EXPERIMENTAL INVESTIGATION OF SURFACE ROUGHNESS FOR MINIMUM QUANTITY LUBRICATION GRINDING UNDER SOYABEAN, RICEBRAN AND CANOLA OIL

Sandeep Gora[1] , Roshan Lal Virdi[2], Baljinder Ram[2]
[1]Research Scholar, [2]Assistant Professor
[1,2]Mechanical Engineering Department,
[1,2] Punjabi University, Patiala, India

Abstract : Minimum quantity lubrication nowadays also known as micro lubrication is an alternate of general cooling system to protect the environment in an alternate of general cooling system to protect the environment. In many organization the large percentage of metal working is done with the flood coolant system. In the present work vegetable oils are used as lubricants in Minimum Quantity Lubrication Technique. L9 array was used to explore the effect of oils on the surface roughness of the workpiece. It was observed that soyabean oil gives minimum value of surface roughness due to stable lubrication film at the grinding zone even at different conditions. The result of this research can be marked as steps towards green and environment friendly manufacturing.

IndexTerms **- MQL, Grinding, L9 array, Surface roughness.**

I. INTRODUCTION

Grinding is a very important tool making process and it produces very fine finish and accurate dimensions. It can be machined the very hard materials. It is an abrasive machining process in which grinding wheel is used as a tool for machining. The number of different wheels and tools are used for the grinding process for example hand cranked knife-sharpening stones which are also referred to as grindstones and angle grinders. Khan et al. (2009)performed an experiment on low alloy steel ASI9310 by using vegetable oils to compare the performance of vegetable oil , dry and wet cutting. The MQL was provided with the spray of air and vegetable oil. This research indicates that the present MQL system enabled reduction is average chip tool interface temperature upto 10% as compared to wet machining. The chips produced under bot dry and wet conditions are of ribbon type surface finishes are improved due to the reduction of wear at the tool tip. **Shashidhara and Jayaram (2010)**studied the application of vegetable oil as potential metal working fluid. In this study they concluded the result of sixty authors on the vegetable based oil as emerging environment friendly cutting fluid. The performances of various vegetable oils are studied in these research soybeans, sunflower, and rapeseed is declared as potential cutting fluid because these oils have relevant properties to the coolant. They apply the test on the SAE S6 40 material using vitrified CBN wheel. **Priarone et al. (2014)** performed milling and turning operations on titanium aluminides Pi-48AC-Cr 2Nb by using maximum quantity lubrication. The main aim of this experiment is evaluate the influence of lubrication strategy on tool wear. It was concluded MQL is much advantageous and environmental friendly solution as coolant. The life of tools also improved under MQL and it indicates that MQL gives the best surface quality is turning. **Boubekri and Shaikh (2015)** learned about the benefits and bad marks of utilization of least amount grease during the time spent machining. It was discovered that MQL was basically noteworthy for the transient tests. It was seen that a noteworthy amount of fog delivered by MQL when contrast it and surge cooling. The principle disadvantage of MQL was that not utilized for long haul tests But rather it was cost decrease technique. It was noticed that with material Ti6Al4V amid the boring by K10 carbide bores under MQL it diminished temperature approx. half. **Rahim et al. (2015)** examined the distinction of least amount grease strategy from the procedure of dry machining. After the trial it was noticed that around 10-30% temperature of granulating zone, powers of cutting 5-28% decreased in MQL when contrasted with dry machining.

Zhang et al. (2015) researched and contrasted least amount grease and dry pounding, nanoparticles MQL and surge granulating. It was observed MoS_2 nanoparticles gave better surface complete among other three sorts. Dry pounding produce more temperature by which instrument harming expanding. It was likewise discovered that with utilization of 2% MoS_2 nanoparticles as a volume fixation gave better outcomes and best oil execution. **Sahid et al. (2015)**optimize the grinding parameters of cast iron in wet condition and with maximum quantity lubrication. This research results that the grinding process with MQL covalent gives the best performance as compared to the conventional coolant. This is determined by the parameters like material removal rate and surface roughness. It also indicates that MQL multiple pass technique is much effective for the surface roughness than the conventional multiple pass. **Wang et al. (2016)**evaluated the temperature of aluminium quantity lubrication cooling of 45 steel, Ni based alloy and modular cast iron. The experiment show that 45 steel achieved highest grinding temperature (363.9 and 352.9 C). The experiment results that the heat transfer intensity of the 2% nano-fluids is slightly higher that of 2.5% nano-fluids. Khalilpourazari and Khalilpourazary (2018)worked on the optimization process of the parameters of surface grinding

