Waste cooking oil as a bio-cutting fluid in turning operation

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Abstract: - In this study, waste cooking oil is used as a bio-cutting fluid in a turning operation. The minimum Quantity Lubrication (MQL) technique is implemented while machining operation. Aluminium rods are chosen for the surface finish test. The experiments are conducted on a CNC milling machining and the experiments are performed at different spindle speeds (300, 500, 700 and 1000 rpm) and depth of cuts (0.1 and 0.2). Furthermore, the waste cooking oil is injected into the workpiece using MQL setup at different pressures (1bar, 1.5 bar and 2 bar). From the experimental trails, it is observed that at 1000rpm and 0.1 depth of cut, the smooth surface finish is observed for an aluminium rod when compared to dry and other conditions.

Key Words— ***Cutting fluids, Tribological Properties and Waste Cooking Oil.***

I. INTRODUCTION

Due to its superior lubrication qualities and a very small amount of cutting fluid, MQL, or Minimum Quantity Lubrication, is gradually receiving interest from researchers across the globe. MQL has a number of benefits[1], including improved tool life and surface quality. A typical MQL uses an atomised lubricant and high-pressure liquid between 2 bar and 5 bar pressure. When combined with the high-pressure air, the atomised lubricant, which has a particle size in the micron range, effectively penetrates the cutting zone. Thus, employing the MQL process for machining offers more lubricity than using the traditional flood cooling method. MQL usually uses lubricant at a rate of 50 ml/hr to 200 ml/hr. Depending on the configuration employed, a MQL setup consists of a spray nozzle in which the atomised lubricant is blended either internally or externally. Researchers tested the MQL approach for various machining techniques and discovered that it was superior to the traditional flood delivery way of cutting fluid supply.

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When compared to conventional flood cooling, MQL technologies have shown in high-volume automotive powertrain manufacturing to lower operating expenses, energy use, and waste while also lowering capital and operating costs. As a result, MQL is being used more frequently in big structural applications like airframes and the machining of automotive powertrains. In order to give readers with a comprehensive and useful understanding, this page summarises MQL on a number of subjects based on both academic and industrial experience. Implementing MQL involves many different aspects, such as delivery systems, cutting tools, machine tools, and optimum settings. This implies that the development process calls for the combined efforts of tool designers, machine tool manufacturers, MQL system developers, and end-users (manufacturers and engineers). Despite the history of success of MQL, many principles, especially the microscale lubrication mechanism, are still only partially understood. It is urged that future research focus on tying fluid mechanics to machining mechanics and enabling a systematic development as opposed to the creation of individual MQL components. The worldwide industrial sector will be severely impacted by MQL's full adoption. The ultimate objective is to establish a productive atmosphere that is clean, sustainable, and highly effective.

The following tribological characteristics of fluid application in MQL mode at the cutting zone are possible: By chilling the chip's underside, MQL machining reduces the chip up curling radius. The droplets reduce overall contact friction by forming a thin fluid layer at the chip-tool interface.

Additionally, it reduces chip-tool contact pressure. The MQL machining's lubricating effect speeds up chip flow. The following thermal features of the fluid application in MQL mode at the cutting zone: In comparison to flood cooling, MQL reduces the temperature at the chip-tool and flank-work piece interfaces. Due to evaporation, it increases the rate of heat transfer compared to conventional cooling.

Additionally, it lessens the pressure between the chip and the tool, which lessens heat production at the chip-tool interface. The quality of the liquid (droplet type), the density, viscosity, thermal conductivity, surface tension, and latent heat of vaporisation (liquid properties), the surface parameters (surface temperature, heat flux, and thermal conductivity), the flow parameters (flow rate and pressure drop across the nozzle), and the geometrical parameters of the spray nozzle all of which affect the droplets' cooling performance are some of the factors that affect it (orifice diameter, cone angle, and nozzle position)

With the advancement of industry 4.0 [2] there is a rapid transformation in the industrial sectors, epically in the manufacturing sectors. With the advent of technology, especially artificial intelligence (AI) [3] more focus has been given to the safety of the worker and provide environmental friendly working conditions. As the manufacturing sectors plays a significant role on the economy by their exports and imports. Environmental safety is also considered as a top priority at the manufacturing sector. Therefore, in this study the application of MQL with waste cooking oil is investigated. For this purpose, aluminum is chosen for machining operation.

