L austenitic stainless steel under MQL with MoS2 powder-mixed cutting fluid. The effect of two different base fluids namely conventional water-soluble cutting oil and paraffin oil has also been investigated. Significant reduction obtained in cutting temperature along with decrease in surface roughness, cutting force and chip thickness when MoS2 powder was added to the base fluid clearly exhibited the supremacy of powder- mixed MQL in turning operation. The outcome thus obtained from the current study is expected to be of immense significance for various machining.

Paulo Davim. J et.al., (2013) performed the experimental analysis on turning high rigid lathe 50 CNC having a maximum spindle power of 18 *kW* and spindle speed of 4500 *rpm*. The turning operation was performed under MQL and flood lubricant condition. The quantities of lubricant supplied under flood conditions was 200 *ml/hr*. As the feed and cutting speed increases, the cutting power was slightly on the higher side for MQL is better composed to flood condition. When feed rate increased surface roughness also increases, and Ra value is found to increase with feed rate. The chip form obtained in MQL, or flood lubrication condition is similar.

Sachin M. Agrawal et.al., (2018) carried out experimental analysis on result of wear and friction test has been undertaken for dry by using conventional lubricant and by using vegetable oil of various speed and loads. In this analysis of variance was used to find the significance and relative influence of each factor. Total 9 trails have been conducted for dry lubricating condition. Its addiction and experiment were repeated twice to eliminate the pure error.

Young Kug Hwang and Choon Man Lee, (2010) conducted the experiments on MQL and wet turning process. In the case of experiment 7 has high feed rate cause the extremely poor surface finish. If it has a very low cutting speed cause to a poor surface finish in experiment 9 and the higher cutting speed also cause to poor surface roughness in experiment 6,7,14,16,17 and 27. those results has been caused chattel vibration and the two-factor interaction wet turning process.

3. MATERIAL AND METHODS

3.1 MATERIAL SELECTION

Present work mainly involves the use of lathes. Turning is the most widely used machining method, and also plays an important role in influencing the quality of machined parts. The choice of equipment for measuring dependent parameters also plays an important role as it provides the result. Thus, the requirements of experiment setups are as follows,

- Machine tool.
- Work material.
- Cutting tool.
- Control parameters and levels.
- Cutting oil.
- Surface roughness measurement.
- Tool wear measurement.
- MRR measurement.

3.1.1 Machine Tool

The purpose of the current work to complete the set of experiment was performed using conventional lathe KIRLOSKAR (TURNMASTER-35) as shown in figure (1).

Figure 1 KIRLOSKAR-TURNMASTER- 35 Conventional lathe.

3.1.2 Work Material Specification

The work material used for the present work was AISI 202 Stainless steel as shown in figure (2). AISI 202 Stainless steel finds its application in general industry and process industry machinery and equipment, automotive industry, electrical machinery, etc.,

Figure 2 Work material AISI 202 SS.

The chemical properties of grade AISI 202 stainless steel are displayed in the table-5.1.

Table-5.1 Chemical properties.

Element	**Content (%)**
Iron, Fe	68
Chromium, Cr	17-19
Magnesium, Mn	7.50-10
Nickel, Ns	4-6
Silicon, Si	<1
Nitrogen, N	<0.25
Carbon, C	<0.15
Phosphorous, P	<0.060
Sulphate, S	<0.030

The mechanical properties of grade AISI 202 stainless steel are displayed in the table-5.2.
Table-5.2 Mechanical Properties.

Properties	**Metric**	**Imperial**
Tensile strength	515 *Mpa*	74698 *Psi*
Yield strength	275 *Mpa*	39900 *Psi*
Elastic modulus	207 *Gpa*	30000 *Ksi*
Poisson’s ratio	0.27-0.30	0.27-0.30
Elongation of break	40%	40%

3.1.3 Cutting Tool

Tool holder

The tool holder used for the present work was MTJNL 2525 M16 manufactured by widax. The rear positions height and width are made 25mm. Tool holder is shown in figure (3).

Figure 3 Tool holder (MTJNL 2525 M16).

Cutting tool INSERT

In present work, the selected insert was tin coated tool TNMG 160404 as shown in figure (4).