process. This optimization process enhanced the final surface quality and production rate and reduces the total cost of processing. The novel approach stochastic fractal search is proposed to solve the problem of optimization efficiently. The parameters are optimized by using the Taguchi method and constraint handling technique to handle the non linear constraints effectively. The proposed Taguchi method compared with existing methods and provides the effective outcomes . **Li et al. (2017)**presented a model based on the grain work piece micro interaction. The three basic components of the grinding are rubbing, plowing and cutting forces. These components of grinding are used for the analyzing process. The work is also focused on the grinding issues like heat, surface topography, and grinding chatter which are mainly faced in micro fabrication and miniaturization. These factors play an important role in the optimization process of grinding tools. Liu et al. (2018)proposed the analytical method of rail grinding and it determines the metal which is eliminated due to rail grinding in initial process of profile correction. The location and patterns of grinding wheel arranged according to the personalized patterns generated by the algorithm. This algorithm improves the grinding quality and field **Ma et al. (2017)** studied the mechanism of fractures and its removal in glass ceramics processing. This model tests the variation tendency of surface roughness and enhances the accuracy of the model. The cross validation testing is performed to test the model and this model was compared with two other models and provides highest precision results. Sato et al. (2018) studied that how water makes an impact on the work bit of steel AISI 4340 amid the utilization of CBN granulating wheel during the time spent pounding. After the analysis it was seen that the most astounding proportion of water when included, increment the impact of cooling and decrease the cutting powers amid MQL. Obstructing happens due to evacuating of chips likewise decline with the expansion of water. It was likewise inferred that development of fog was in every case more when contrasted with MQL. Because of which it diminishes the significance of surge cool. Staniewicz-Brudnik et al. (2018)worked on the diamond wheel grinding process on the boron cemented carbide. This work is mainly the analysis of BNDCC tool results. The grinding parameters consider in this experiment were rate of grinding, material removal rate, and roughness of flank face. The outcomes indicated that the diamond abrasive wheel is effective in grinding

Wang et al. (2018)evaluate the improvement in technology of minimum quantity lubrication grinding metallic material with nano fluids. The author investigated that from the total cost of part processing 7% is cutter cost and 18% is cooling liquid cost which can be decreased by the MQL technique. The service life of grinding wheel is 7 times longer than that of dry grinding by using MQL technique. The whole experiment was performed on the 45 steel and MoS2 nano-particles, Zro2 and CNT of diameter 50nm is used as a nano fluids. MQL flow ratio 50 ml/hat air pressure 0.6 Mpa has fixed in the experiment. This research describes that the different nano-fluids, different base oils, different concentration and efflux parameters in MQL enhance the surface roughness quality.

EXPERIMENTATION

The experiment was performed at the constant speed of the grinding wheel which was 28m/sec (2985Rpm). While the feed rate of vegetable oils changed according to the requirements. The speed of air pressure used under three values 3 bar, 4 bar and 5 bar while the speed of flow rate was set at 80ml/hr, 100ml/hr, and 120ml/hr. 20-micron values were choosen as the depth of cut. Three types of vegetables were used as a variable factor. Experimentation process was done under both techniques MQL and flood cooling or conventional cooling as a comparison process. In this experiment, there was main four variable factor:-

- Vegetable oils
- Oil flow rate
- Air pressure
- Nozzle distance

Table 1: Different Grinding Process Parameters

Grinding type	Surface Grinding of EN31
Grinding environment	MQL, Flood, Dry
Cooling Fluids	Soyabean Ricebran, Canola Oils
MQL flow rate(ml/hr)	80, 100, 120
Wheel speed	28m/sec
Depth of cut	20 microns
Grinding wheel passes	5
Compressed air pressure(bar)	3,4,5

Flood cutting fluid	Water Soluble Servo Oil
Flood cutting flow rate	8000 ml/hr.