II. METHODOLOGY

In this study, MQL technique is implemented to test the surface finish of the aluminium rod. Waste cooking oil is used as a bio-cutting fluid due to its availability and low cost[4-6]. The MQL set as shown in the figure.1 consists of air compressor unit and oil and pressurised air mixing unit. With the support of compressed air the bio-coolant can be delivered on the workpiece with varying pressures (1bar to 5 bar). In our experiments, we have varied the pressure from 2bar, 2.5 bar and 3 bar with the help of a throttle control fitted at the delivery end of the nozzle. The technical specifications of the MQL set is shown in the following table.1

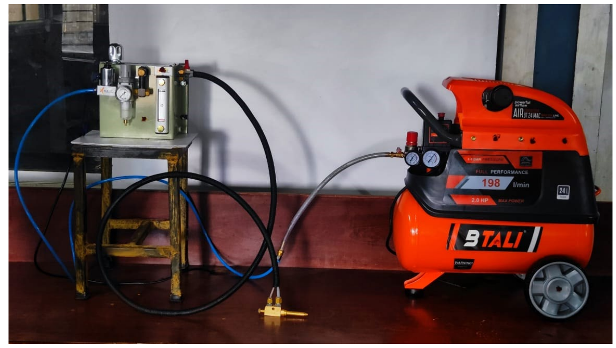

Fig.1. Used Cooking Oil

Table.1. Specifications of MQL setup

PARAMETERS	SPECIFICATIONS
Spray type	External jet micro mist spray.
Reservoir capacity	3 liters.
Tank type	Non-Pressurized.
Pipe length7 from Tank to each Nozzle	Std 2 meter Nylon pipe with guard
Operation Source	Compressed air supply.
Working air pressure	1.5 kg/cm2 to 3 kg/cm2
Maximum inlet Pressure	7 kg/cm2
Type of lubricant	Water based soluble coolant / mist oil.
Lubricant controlling	Control screw on nozzle block
Air controlling	Air control knob on filter regulator unit.
Lubricant / coolant drain	Manual.
Solenoid valve air inlet	230VAC

The main advantages of MQL are: The MQL concept promoted the idea that using cutting fluid as little as possible is extremely beneficial economically because it considerably reduces the expense of lubrication.The most effective method of delivering cutting fluid to the interface of a tool and work piece is MQL, also known as "Near-dry machining," "Small quantity lubrication," and "Micro lubrication.". The procedure that is followed in this study for calibration of the MQL setup as follows.

- Fill the MQL machine tank with the selected coolant.
- Then place the filled MQL machine on the digital weighing machine.
- Note down the weight of the filled MQL machine (initial weight).

- Now, set the MQL machine at the required pressure and open the nozzle (1/2 turn), turn on the stop watch and wait for certain time (120-180 sec).
- Note down the weight of the MQL machine (final weight) and calculate the readings in the discharge formula.
- Repeat the above procedure at required pressures.

The metal removal operations are performed on a CNC machine as shown in figure.2.

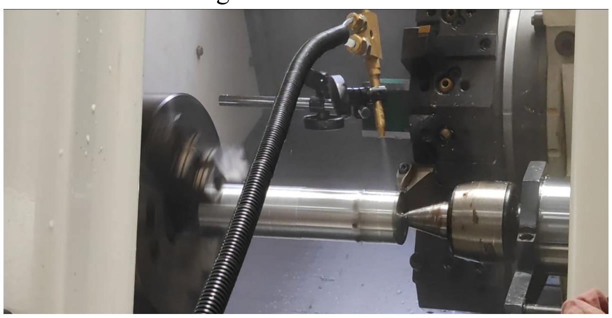

Fig.2. Used Transformer Oil

The MQL pressure calibrations are performed as shown in tables 2-4.

Table.2. At 2bar pressure.

NOZZLE TURN	INITIAL LOAD	FINAL LOAD	DIFFERENCE	TIME
½	5.700 kg	5.655 kg	0.045 kg	180 sec
½	5.645 kg	5.605 kg	0.04 kg	180 sec
½	5.600 kg	5.555 kg	0.045 kg	180 sec

Table.3. at 2.5 bar pressure

NOZZLE TURN	INITIAL LOAD	FINAL LOAD	DIFFERENCE	TIME
½	6.510 kg	6.480 kg	0.003 kg	120 sec
½	6.480 kg	6.450 kg	0.003 kg	120 sec

Table.4. at 3 bar pressure.

NOZZLE TURN	INITIAL LOAD	FINAL LOAD	DIFFERENCE	TIME
½	6.420 kg	6.385 kg	0.035 kg	120 sec
½	6.270 kg	6.230 kg	0.04 kg	120 sec

III. RESULTS AND DISCUSSION

The results of surface finish values are plotted in figures from 3 to 6 measured at varying spindle speeds of 300, 500, 700 and 1000 rpm. The results show that at low pressure, the surface finish appears to be good. The same can be evident from the 300 and 500 rpm plots.

