DESIGN AND FABRICATION OF MINIMUM QUANTITY LUBRICATION SYSTEM

Submitted in partial fulfillment of the requirements of the degree of

Bachelor of Engineering

by

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CERTIFICATE

This is to certify that the project entitled **"DESIGN AND FABRICATION OF MINIMUM QUANTITY LUBRICATION SYSTEM"** is a bonafide work of **Kunal Kuldip Pradhan (A-11), Abhishek Namaskar Kamble (A-12), Nihar Arun Nandanwar (A-20), Anshul Sandeep Kumbhare (A-47)** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **"Bachelor's of Engineering" in "Mechanical Engineering".**

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Project Report Approval Sheet

This project report entitled **Design and Fabrication of Minimum Quantity Lubrication System** by **KUNAL KULDIP PRADHAN (TU5F1920014), ABHISHEK NAMASKAR KAMBLE (TU5F1920015), NIHAR ARUN NANDANWAR (TU5F1920023), ANSHUL SANDEEP KUMBHARE (TU5F1920051) is approved for the Semester VIII Degree of Bachelor's of Engineering in Mechanical Engineering.**

Examiners: **1.___________________**

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Date:

Place:

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Minimum Quantity Lubrication (MQL) is a near-dry machining method that may be applied to reduce coolant usage in operations such as drilling, which cannot be performed completely dry. Although significant research has been reported on MQL, relatively little information on production applications and experience has appeared in the technical literature. Modern manufacturing industries are seeking different alternatives to attain the need of higher machining speeds, lower wastage and a better product quality as well as reducing the cost of the manufacturing process. The most common high-volume production application for MQL is cross and oil hole drilling on steel crankshafts. This report reviews MQL results for deep-hole drilling. The results show that MQL can yield tool life equivalent to gun drills at higher penetration rates under these conditions. This result is consistent with production experience with steel crankshafts, and shows that MQL may also be useful for cross and oil hole drilling of cast crankshafts. Limited test and production data for MQL machining of aluminum prismatics is also described

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Chapter 1

Introduction

The need for sustainable machining has been the main driving force behind the technology that minimizes cutting fluid consumption. Flood cooling is a common method used to extract heat from the cutting zone during the machining process. Flood cooling leads to increased consumption of cutting fluid and causes environmental concern. However, their application has some adverse effects, such as respiratory diseases among the workers, environmental concerns, and handling and disposal of the cutting fluids. In addition, as the cutting fluid is harmful to health, it is estimated that the cost of conventional cutting fluid accounts for up to 7- 17% of overall production costs. Therefore, there is a need to implement environmentally friendly lubrication strategies to overcome flood lubrication problems. Dry machining has been used as an alternative because of the disadvantages of flood cooling. However, dry machining allows for a narrow range of cutting conditions and is therefore not appropriate for industrial production in many cases. Different strategies are developed to apply cutting fluids in cutting zones to achieve sustainable machining among which MQL has been outstanding. Due to sustainability issues, MQL is preferred over flood cooling and dry machining.

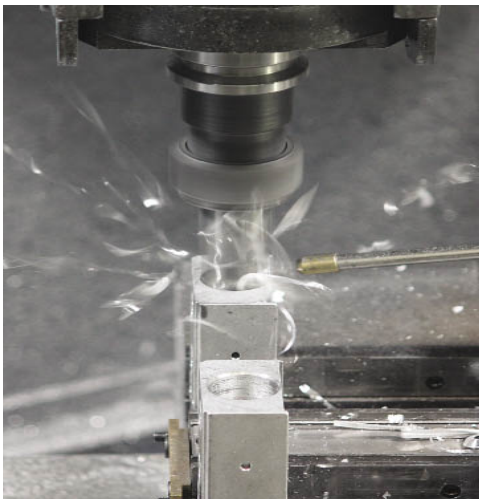

Fig No. 1 Use of MQL system while performing drilling operation

The MQL is a strategy of spraying a small amount of lubricant near the tool chip and/or the tool-work interface that provides the necessary lubricity/cooling, as shown in Fig. 2. Compared to conventional flood cooling, near dry or MQL machining can significantly reduce cutting fluid consumption and improved machinability compared to dry machining.

Therefore, MQL machining provides a link between conventional cooling and dry machining, and its use has been recognised as successful, especially at high speed and very hard machining. With the invention of new versions, e.g. multi-injection MQL the MQL is continuously improving.

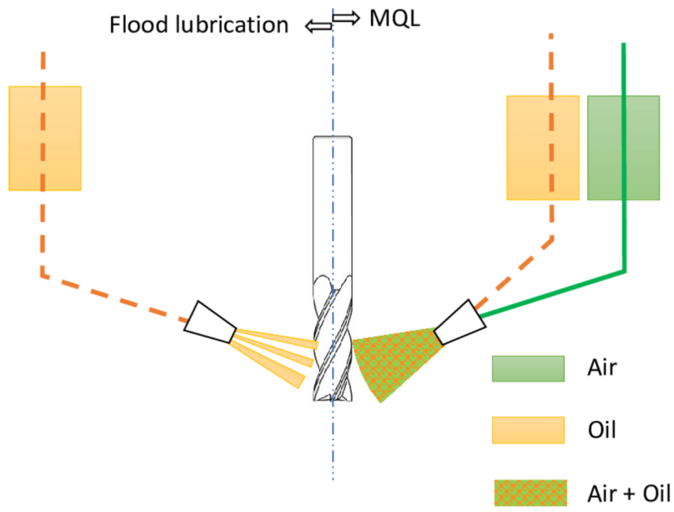

Fig No. 2 Flood lubrication v/s MQL

1.1 Advantages:

1. Improved Tool Life: The MQL system can extend the life of cutting tools by reducing wear and tear. It provides a thin film of lubricant that reduces friction and heat, which are the primary causes of tool wear.
2. Reduced Energy Consumption: MQL system requires less energy to operate compared to flood cooling systems. The reduced energy consumption translates to lower operating costs.
3. Reduced Environmental Impact: MQL system uses less lubricant compared to flood cooling systems, which reduces the amount of waste generated. This makes the MQL system more environmentally friendly.
4. Improved Surface Finish: MQL system can improve surface finish by reducing the amount of heat generated during machining. This reduces the likelihood of thermal distortion and improves the accuracy of the machining operation.

1.2 Disadvantages:

1. Limited Applicability: MQL system is not suitable for all machining operations. It is best suited for operations that require low to medium levels of lubrication.
2. Increased Complexity: MQL system requires additional components compared to flood cooling systems. This increases the complexity of the system and requires additional maintenance.
3. Cost: MQL systems can be more expensive to install compared to flood cooling systems. However, the reduced operating costs can offset the initial investment over time.

1.3 MQL in Machining:

Machining is any of several procedures that use a controlled material-removal process to shape and size a piece of raw material. The use of a coolant does not necessarily minimize tool wear because there is less tool wear under MQL circumstances, but the amount of coolant used determines the level of material adherence to the tool surface. Using cutting fluids in the machining process has a major impact on the tool and workpiece temperature and lubrication, resulting in extended tool life.

Machining is a controlled material removal process used to cut raw material into a desired shape and size. This process is collectively known as subtractive machining, and it involves the use of coolants to help cool the tool and workpiece, remove chips from the cutting zone, and protect the machine tool from corrosion. However, the use of cutting fluids in machining can present environmental problems and harmful effects to machine operators, as well as in the disposal of hazardous waste. The elimination of cutting fluids in machining operations is one solution to minimize environmental damage and associated costs. Alternatives such as dry machining and MQL can help achieve these objectives.

1.4 Principles of MQL:

Minimum Quantity Lubrication (MQL) is a method of lubrication in which a small amount of lubricant is used to lubricate the cutting tool and workpiece. The basic principle of MQL is to use a minimal amount of lubricant in order to reduce costs and improve environmental sustainability. The MQL system works by delivering a controlled amount of lubricant directly to the cutting zone using an air or oil mist.

The key principle of MQL systems is that they use a very small amount of lubricant to achieve effective lubrication. The amount of lubricant used in MQL is typically in the range of 5-100 ml/hour, compared to conventional flood or spray lubrication systems that can use several liters per hour. The lubricant is atomized into small droplets, which are then carried by a compressed air stream to the cutting zone. This results in a fine mist of lubricant that effectively lubricates the cutting tool and workpiece.