TAGUCHI METHOD

In this experiment four type of variables air pressure, vegetable oils, nozzle distance and flow rate were taken. All these parameters were set according to orthogonal array L_9.

Table 2: Parameters as accordance with orthogonal L9 Array

S.No.	Vegetable oil	Air Pressure	Flow rate	Nozzle Distance
1.	Canola	3	80	5
2.	Canola	4	100	6
3.	Canola	5	120	7
4.	Rice Bran	3	100	7
5.	Rice Bran	4	120	5
6.	Rice Bran	5	80	6
7.	Soya bean	3	120	6
8.	Soya bean	4	80	7
9.	Soya bean	5	100	5

SURFACE ROUGHNESS

Surface roughness was the last yield which we had estimated in the wake of doing all the investigation. Surface roughness was reliant upon various factors, for example, the generation of temperature, stream rate, pneumatic force, spout separate, chip creation and so forth.

Surface roughness Across the feed

The below given table represents the value of surface roughness across the feed y using parameter vegetable oil, air pressure, flow rate and nozzle distance at three different levels.

Table 3: Surface Roughness across the feed

Process Parameters	Levels		
	Level 1	Level 2	Level 3
Vegetable Oil	2.38	2.02	1.98
Air Pressure	2.27	2.19	1.92

Flow Rate	2.33	2.18	1.88
Nozzle Distance	2.14	2.23	2.02

Effects of Vegetable Oils

In the research, it was found that the value of surface roughness depends upon the viscosity. Value of surface roughness across the feed was also high in canola oil and rice bran oil as compared to soybeans oil. In soyabean oil due to perfect film formation it has high fluidity which helped in removal of more chips concentrate on the grinding zone. Given chart shows that value of surface roughness is very less in soybeans oil while very high in canola oil.

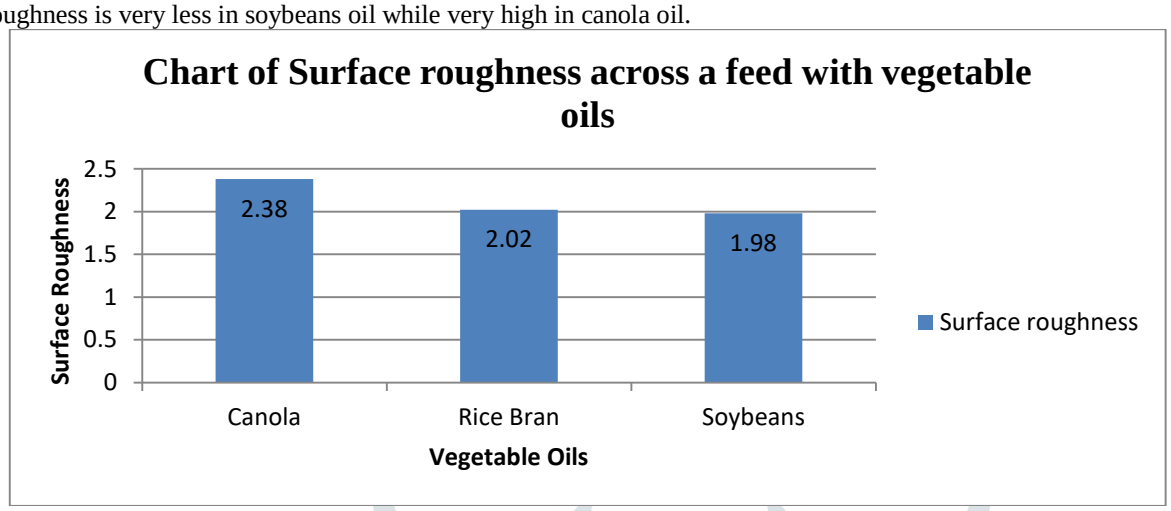


Figure 1: Chart of Surface Roughness across a feed and Vegetable Oils

Effect of Air Pressure

Amid the experimental process, it was explored that surface unpleasantness esteem diminished constantly as we increment the pneumatic force. Diagram demonstrates that estimation of surface harshness is high when weight is set at the 3 bar yet when we increment the weight up to 5 bar then the estimation of surface unpleasantness diminishes. High pneumatic stress expanded the speed of oil beads falling upon the granulating zone and completed more warmth. With expanding gaseous tension number of oil beads strike on granulating zone likewise increment. Because of which it decline the surface harshness.