Figure 4 INSERT TNMG 160404.

3.1.4 Control parameters and levels

A total of three process parameters with three levels are selected as the control parameters so that the levels are far enough apart to cover a wide range. Process parameters and their range are determined based on literature and the experience of machine operators. The three control parameters selected were speed, feed, and depth of cut.

Table-3 Factors with different values.

SPEED (*m/min*)	**FEED RATE (*mm/rev*)**	**DEPTH OF CUT (*mm*)**
80	0.1	0.1
100	0.15	0.25
120	0.2	0.5

3.1.5 Cutting oil

Cotton seed oil was used as it is cheaper compared to other vegetable alternate, and it is available abundantly in India. Cotton grown for oil extraction is one of the big four genetically modified crops grown around the world, next to soy, corn, and rapeseed (canola). The specification of cotton seed oil is given below.

Table-4 Specification of cotton seed oil.

Properties	**Cotton seed oil**
Viscosity (cSt at 40^0c)	33.86
Viscosity (cSt at 100^0c)	7.75
Viscosity index	211
Flash point	252
Heat transfer co-efficient at 70^0c	2190
Heat transfer co-efficient at 45^0c	1970
Lubricity (HFRR) (Mic, M)	295

3.1.6 Surface Roughness

Surface roughness is the measure of the finely spaced micro-irregularities on the surface texture which is composed of three components, namely roughness, waviness, and form. Surface roughness Ra is commonly used to indicate the level of surface roughness. To get good surface finish and high accuracy in machining operation. It is essential to cut a low-chip load. Chip load is the most influential factor that affects surface roughness deterirates with the increase chip load. surface roughness was measured by profile projector, surface roughness measurement is the small-scale variation is the high if physical surface. Surface roughness is measured by using surface roughness tester (MITUTOYO SURFTEST – SJ-210) as shown in figure (5.3).

Figure 5 Surface tester MITUTOYO SURFTEST – SJ-210.

3.1.7 Tool Wear (or) Flank Wear

Tool wear is the gradual failure of cutting tool due to regular position. Tools affected include tipped tool, tool bits and drill bits that are used with machine tools. The cutting tool wears out during machining for a number of different reasons, which adversely affect the cutting results.

3.1.8 Material Removal Rate

MRR is the amount of material removed per time unit (usually per minute) when performing machining operation such as using a lathe machine. Material removed per minute is the highest material removal rate. The MRR is calculated using the formula,

MRR= wi-wf/t *gm/min*

Where,

Wi- Initial weight of work piece in *gm*.

Wf- Final weight of work piece in *gm.*

t- Machining time in *second.*

4. EXPERIMENTAL PROCEDURE

The outermost layer diameter-36 *mm* and length 150 *mm* of the workpiece was turned off using tin coated insert (TNMG 160404) to outer machining of the oxidized layer. Subsequently longitudinal turning test were carried out on a conventional lathe, Make: KIRLOSKAR, Model: TURNMASTER- 35 with Specification: spindle motor = 3 *HP* /2.2 *KW* DC compound motor, Feed motor =1 *HP*/DC motor. Each experimental run was conducted by using a fresh cutting-edge during experimentation cutting oil was applied on tool edge in the form of fine mist (mixture of compressed air and cutting oil) with the help of spray gun. The flow rate cutting of oil was regulated to obtain different MQL regimes of 15 *ml/min* was used in forming the oil mist. After finding the optimized levels for machining parameters cutting speed, feed, depth of cut and cutting oil flow rate under MQL condition. The experiments were also performed at this optimal

cutting condition under dry and wet (flooded coolant) condition to compare tool performance. During experimentation the flank wear of worn-out insert was measured using profile projection. The machined specimens were evaluated with a surface roughness analysis (MITUTOYO SURFTEST – SJ-210).

4. RESULT AND DISCUSSION

Using the Taguchi approach, we will discuss the surface roughness, tool wear, and effects of cutting parameters such as speed, feed, and cutting depth on the machined cottonseed oil work material. Table 6.1 below shows the surface roughness during machining with cottonseed oil-based coolant, tool wear, MRR experimental results, and the signal-to-noise ratios corresponding to the results obtained.