MQL systems are designed to be highly efficient and effective in providing lubrication to the cutting zone. They are typically used in applications where high-speed machining is required, such as in aerospace, automotive, and medical industries. MQL systems are also effective in reducing friction and heat generation in the cutting zone, which can improve tool life and reduce tool wear.

The principles of MQL systems can be summarized as follows:

1. Use a minimal amount of lubricant: MQL systems use a small amount of lubricant to achieve effective lubrication. This reduces costs and improves environmental sustainability.
2. Atomize the lubricant: The lubricant is atomized into small droplets, which are then carried by a compressed air stream to the cutting zone.
3. Direct lubricant delivery: MQL systems deliver lubricant directly to the cutting zone, which improves lubrication efficiency and reduces waste.
4. High-speed machining: MQL systems are effective in high-speed machining applications, where conventional flood or spray lubrication systems may not be effective.
5. Reduce friction and heat generation: MQL systems are effective in reducing friction and heat generation in the cutting zone, which can improve tool life and reduce tool wear.

Overall, the principles of MQL systems are focused on achieving efficient and effective lubrication in machining operations while minimizing the use of lubricant and reducing environmental impact.

1.5 Problem Definition:

The major challenges faced by the manufacturing industry are improved quality, enhanced productivity as well as economic production. While dealing with these issues, one of the predominating challenges is the mitigation of excessive heat generated in the cutting zone. Hence it is essential to maintain this cutting temperature at such an optimum level so as to attain superior surface finish and overall machining economy in terms of longer tool life and productivity. In flood cutting, because of lubricant, there is the problem of disposal and more maintenance and it is an expensive process. Due to these issues of using fluids in machining that need to be solved, then, minimizing the use of cutting fluids can be considered an economic stimulant. These problems posed by conventional coolants and lubricants can be addressed by the application of minimum quantity lubrication (MQL) using vegetable oil as the base fluid instead of conventional emulsion flood cooling.

1.6 Objectives:

The main objectives are:

1. Minimize the flank wear.
2. Increase and enhance Tool life and surface finish.
3. Reducing the cost and wastage of lubricant.
4. Making an initiative towards sustainable manufacturing.

1.7 Limitations:

1. MQL does not have comparable chip evacuation abilities to those of wet machining.
2. It is still not well suited for deep-hole drilling, energy-intensive processes such as grinding and other special operations like small-hole drilling, or for difficult-to-machine materials such as titanium and nickel-based alloys.
3. It will not prevent corrosion on either chips or parts.
4. Its implementation may require changes to the machine tool and processing strategy.

Chapter 2

Literature Survey

In machining, there is a high temperature in most of the functions because of friction between working and cutting tools. The high temperature at the workplace is very dangerous. Moreover, high temperature harms various types of machines such as it reduces the lifetime of the cutting tool. Its effect is also included in a workpiece. So to get rid of this problem, we use a high amount of cutting fluid. Because cutting fluid reduces the temperature. As a result, cutting tools and workpieces get a long life. With the growing demand for higher productivity and product quality in both machining the need for use of cutting fluids are becoming more intensive. The conventional types and methods of application of cutting fluid have been found to be much less effective under high productive machining. Besides that the vicinity becomes dirty and the environment becomes severely polluted by the harmful gasses, smokes and fumes generated due to heating and boiling of the cutting fluids. In this hard situation MQL provides a successful process in achieving a clean and pollution free environment in and around the machining places.

There are 3 different cooling systems in Machining Technique:

1. Dry Machining.
2. Conventional Flood System
3. MQL system

Dry Machining: Dry machining requires no cutting fluid thus it is considered the cleanest manufacturing technique. In dry machining, the machining components like the workpiece material, cutting tool as well as machining process parameters must be considered very carefully for successful operation. Rate of heat generation during machining is considerably more due to which cutting temperatures remain very high during machining. As a result, it can damage the tool which reduces the tool life and also affects the product quality and surface finish. Nevertheless, this method is also dangerous to human health.

Conventional Flood System (Wet Machining): In this machining appropriate cutting fluid is present due to which heat generation is reduced compared to dry machining. Proper fluid system must be installed with the machine tool for controlled delivery of cutting fluid. Additional accessories like storage tank, pump, pipeline, nozzle, recycle system, etc. are required. So the machine becomes heavy and bulky.

MQL Machining: C.P. Khunt, et al. (2021) found that vegetable-based MQL can be considered as an effective alternative compared to flood cooling to enhance the performance of drilling [1]. **Pralhad B. Patole, et al. (2021)** studied and compared the variation of surface roughness with varying speed and feed rates [2].

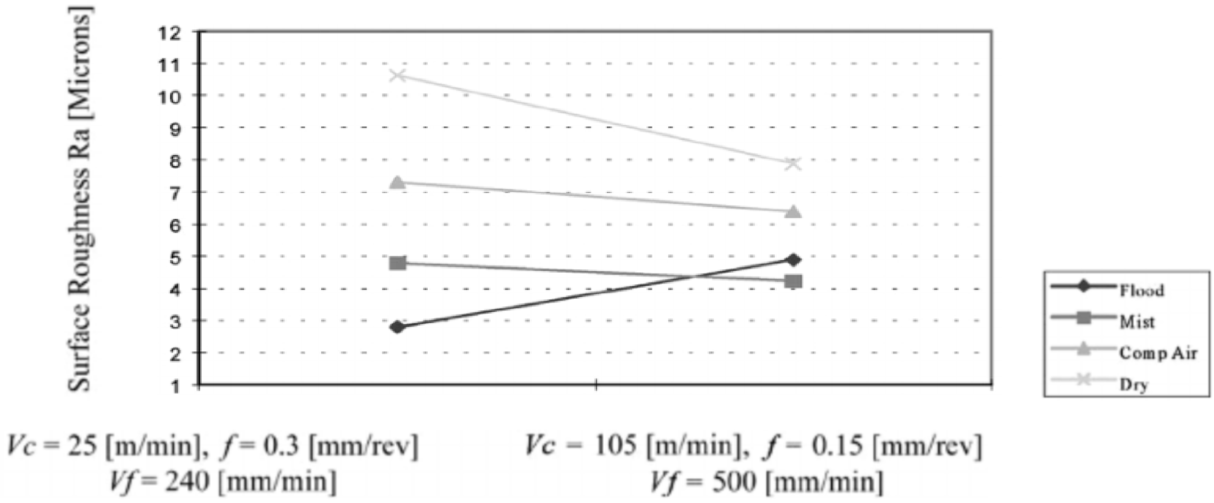

Fig No.3 Comparison of Surface Roughness and Varying Speed and feed rate

Table 1 shows the comparison of average values of surface roughness against varying speeds and feed rates.

Table 1 Comparison between Wet Machining and MQL Machining

Wet Machining	**MQL Machining**
This is the standard method.	Increased Cutting Speed
Extremely High Cooling Lubricant Requirement	Lower System Investment
High Process Cost	Improved Chip Evaluation
Costly recycling and disposal	Environmentally-friendly Process
	Clear Reduction in Process Costs

Low cost, simple installation, and the ability to deploy conventional tools are the key advantages of using external nozzles. However, there are several disadvantages too. Nozzles have to be manually adjusted and positioned in ways that do not interfere with the tool or other moving parts in or around the machine. They may need to be adjusted to accommodate different lengths and sizes of tools. The output from a single nozzle cannot completely cover the circumference of a tool because of shadowing effects. There are also losses due to the dispersion of the lubricant as it is delivered to the work piece. In cases where the cutting edge is embedded or hidden, such as when deep hole drilling, it is often wholly inadequate.

Types of MQL Feed:

1) External Feed
2) Internal Feed

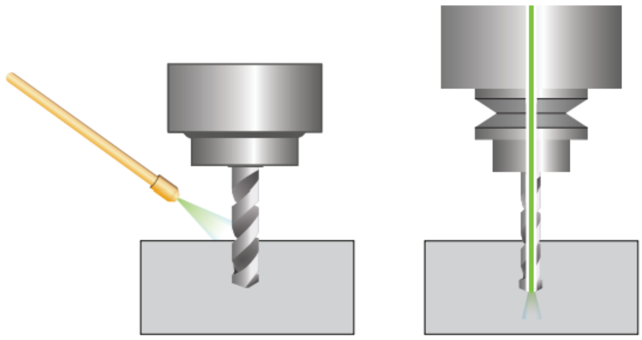

Fig No.4 External Feed and Internal Feed

Internal Feed:

1. Allow direct supply of the lubrication to the working zone.
2. The lubricant must be channeled through the tool revolver, the spindle or any other tool being used.
3. The machine components designs are significantly influenced by the operation of the minimum quantity lubrication system.
4. Internal feeds are applied when the external feeds are no longer feasible such as when drilling with large L/D ratio.