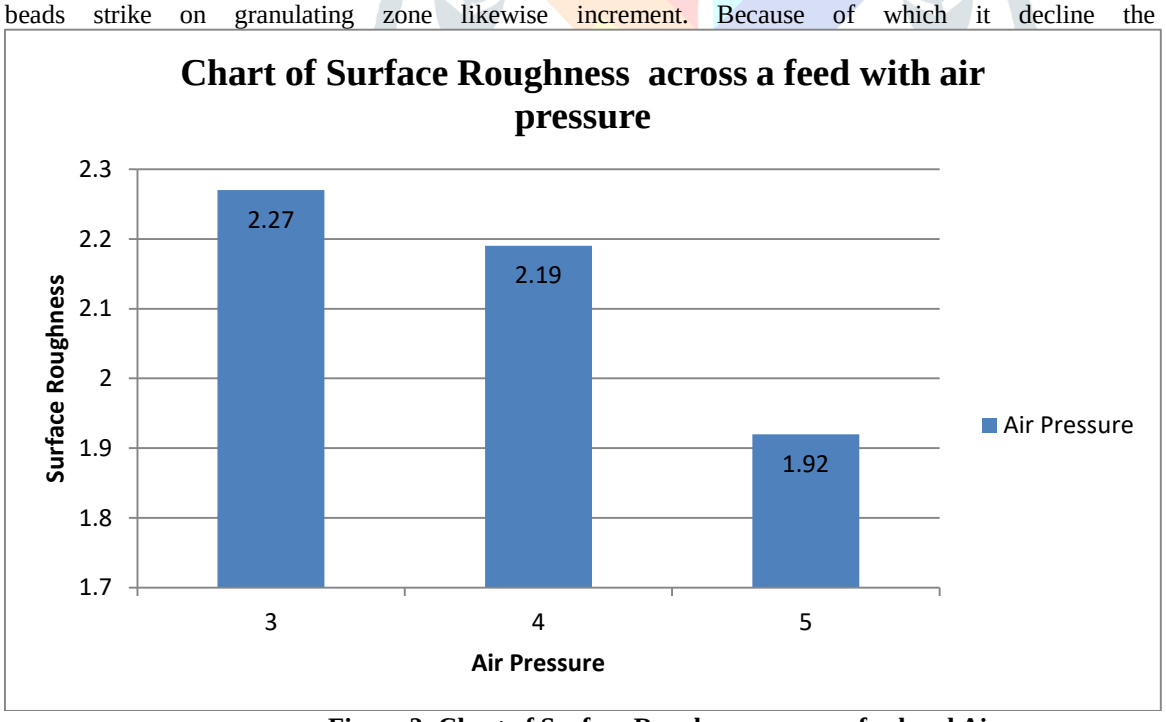


Figure 2: Chart of Surface Roughness across a feed and Air pressure

Effect of Flow Rate

The below given graph depicts that the value of surface roughness decreases with increasing the value of flow rate. With more flow rate more oil droplets fall upon the tool and workpiece which make an oil film in grinding zone. Due to which very less temperature produced and helps in decreasing surface roughness. So the value of surface roughness was very high when the range of flow rate set at 80 ml/hr as compared to the value at 120 ml/hr.