The values of each response obtained from the experimental runs, designed by Taguchi method, the corresponding values of signal to noise ratio is mentioned for each run is shown in table-6.

Table-6 Experimental result with S/N ratio

Expt No	**Speed (*m/min*)**	**Feed (*mm/rev*)**	**Depth Of Cut (*mm*)**	**Ra (*mm*)**	**S/N Ratio**	**Tool Wear (*mm*)**	**S/N Ratio**	**MRR (mm^3/sec)**	**S/N Ratio**
1	80	0.1	0.1	1.347	-2.5874	0.1	20	0.099	-20.087
2	80	0.15	0.25	1.012	-0.1036	0.26	11.7005	0.328	-9.6825
3	80	0.2	0.5	3.538	-10.975	0.5	6.0206	0.792	-2.0255
4	100	0.1	0.25	1.261	-2.0143	0.2	13.9794	0.352	-9.0691
5	100	0.15	0.5	2.166	-6.7132	0.45	6.9357	0.83	-1.6184
6	100	0.2	0.1	4.064	-12.179	0.61	4.2934	0.315	-10.033
7	120	0.1	0.5	2.183	-6.7811	0.29	10.752	0.455	-6.8398
8	120	0.15	0.1	2.628	-8.3925	0.52	5.6799	0.428	-7.3711
9	120	0.2	0.25	3.938	-11.905	0.74	2.6154	1.615	4.1635

5.1 SURFACE ROUGHNESS

The effect of cutting speed at three different conditions are dry, flood and MQL. In this current work dry and MQL are used in turning operation. It was observed that an increasing cutting speed will lead to decreasing surface finish. It is well known fact that the increase in cutting speeds leads to decrease in the co-efficient of friction between the workpiece and tool interface. This chip formed under such conditions are continuous chip which yield less contact between the workpiece and tool interface, thus resulting in a lower co-efficient of friction, which in turns results in better surface finish.

Table-7 Response table for S/N ratio for surface roughness.

LEVELS	**SPEED (*m/min*)**	**FEED (*mm/rev*)**	**DEPTH OF CUT (*mm*)**
1	-4.555	-3.794	-7.720
2	-6.969	-5.070	-4.674
3	-9.026	-11.687	-8.156
DELTA	4.471	7.892	3.482
RANK	2	1	3

Table-7 shows the response for S/N ratio for smaller is better for surface roughness each level of parameter.

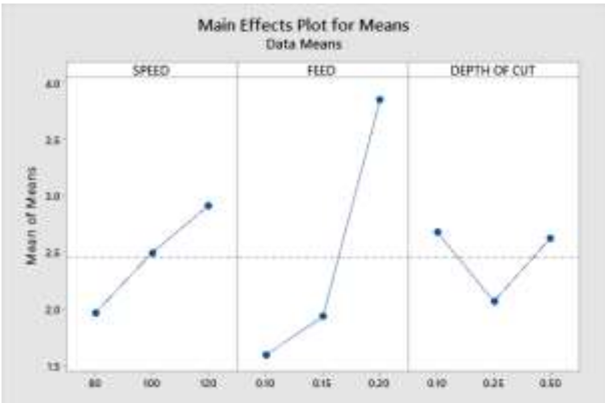

Figure 6 Means graph for surface roughness.

Figures 6 and 7 evaluate the main effect of each parameter on different level conditions. According to Figures 6 and 7, surface roughness decreases with three main parameters: speed, feed, and depth of cut.

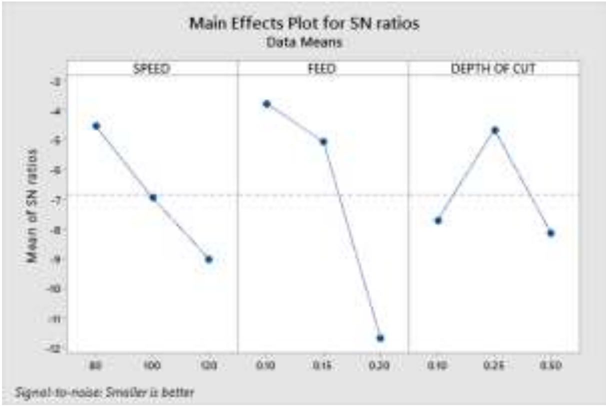

Figure 7 S/N graph for surface roughness.