External Feed:

1. Lubrication is usually applied via spray nozzles surrounding the circumference of the tool.
2. The devices usually transport the lubricant and atomize it at the contact point.
3. There are two technologies in use whose key differences are in lubrication transportation.
4. Devices with metering pumps, and oil droplets target bombardment.

5. Device with Pressure tank.

The minimization of cutting fluid also leads to economic benefits by way of saving lubricant costs and cycle time for cleaning workpiece, tool, and machine.

A. S. Awale et al. (2020) studied and researched on the multi-objective optimization of MQL mist parameters for eco-friendly grinding and found that the nozzle angle significantly affected the MQL grinding process. Effective mist performance was observed at a nozzle angle of 12° with a horizontal reference plane. The average droplet size was observed to be 51.03 μm under optimal spray conditions [3]. **Ahmad Sultan et al. (2019)** studied the effect of using TiAlN and TiSiN coated carbide drill bits as cutting tools with MQL in drilling of austenitic stainless steel using refined palm olein (RPO) as lubricant/cutting fluid found that tool condition (new or worn tool) affects the surface roughness of the machined surface [4].

Munish Kumar Gupta, et al. (2018) studied the machining of hardened steel using different cooling lubricants and found that a lower cutting temperature is attainable at a lower cutting speed and feed rate; and the cutting depth exhibited insignificant effect and the enhanced heat transfer by oil droplets in MQL may be responsible for this significant temperature reduction [5]. **S. Sartori, et al. (2018)** studied the Solid Lubricant-assisted Minimum Quantity Lubrication and cooling strategies to improve Ti6Al4V machinability in finishing turning and reported that the simultaneous cooling and lubricating capacities of the SL-assisted MQC strategies guaranteed the lowest tool wear in terms of both crater and nose wear with very slight differences as a function of the graphite content [6].

W. Safiei, et al. (2018) found that MQL parameters have remark-able effects to the machining performance. There are few parameters of MQL that should be controlled when employing the MQL system in supplying lubricant into the cutting zone. Thus, it is important to determine the best combination of MQL in attempts for maximizing machining performance [7]. **R. Ramana, et al. (2015)** studied the performance evaluation of vegetable emulsifier-based green cutting fluid in turning of AISI 1040 steel and found that a new class of green cutting fluids was developed using vegetable-based oil and emulsifier [8]. **Sayuti, et al. (2014)** reported that MQL technique improves the tool-life and surface characteristics by lowering the cutting temperature and ensuring favorable changes in the cutting zone [9].

Hadad and Sadeghi (2013) applied MQL in turning operation and compared the results to dry and flood cooling in terms of machining forces, sur- face roughness, and temperature distribution. MQL resulted in improved machining performance by reducing the cutting forces and retaining the cutting edge of the tool and thus reduced cutting temperatures [10].

Nikhil Ranjan Dhar (2007) studied and found that surface finish and dimensional accuracy is improved mainly due to the reduction of wear and damage at the tooltip by the application of MQL [11]. **Nikhil Ranjan Dhar (2006)** studied the role of minimum quantity lubrication (MQL) by vegetable oil on cutting temperature, chip formation mode and cutting forces in the machining of AISI-1060 steel at industrial speed-feed combinations by uncoated carbide insert. The results include a significant reduction in cutting temperature such reduced temperature along with a reduction in chip-tool contact length and favourable chip-tool interaction also provides a significant reduction in cutting forces [12]. **Kelly and Cotter (2002)** have done experimental work on material aluminium alloy in MQL mode. By using cutting speed, feed rate and depth of cut process parameters they have analyzed response variables cutting temperature and chip morphology. By carrying out the experimental work the researchers found that at a lower feed rate better surface roughness can be achieved [13].

Gressel, et al. (2001) investigated the comparison of conventional flood lubrication with micro lubrication in machining performance [14]. **Kwon P. (2000)** studied flank wear by incorporating cutter temperature and physical properties of coating and work materials. He stated that use of cutting fluid has a positive impact on flank wear but the flood cooling method also reduces the effectiveness of the cutting fluid as too little amount of the cutting fluid reaches the tool workpiece interface. Thus it is recommended that a proper amount of cutting fluid as well as certain attributes of the cutting fluids is also necessary to provide the required cooling during the machining process [15].

Satoshi Ito et al. (1997) found that proper selection and application of cutting fluid generally improves tool life. At low cutting speed almost four times longer tool life was obtained by such cutting fluid [16]. **Machado & Wallbank, etl al. (1996)** found that in the initial stages of MQL development low quantities (such as 200 – 300 ml/hr) of lubricants were used in machining. These low quantities were applied in fast flowing air streams. It was proved that MQL was more efficient when low cutting speeds and high feed rates were used (i.e. cutting speed of 200 m/min and feed rate of 0.15 mm/rev) [17].

2.1 Research Gap:

In the Machining process previously, Dry System was introduced due to which the wear and tear was observed and the tool life was getting compromised. Lubrication process was much needed to solve this problem. Flood System was introduced to avoid wear and tear and tool damage but it was observed that there were no such parameters implemented for the flow of lubricants due to which excessive amounts of lubricants were wasted and also workshop maintenance was increased.

MQL was introduced in which the lubricants will flow only according to the limits set by the operator in mist form so that wastage of lubricants can be avoided and the lubricant can be reused. Currently, there is a wide-scale evaluation of the use of metalworking fluids (MWFs) in machining. Industries are looking for ways to reduce the amount of lubricants in metal removing operations due to the ecological, economical and most importantly occupational pressure.

Chapter 3

Methodology

Minimum Quantity Lubrication (MQL) is a near-dry machining method that may be applied to reduce coolant usage in operations such as drilling, which cannot be performed completely dry. Although significant research has been reported on MQL, relatively little information on production applications and experience has appeared in the technical literature. The most common high-volume production application for MQL is cross and oil hole drilling on steel crankshafts. Minimum quantity lubrication (MQL), where a very low amount of cooling and lubrication agent is implemented during the machining process, is able to reduce the cutting temperature and at the same time facilitates lubrication at the tool-work interface. Indeed, the MQL has shown superior performance over other notable fluid application techniques such as high-pressure coolant.

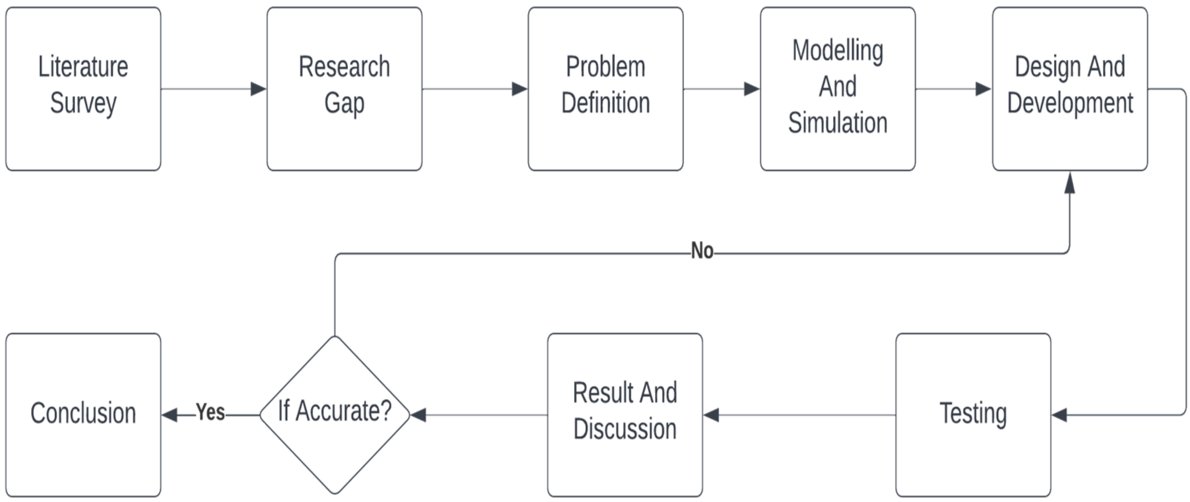

Fig No.5. Flowchart depicting the structural outline of the steps involved in designing and fabrication of the MQL system

3.1 Working of MQL System:

The MQL needs to be supplied at high pressure and impinged at high speed through the nozzle at the cutting zone. Considering the conditions required for the present research work and uninterrupted supply of MQL at a constant pressure of around 5 or 6 bar over a reasonably long cut, a MQL delivery system was designed, fabricated and used. The schematic view of the MQL setup is shown in Figure 6. In this system a compressor was used to supply air at a high pressure of 6 bar. This high pressure air from the compressor entered into two chambers, fluid chamber and mixing chamber at same pressure so that it prevented the reverse flow of the fluid. The fluid chamber is connected at the bottom with the mixing chamber by a very small diameter tube. The air and the oil were mixed in a mixing chamber so that the mixture of the oil and air impinged at a high velocity through the nozzle at the chip tool interface.