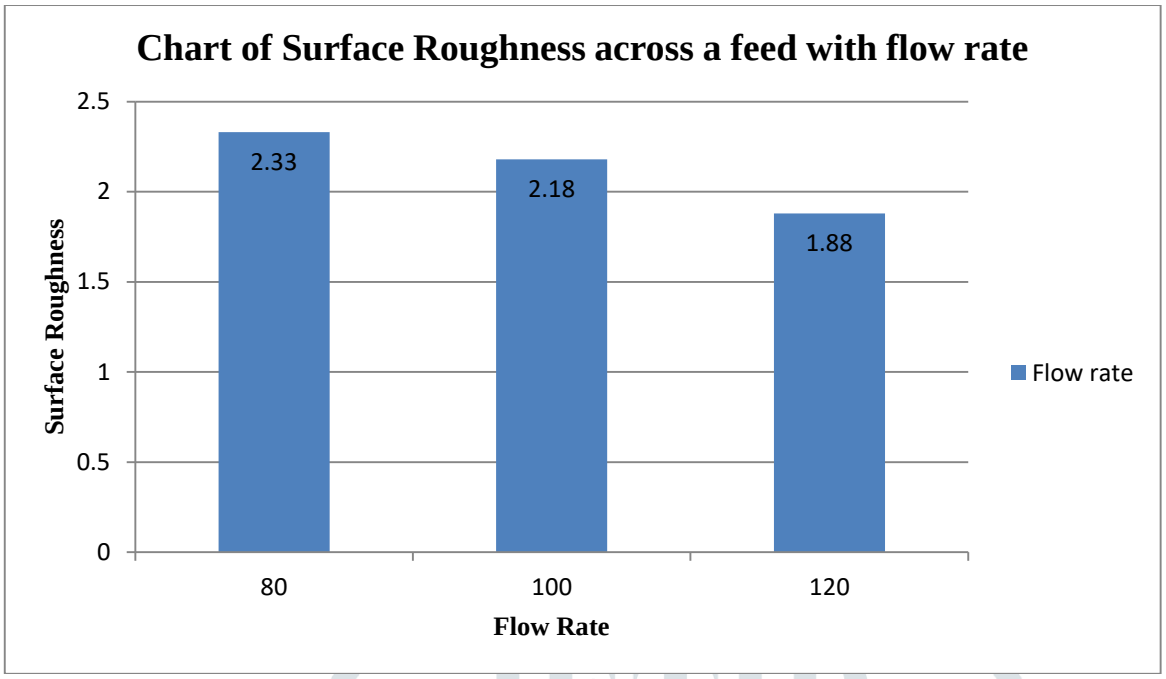


Figure 3: Chart of Surface Roughness across a feed and Flow Rate

Effect of Nozzle Distance

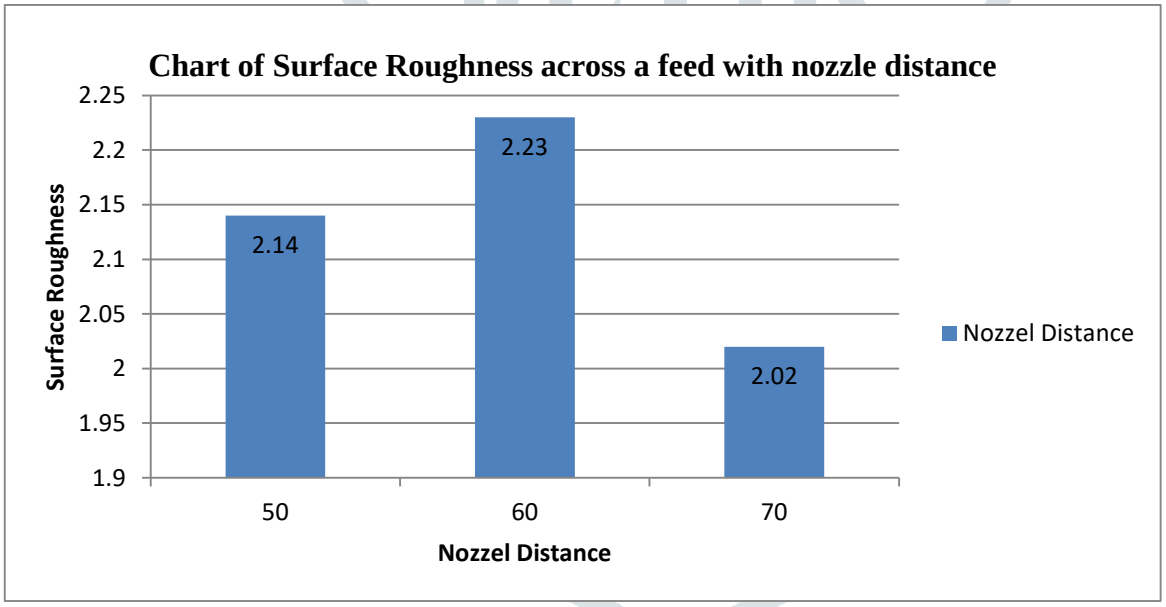


Figure 4: Chart of Surface Roughness across a feed and Nozzle Distance

The graph represents the relation between the surface roughness and nozzle distance. The surface roughness at 60 mm is high as compared to 50 mm and 70 mm. For less surface roughness it was necessary that oil spray should directly fall upon the grinding zone. With increasing nozzle distance oil spray cannot fall in the grinding zone because its spray area increased. Because of this it led to increase in surface roughness.