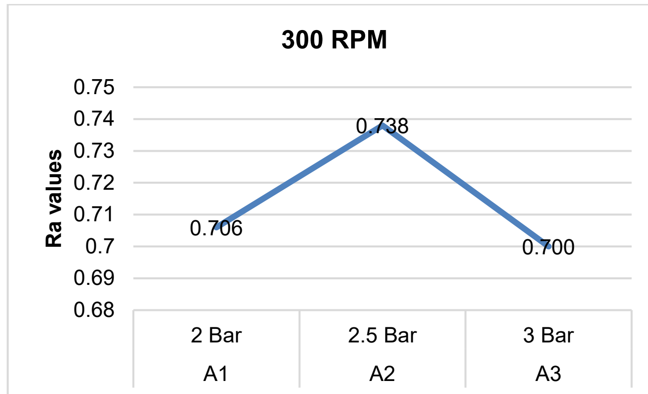

Fig.3. Surface finish at 300 rpm spindle speed.

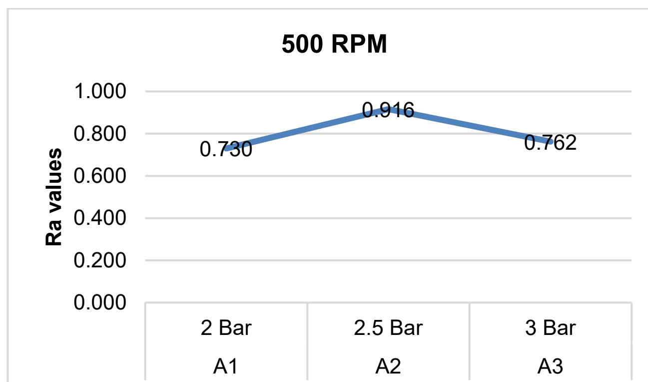

Fig.4. Surface finish at 500 rpm spindle speed.

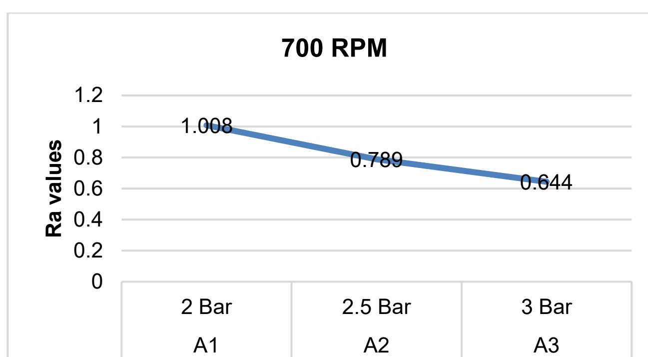

Fig.5. Surface finish at 700 rpm spindle speed.

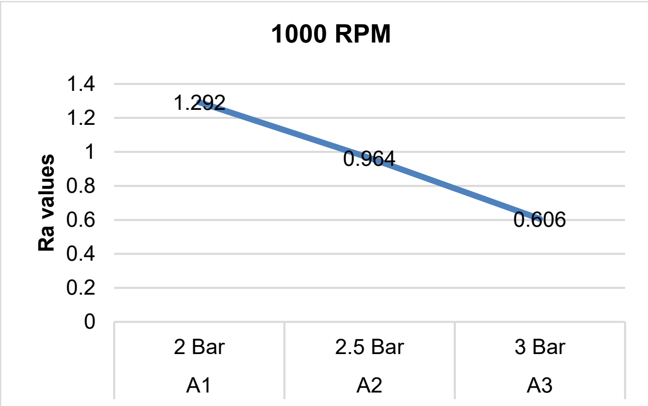

Fig.6. Surface finish at 1000 rpm spindle speed.

Table.5 represents the significant properties of waste cooking oil. The kinematic viscosity of the oil is 42.86, which shows that high viscosity helps in better lubrication and cooling property. Similarly, the flash and thermal conductivity are also high, which further helps better safety at the working environment.

Table.5. Charaterization of waste cooking oil.

Property	Units	Results
Thermal Conductivity at 30^{0}C	W/mK	0.192
Kinematic Viscosity at 40^{0}C	mm^2/sec	42.86
Density at 20^{0}C	Kg/m^3	910
Flash Point	^{0}C	230
Pour Point	^{0}C	-18
Specific Heat at 40^{0}C	J/g K	2.014
pH value	-	6.23

IV. Conclusion

Among the many techniques for applying coolant, minimum quantity lubrication (MQL) has recently received a lot of attention from researchers. This is because MQL uses improved spurting to inject a mixture of compressed air and cutting fluid instead of flood cooling, which reduces the usage of coolant. As it satisfies the requirements of "green" machining, the MQL approach has been shown to be appropriate. From the experimental results, it is concluded that MQL at low spindle speed yield better results than dry cutting. Furthermore, by utilising the waste cooking oil as a bio-coolant can eliminate the free dumping and control environmental pollution.

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