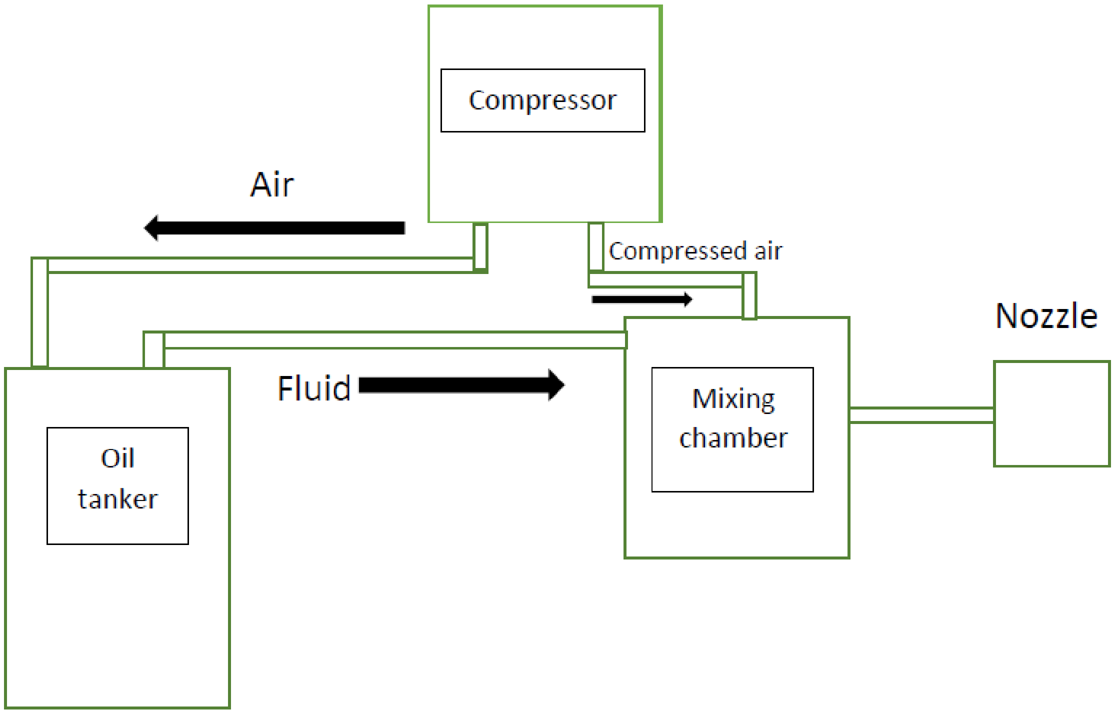

Fig No.6. Schematic View of MQL Unit

3.2 Components of the MQL System:

MQL offers a highly efficient alternative to traditional flood cooling methods by applying small quantities of lubricant directly to the cutting tool or workpiece interface. This approach significantly reduces the environmental impact of machining by minimizing fluid usage and eliminating the need for coolant treatment and disposal. The advantages of MQL are further enhanced when using biodegradable lubricants made from renewable plant-based oils. Considering these benefits, it is clear that MQL, coupled with an external supply system such as one or more nozzle systems, is the way forward for metal-cutting fluid lubrication. Compared to flood cooling methods, MQL typically uses 3-4 orders of magnitude less coolant, with as little as a few millilitres of lubricant being applied per minute. The working of the Minimum Quantity Lubrication setup is based on the following components:

1. Air Compressor
2. Nozzle
3. MQL System
4. Pressure Gauge and Flow Rate Control Valve
5. Connecting Pipes

1. Air Compressor:

An Air Compressor is a pneumatic device that converts power into potential energy stored in pressurized air. By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure. When the tank's pressure reaches its engineered upper limit, the air compressor shuts off. The compressed air, then, is held in the tank until called into use. When tank pressure reaches its lower limit, the air compressor turns on again and re-pressurizes the tank.

Fig. No. 7 Air Compressor

The table below shows the specifications of the Air compressor used.

Table 2: Specifications of the Compressor

Condition	New
Configuration	Portable
Brand Name	Delcon
Model	DL-350
Type	Direct Air Compressor
Voltage	220V
Current	6.6A
Power	3 HP
Tank Capacity	50L
Speed	2850 RPM
Frequency	50 Hz
Production Date	2021
Net Weight	28 kg
Pressure	8 BAR
Dimensions (L*W*H)	670*300*700 mm

2. Nozzle

A nozzle is often a pipe or tube of varying cross sectional area, and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.

Fig. No. 8 Nozzle

3. MQL System

The MQL System bears the oil or lubricant. This system can bear 3 litres of oil or lubricant. Its main function is to combine the oil inside with compressed air from the air compressor in order to produce a mist-like output.

Fig. No. 9 MQL System

4. Pressure Gauge and Flow Rate Control Valve

The device used for measuring pressure is called Pressure Guage. The Flow Rate Control Valve is used to regulate the flow rate at the output.

Fig. No. 10 Pressure Gauge and Flow Rate Control Valve

5. Connecting Pipes

The pipes are used to connect, the MQL System, air compressor, and nozzle to each other to form a complete system.

Fig. No. 11 Connecting Pipes

6. Flask

It is used to measure the amount of lubricant used.

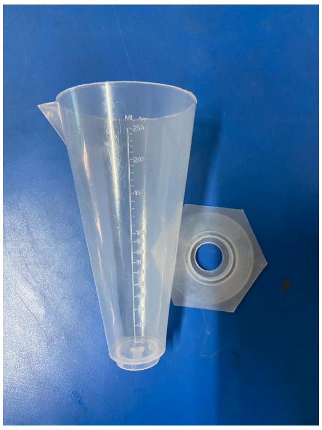

Fig. No. 12 Flask

3.3 Lubricant:

The lubricants used in the machining operations are Palm Oil and Soyabean Oil. The reason behind choosing these two oils is that they are edible oil without any synthetic components and they are eco-friendly as they do not cause any health-related problems.
The details of the oils are shown in the table below.

Table 3: Details of the oils used

Oil	Kinematic Viscosity (at 40 degrees Celsius) (in cSt)	Health Effects	Cost (INR)	Availability
Palm Oil	47.7	None	100/litre	Very good
Soyabean Oil	28.86	None	140/litre	Very good

3.4 Cost of the project:

The table below shows the cost of various components used in the project.

Table 4: Total cost of the project

Sr No.	Materials	Cost
1	MQL System with Nozzle and Pipe	13000/-
2	Compressor	11000/-
3	Palm Oil	500/-
4	Soyabean Oil	725/-
5	Digital Thermometer	120/-
6	Miscellaneous	2000/-
	Total cost	27345/-

3.5 Future Directions of MQL System:

The use of Minimum Quantity Lubrication (MQL) systems is gaining popularity in various industries due to their ability to reduce the amount of lubricant used and lower the environmental impact. However, there is still room for improvement and further research in this area. Some of the future research directions of MQL systems are:

1. Optimization of lubricant properties: The performance of MQL systems heavily depends on the lubricant properties. Future research can focus on developing lubricants with improved properties such as better thermal stability, higher lubricity, and lower viscosity. This can improve the efficiency of MQL systems and reduce tool wear.
2. Advanced cooling techniques: Although MQL systems are efficient in reducing the amount of lubricant used, they can still generate significant heat during machining. Future research can focus on developing advanced cooling techniques such as cryogenic cooling or air-cooling to further reduce the temperature rise and improve the surface

quality of the machined part.