Effects of Process Parameters on the Surface Roughness across the feed

S/N Ratio for Surface Roughness across the feed

The below given table depicts the SN ratio of the surface roughness across the feed and calculate the effect of a number of parameters such as nozzle distance, vegetable oils, air pressure, the flow rate. First, calculate values of surface roughness and giving them ranking according to their significance by using TAGUCHI method in the MINI TAB software. For finding the contribution of all parameters ANOVA method is used. More value of SN ratio, the more optimum result will come.

Table 4: S/N Ratio for Surface Roughness across

S.No.	Vegetable oil	Air Pressure	Flow rate	Nozzle Distance	Surface Roughness(across)	SN ratio
1.	Canola	3	80	5	2.74	-8.755
2.	Canola	4	100	6	2.60	-8.299

3.	Canola	5	120	7	1.82	-5.201
4.	Rice Bran	3	100	7	2.10	-6.444
5.	Rice Bran	4	120	5	1.84	-9.066
6.	Rice Bran	5	80	6	2.12	-6.526
7.	Soya bean	3	120	6	1.98	-5.933
8.	Soya bean	4	80	7	2.14	-6.608
9.	Soya bean	5	100	5	1.84	-5.296

Analysis of S/N Ratio for Surface Roughness Across the feed

The minimum value of surface roughness across the feed is gained with gaining the maximum value of the signal to noise ratio. The last row of the table describes the ranks of the all parameters according to their significance and their importance. The air pressure got rank 1st because of their significance and followed by vegetable oil. The 4th rank got by flow rate because it is least significant among all four parameters in surface roughness across the feed.

Table 5: Response Table for Means

Level	vegetable oils	air pressure	flow rate	nozzle distance
1	**-7.41**	**-7.04**	**-7.29**	**-7.70**
2	**-7.34**	**-7.99**	**-6.17**	**-6.91**
3	**-5.94***	**-5.67***	**-6.73***	**-6.084***
Delta	**1.47**	**2.32**	**0.56**	**0.77**
Rank	**2**	**1**	**4**	**3**

Main Effect Plot for S/N Ratio of Surface Roughness across the feed

The graph given below describes the main effects of SN ratio on the parameters and performance of surface roughness across the feed. In this graph, x-axis show the value of parameters and y-axis show the value of mean of SN ratio. The graph represents in this line form.

The SN ratio in soybeans oil is high and low in canola oil because of low viscosity. Low viscosity helps in reduction of cutting forces by which it decrease the temperature and increase the SN ratio. While SN ratio is very low during use of canola oil. Value of SN ratio continuously increasing with the increase of air pressure. During the value of 3bar SN ratio is very less after increasing up to 5 bar value of SN also increase.

SN ratio increase with an increase in flow rate. As shown in the graph SN ratio is very low at the value of 80ml/hr and it becomes very high when flow rate increased up to 120ml/hr and show high surface roughness across the feed. But during variation of nozzle distance SN ratio decrease with increase its value and show high surface roughness at 70mm.