Surface roughness is minimum at speed level 3 (120 m / min), minimum at feed rate level 3 (0.20 mm / rev), and under cutting conditions, surface roughness is minimum at level 1 (0.1 mm). Therefore, the optimum parameter settings for the minimum surface roughness are velocity (120 m / min), feed (0.20 mm / rev), and depth of cut (0.10 mm), and the maximum variation in surface roughness due to feed is seen.

5.2 MATERIAL REMOVAL RATE

High MRR is desirable in the turning operation. It shows the unit amount of material removal for a particular set of parameters. Burr-Shaped chips generated during surface finish are small to be removed, due to high temperature the material removal rate can be calculated from volume of material removed or from the weight difference between before machining and after machining. Higher machining productivity must also be achieved with a desired accuracy and surface finish.

Table-8 Response table for S/N ration for MRR.

LEVELS	**SPEED (*m/min*)**	**FEED (*mm/rev*)**	**DEPTH OF CUT (*mm*)**
1	-10.598	-11.999	-12.497
2	-6.907	-6.224	-4.863
3	-3.349	-2.632	-3.495
DELTA	7.249	9.367	9.003
RANK	3	1	2

Table-8 shows the response for S/N ratio for larger is better for material removal rate each level of parameter.

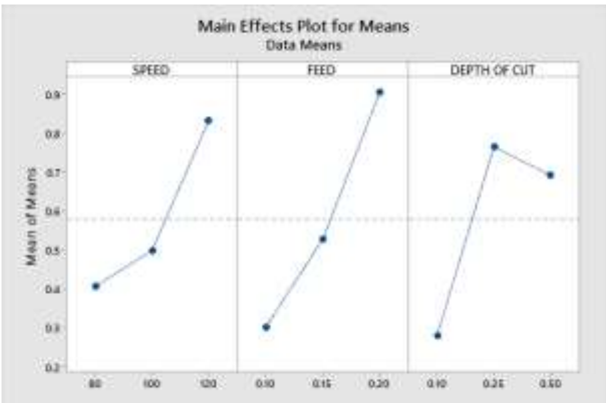

Figure 8 Means graph for MRR.

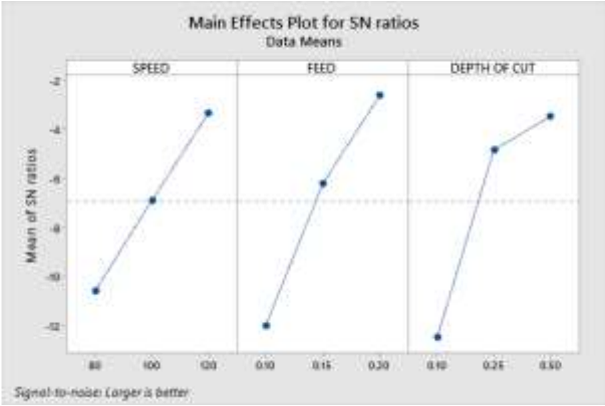

Figure-9 S/N graph for MRR.

The main effects of MRR for each parameter under different level conditions are shown in Figures 8 and 9. According to Figures 8 and 9, MRR increases with three main parameters: speed, feed, and depth of cut. MRR is maximized at level 3 (0.20 mm / rev) feeds, level 3 (120 m / min) speed, and level 3 (0.50 mm) depth of cut. Thus, the optimum parameter settings for MRR were found for speed (120m / min), feed (0.20mm / rev), and depth of cut (0.50mm), and variations due to spindle speed were found on MRR.

4.3 TOOL WEAR

Poor performance of the tool at the lower cutting speeds can be explained by the influence of heat on the cutting tool. That is because of metal cutting involved the large amount of heat generation and in the machining of AISI 202 Stainless steel it is not dissipated quickly due to the low thermal conductivity of the material. The heat generation mainly occurs near the shear zone, rake face and on the side of the cutting edge.