3. Integration with Industry 4.0: The integration of MQL systems with Industry 4.0 technologies can provide real-time monitoring and control of the lubrication process. This can lead to improved process control and better quality assurance.
4. Biodegradable lubricants: The use of biodegradable lubricants can reduce the environmental impact of MQL systems. Future research can focus on developing biodegradable lubricants that offer similar or better performance compared to conventional lubricants.
5. Modeling and simulation: The use of modeling and simulation techniques can provide insights into the lubrication process and help optimize the MQL system parameters. Future research can focus on developing accurate models and simulation tools to predict the lubrication performance of MQL systems.

The MQL systems have the potential to revolutionize the lubrication process in various industries. Future research can focus on optimizing lubricant properties, developing advanced cooling techniques, integrating with Industry 4.0, using biodegradable lubricants, and modeling and simulation. These efforts can lead to further improvements in efficiency, quality, and sustainability.

Chapter 4

Design and Development

The MQL System is connected to the air compressor and the nozzle using the connecting pipes. The compressed air is used as an input to the MQL System which is carrying the lubricant. The Lubricant along with the compressed air is sent out through the nozzle in the mist form. The nozzle is pointed at the point of contact during the machining process to achieve proper lubrication.

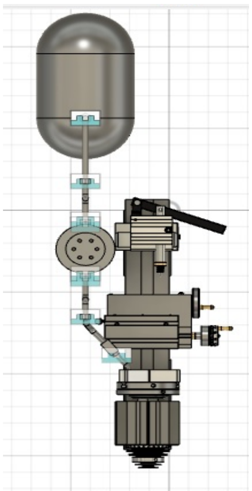

Fig.No.13 Top View of MQL System

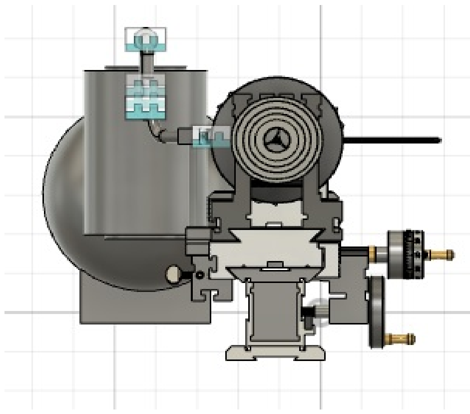

Fig.No.14 Front View

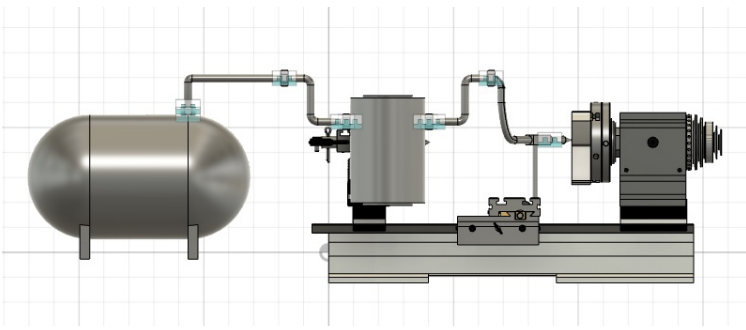

Fig.No.15 Left Hand Side View

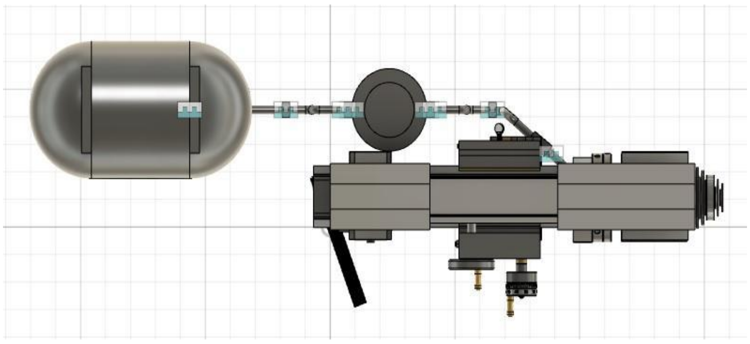

Fig.No.16 Bottom View