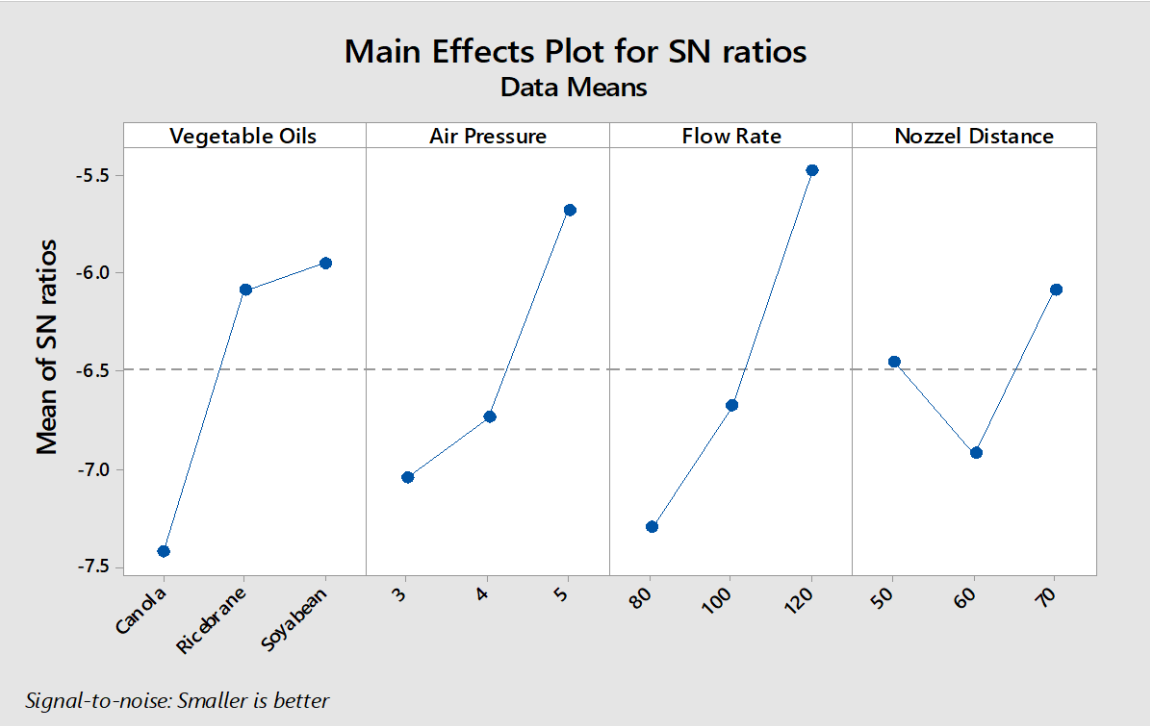


Figure 5: Main Effect Plot of Data Means for Surface Roughness cross

Analysis of Variance (ANOVA) for Surface Roughness

Initial Analysis of Variance for S/N Ratios

ANOVA is a way to accept the alternate hypothesis by rejecting other. The main reason behind using ANOVA is to analyze how different parameter affects the surface roughness. After evaluation of results degree of freedom is 8 while residual error comes as zero.

ANOVA for S/N Ratio of Surface Roughness cross the feed

Source	DF	Adj SS	Adj MS	F-Value	P-Value
vegetable oils	2	16.6088	8.3044	*	*
air pressure	2	24.0387	12.0193	*	*
flow rate	2	0.0757	0.0378	*	*
nozzle distance	2	0.5528	0.2764	*	*
Error	0	*	*		
Total	8	41.2759			

Pooled Analysis of Variance for S/N Ratios

Pooled ANOVA for S/N Ratio of Surface Roughness

Source of variation	Degree of freedom	Sum of squares	Mean squares	F	Status	Percentage contribution
Vegetable oil	2	28.749	14.375	4.8	Significant	56.44
Air pressure	2	6.742	3.371	1.12	Insignificant	13.23
Flow rate	0	9.458	4.729	1.4	Insignificant	18.57
Nozzle distance	2					

Residual error	**2**	**5.980**	**2.990**			**11.74**
Total	**8**	**20.929**				**100**

The above given table depicts the pooled ANOVA test for the SN ration of normal forces. In this table F represents the significant process parameters on desired performance characteristics. If the f- value is high then the results are more optimal. The F-value of vegetable oil is high and f-value of air pressure is low. The residual error in overall is 11.74%.

Optimum Set of Parameters for Surface Roughness

The table given below represents the best optimal results among all parameters such as vegetable oils, air pressure, and nozzle distance.