Table-9 Response table for S/N ratio for tool wear

LEVELS	**SPEED (*m/min*)**	**FEED (*mm/rev*)**	**DEPTH OF CUT (*mm*)**
1	12.574	14.910	9.991
2	8.403	8.105	9.432
3	6.349	4.310	7.903
DELTA	6.225	10.601	2.088
RANK	2	1	3

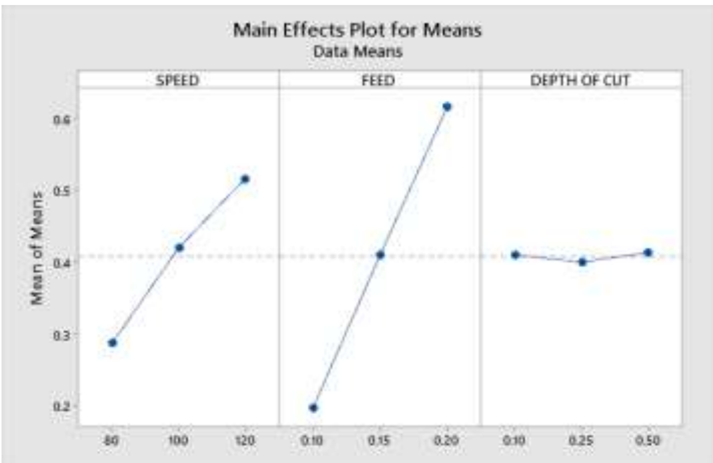

Figure 10 Means graph for tool wear

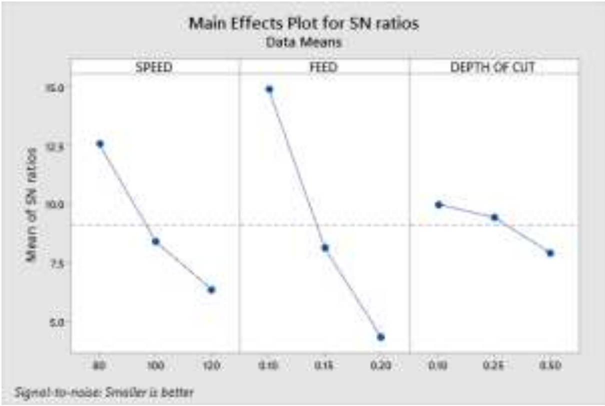

Figure 11 S/N graph for tool wear

Figures 10 and 11 evaluate the main effect of each parameter on different level conditions. According to Figures 10 and 11, tool wear is reduced by three main parameters: speed, feed, and depth of cut. Tool wear is minimal at speed level 3 (120 m / min), feed rate is level 3 (0.20 mm / rev), and tool wear under cutting depth conditions is minimal at level 3 (0.5 mm). Therefore, the optimum parameter settings for minimum tool wear are speed (120 m/min), feed (0.20 mm / rev), and notch (0.5 mm), with maximum variation in tool wear with feed and depth.

Table-8 gives the rank of parameters for MRR cutting speed is the most significant parameters whereas feed rate is the least significant parameters as far as MRR is concerned. Table-7 gives the rank of parameters for surface roughness feed rate is the most significant parameters whereas spindle speed is the least significant parameters as far as surface roughness is concerned.

6. CONCLUSION

The main goal if the experiment was to carried out the performance of cutting fluid in terms of material removal rate and surface roughness by using cotton seed oil. Here, to find the difference between cutting parameters like speed, feed, and depth of cut. Surface roughness and MRR were investigated using a L9 orthogonal array in statistically designed experiment based on Taguchi method.

1. The optimal parameters for surface roughness using cotton seed oil as a cutting fluid to speed of (120 rpm), feed at (0.20 mm/rev) and depth of cut (0.10 mm). The result obtained for the surface roughness here, found that greatest variation in feed rate of surface roughness.

2. The optimal parameters for MRR using cotton seed oil was at increase with maximum speed of (120 rpm), feed at (0.20 mm/rev) and depth of cut (0.50 mm). The result obtained for the MRR, here found that variation due to spindle speed on MRR.

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