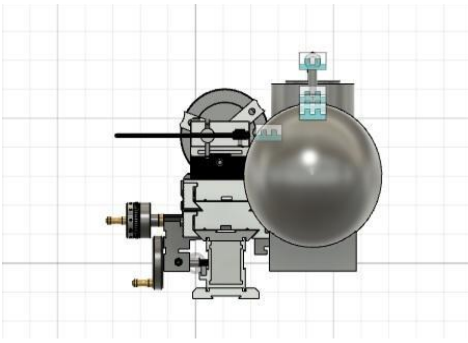

Fig.No.17 Back View

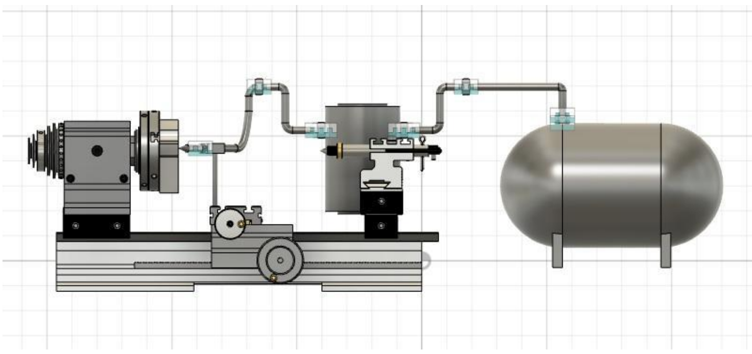

Fig.No.18 Right Hand Side View

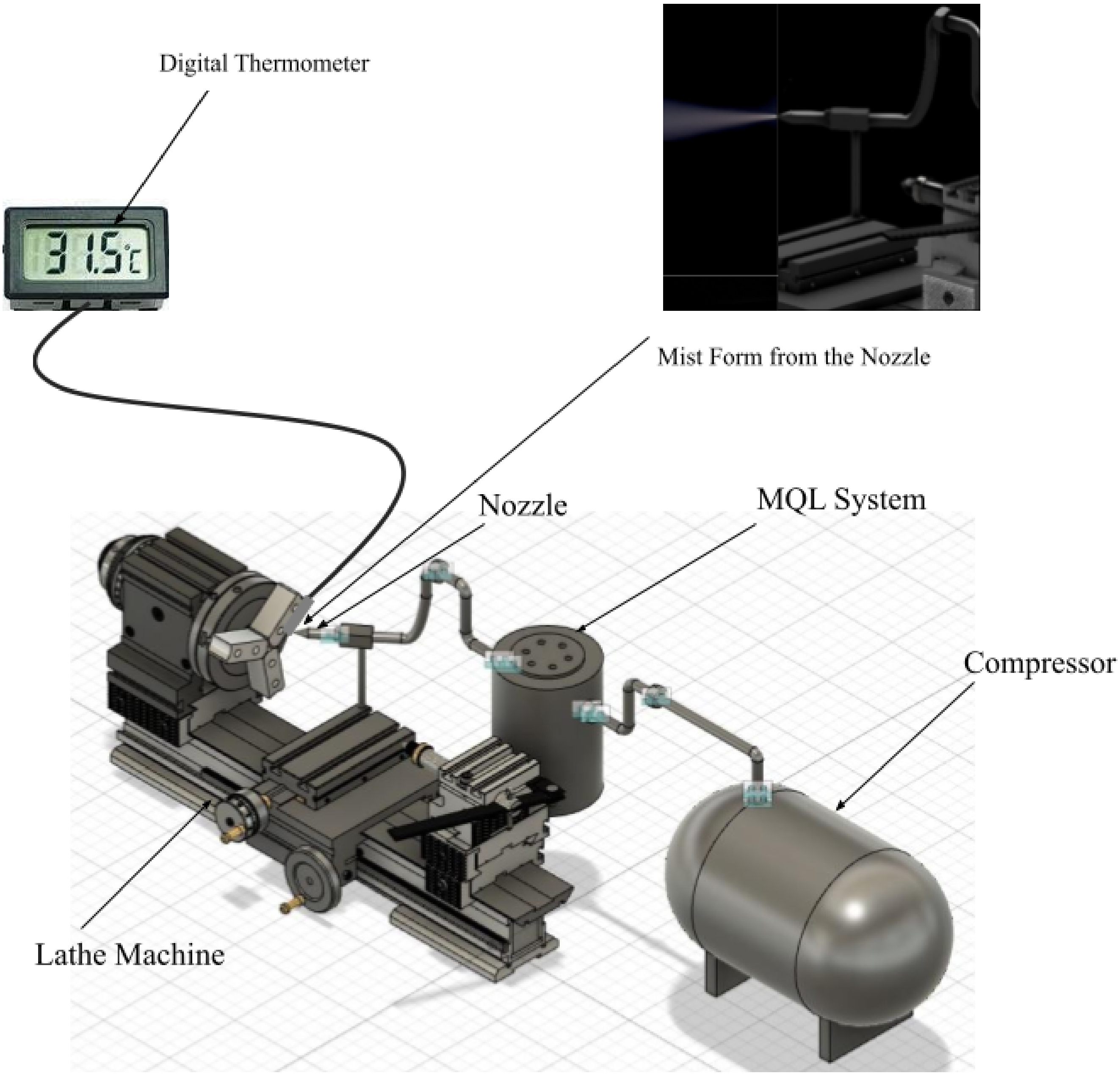

Fig.No.19 Detailed Orthogonal View

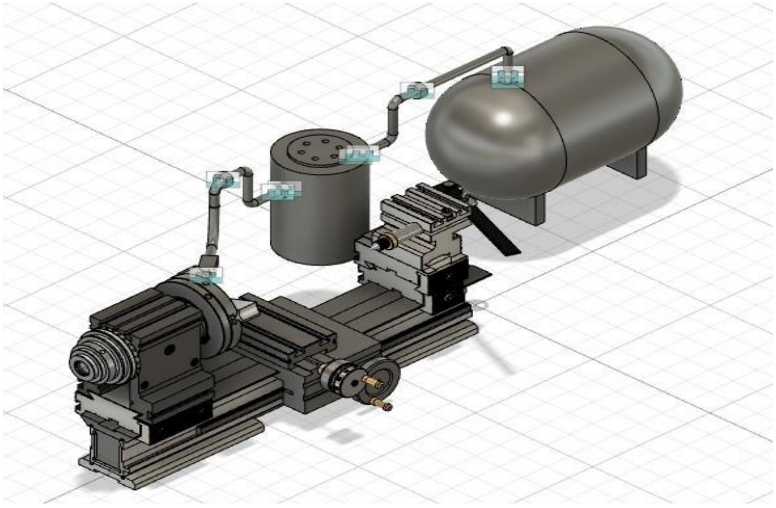

Fig.No.20 Isometric View

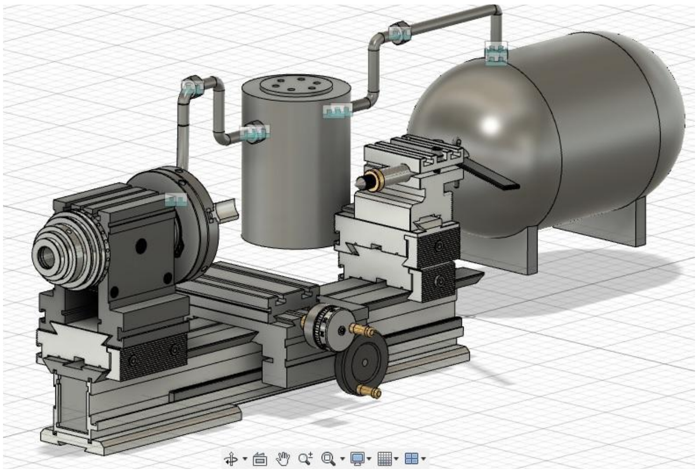

Fig.No.21 Oblique View

Chapter 5

Results and Discussions

In this chapter, the results of the testing conducted on the lathe machine with Dry Machining are compared with Minimum Quantity Lubrication. During the testing, aluminium and mild steel were used as the materials. The main objective of the experiment is to record the temperature using a digital thermometer during the operations. The lubrication is carried out by using two vegetable oils; Palm oil, and Soyabean oil. The reason for selecting these two oils is their availability and also there are no harmful effects and keeping the cost as a prime factor. The flow rate of the lubricants is constant for all the MQL operations carried out on both metals is 300 ml/hr. During the operations, we observed that the temperature of Mild Steel is higher than Aluminium due to Mild Steel being harder than Aluminium. Additionally, the MQL System allows us to control the area covered by the lubricant with a flow rate control valve.

The following table represents the temperature obtained after machining on the Aluminium and Mild Steel using Dry Machining.

Table 5: Temperature obtained using Dry Machining

(*The temperatures in the table are* in °C)

	Operations		
Material	**Facing**	**Turning**	**Drilling**
Aluminium	47.1	46.5	45.4
Mild Steel	68.8	55.3	51.3

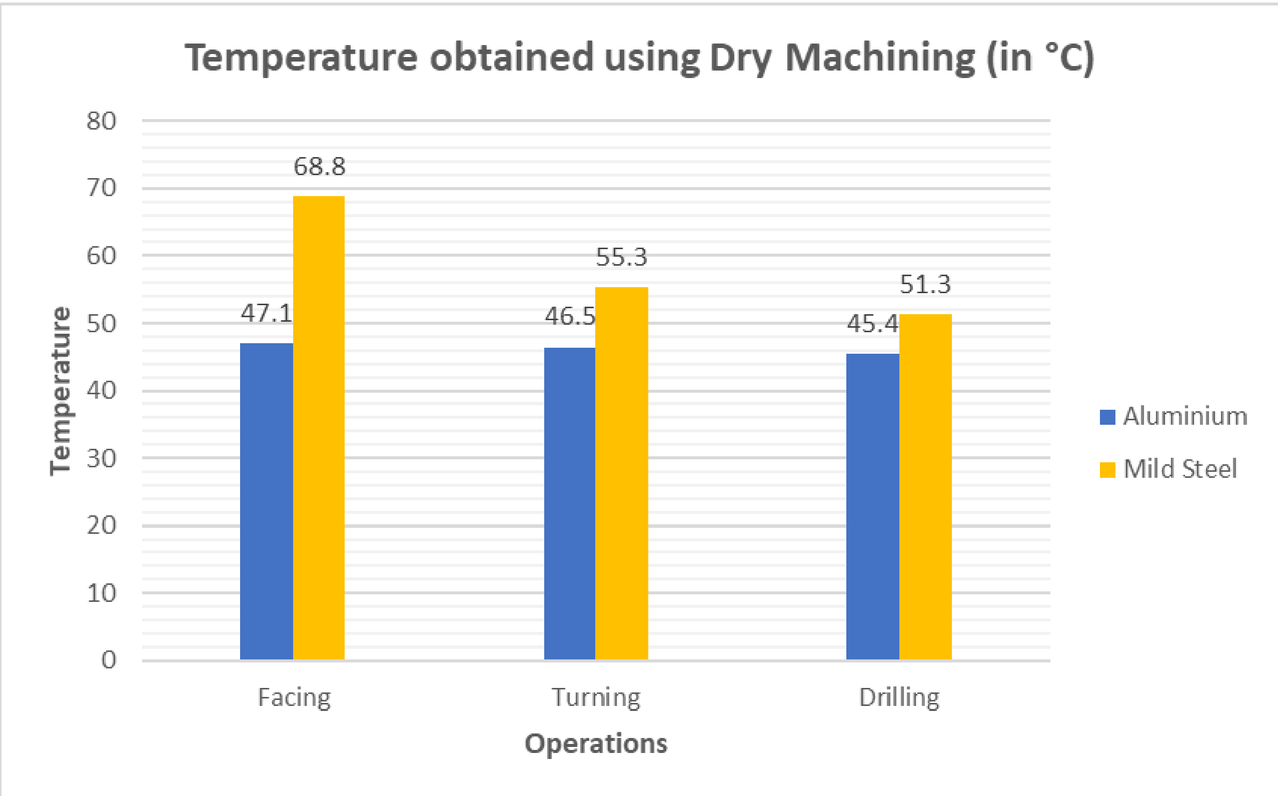

Fig. No. 22 Graphical Representation of Temperature obtained using Dry Machining

The following table represents the temperature obtained after machining on the Aluminium and Mild Steel using Palm Oil.