Table 4: Optimum Level and Optimum Value

Factor	Highest Mean S/N Ratio	Optimum Level	Optimum Value
Vegetable Oil	**-5.94**	**3**	**Soybeans oil**
Air Pressure	**-5.67**	**3**	**5 Bar**
Nozzle distance	**-6.084**	**3**	**70 mm**

Surface Roughness (Across)

We see that in the above graph about temperature production which is very less in flood cooling but it increases its surface roughness as compared to the MQL process. Surface roughness across a feed is very less during MQL because of less production in cutting forces. Surface roughness is actually directly related with the grinding forces. If grinding forces will increase, surface roughness will also increase. We can see values of surface roughness across the feed with different machining processes in the given graph.

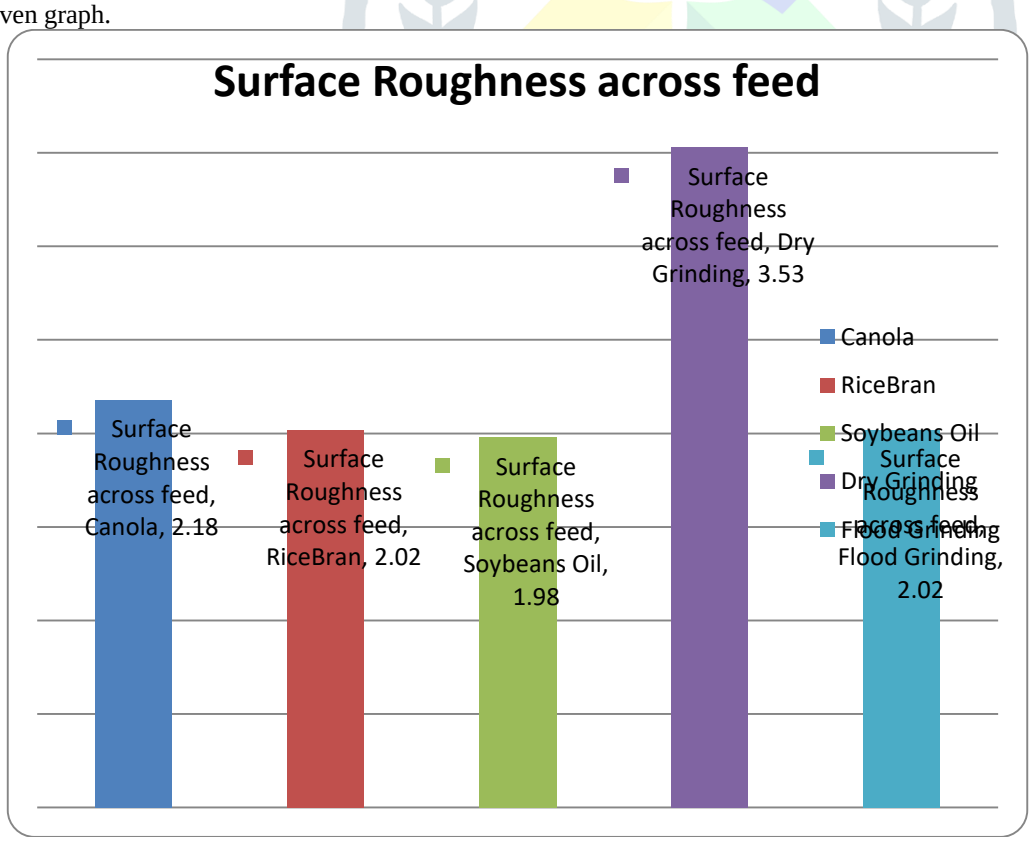


Figure 6: Chart of Surface Roughness across a feed v/s Lubricant/Coolant

According to the given graph values of surface roughness is very high in dry machining process with a value of 3.53 while it is very low in soyabean oil because of their high viscosity. Viscosity always helps in reduce friction forces which help in reduction of grinding temperature. Values of surface roughness across feed-in soybean oil is 1.98 which is very less in a comparison to others.

II. CONCLUSIONS

From the present research it was concluded that:

• Among all the oils used in the experiment soya bean oil an optimum oil for lubrication which gives better surface roughness. The nozzle distance of 70 mm is optimum for the better surface roughness quality to maintain the proper temperature and getting better results. At this distance nozzle spray the proper liquid on working zone.

• MQL vegetable oils are acceptable as less hazard and environment friendly fluids as compared to conventional fluids and it's cost is less then flood type coolants .

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