Table 6: Temperature obtained using MQL Machining with Palm Oil

(*The temperatures in the table are in °C*)

	Operations		
Material	**Facing**	**Turning**	**Drilling**
Aluminium	37.9	34.3	37.8
Mild Steel	53.9	50.5	46.3

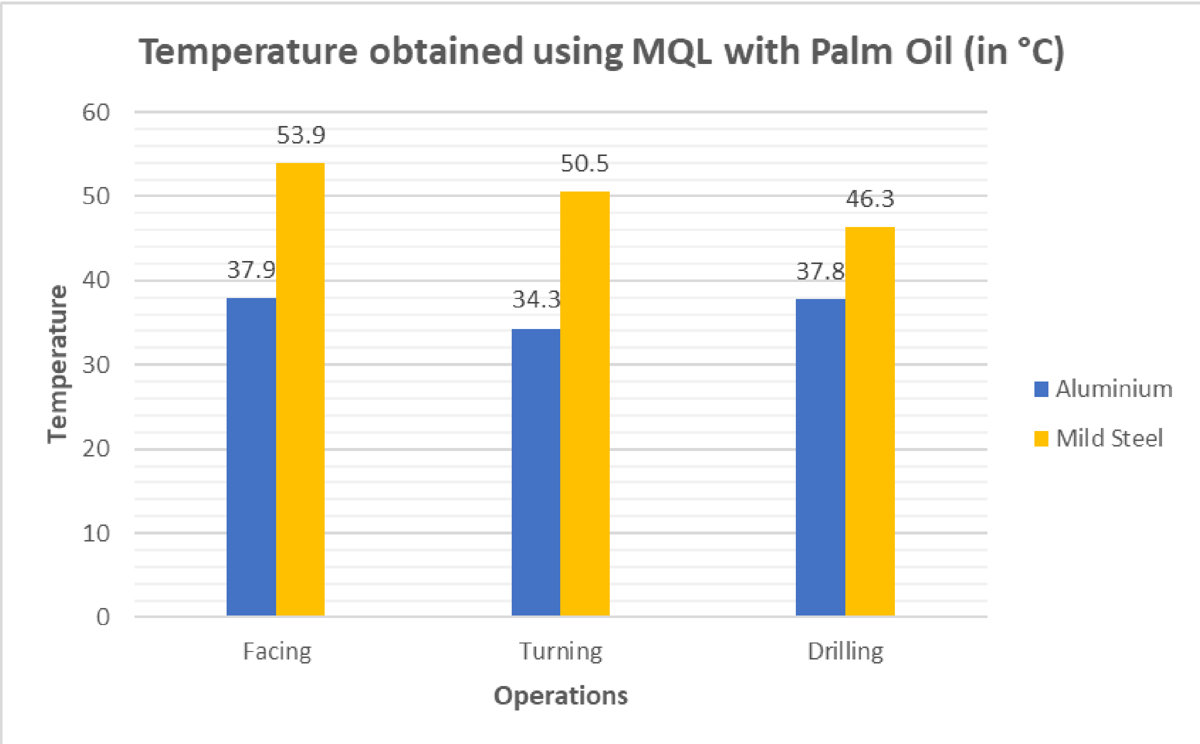

Fig.No. 23 Graphical Representation of Temperature Obtained using MQL Machining with Palm Oil

The following table represents the temperature obtained using Machining with Soyabean Oil.

Table 7: Temperature obtained using the MQL Machining with Soyabean Oil

(The temperatures in the table are in °C)

	Operations		
Material	**Facing**	**Turning**	**Drilling**
Aluminium	35.7	32.6	35.1
Mild Steel	51.8	47.7	43.9

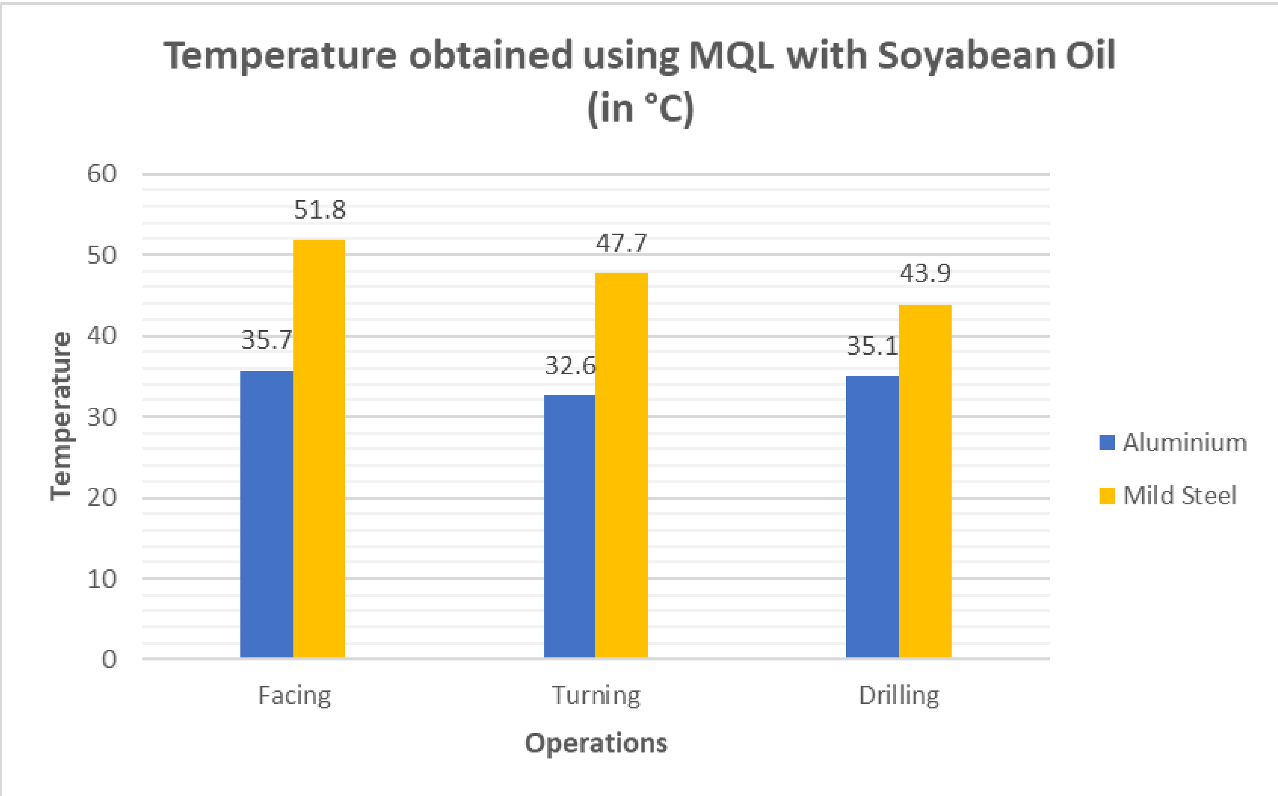

Fig.No. 24 Graphical Representation of Temperature obtained using MQL Machining with Soybean Oil

The following graph represents the variation of temperature in Facing using Dry Machining and MQL Machining with Palm Oil and Soyabean Oil.

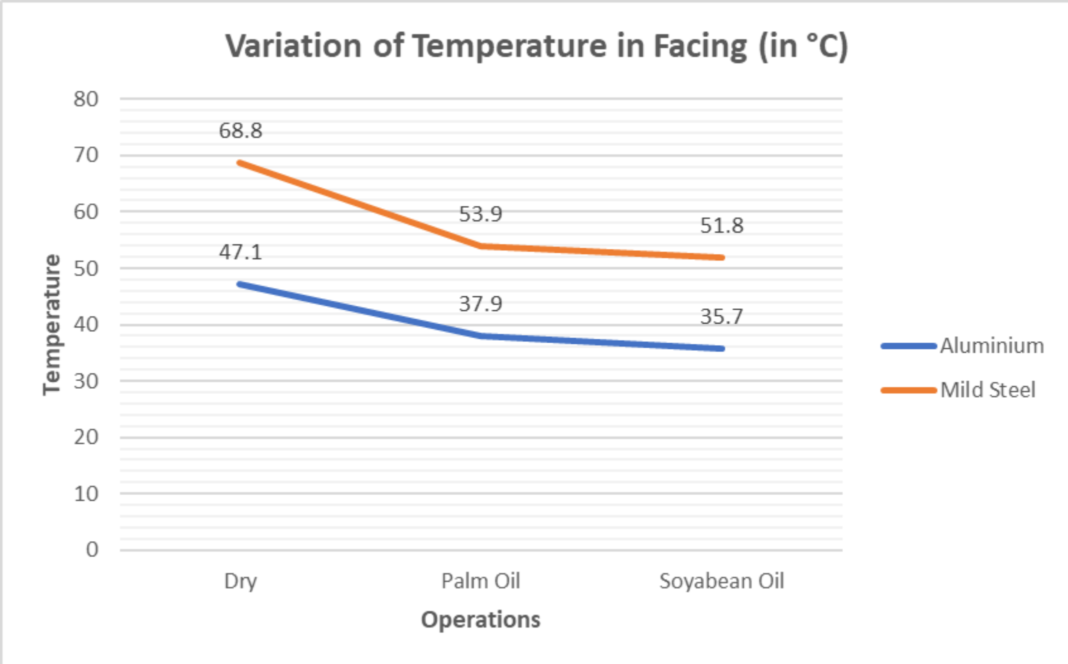

Fig.No.25 Graphical Representation showing variations in Temperature in Facing Operation

The following graph represents the variation of temperature in Turning using Dry Machining and MQL Machining with Palm Oil and Soyabean Oil.

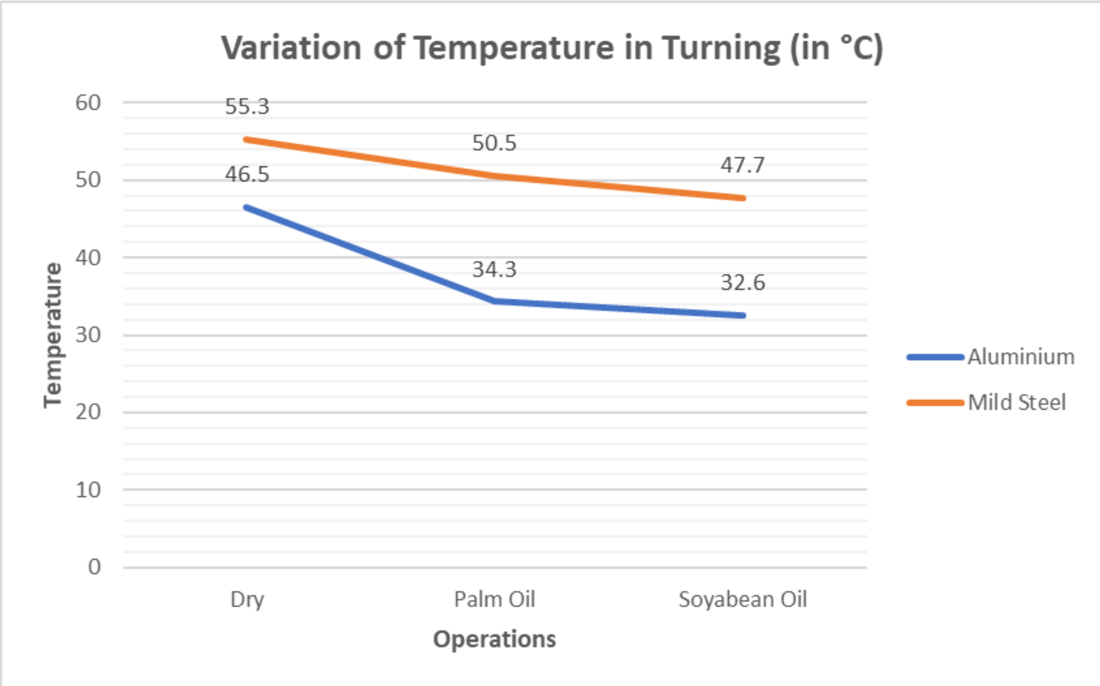

Fig.No.26 Graphical Representation showing variations in Temperature in Turning

The following graph represents the variation of temperature in Drilling using Dry Machining and MQL Machining with Palm Oil and Soyabean Oil.

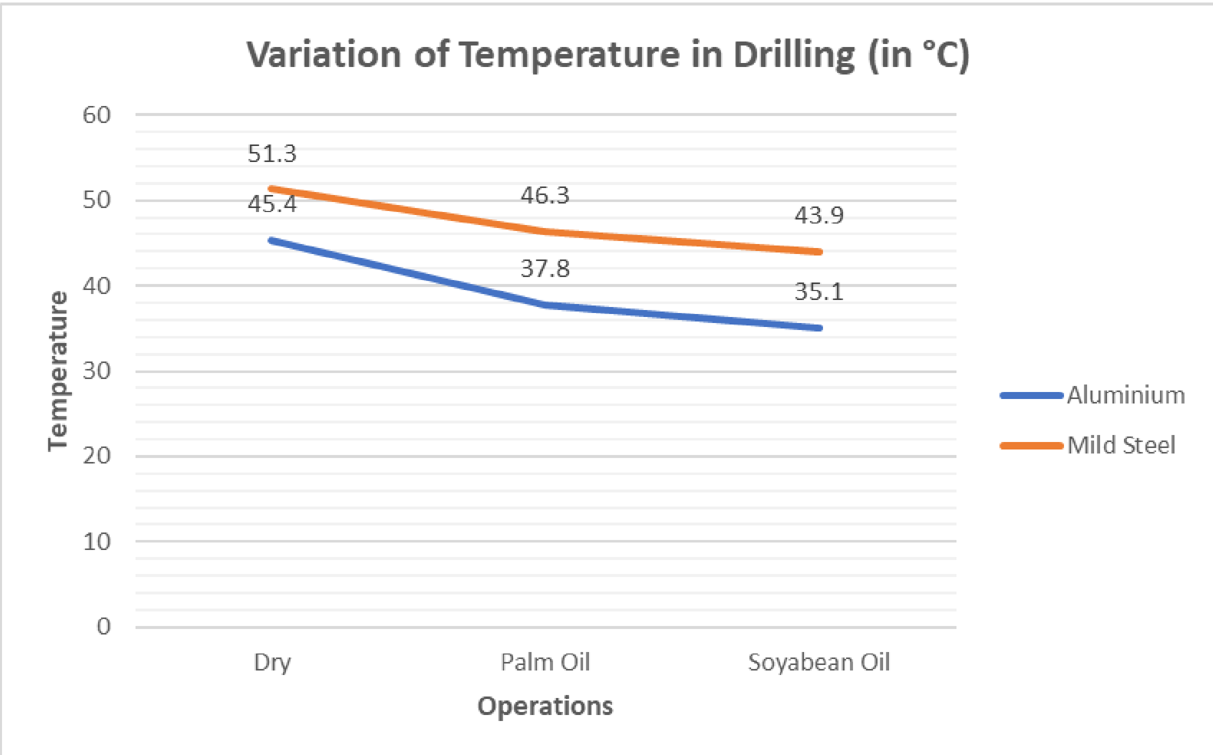

Fig.No.27 Graphical Representation showing variations in Temperature in Drilling Operation

Chapter 6

Summary

The main benefit of MQL is that it primarily focuses on improving the frictional behavior, therefore, controlling the heat generation at its source rather than just trying to remove as much heat as possible such as conventional cooling does. This results in improved tool life and good workpiece surface integrity. Minimum quantity lubrication (MQL) is one of the most promising machining techniques that can yield a reduction in consumption of cutting fluid more than 90 % while ensuring the surface quality and tool life. The significance of the MQL in machining makes it imperative to consolidate and analyze the current direction and status of research in MQL**.**

This literature clearly reveals that MQL systems provide better performance than dry machining. These researches show that the flood system can be replaced by the MQL system. MQL has reduced the cutting force, provided efficient cooling at the shear zone which reduces temp, provided proper lubrication and retention of tool sharpness for a long period of time.

References

1. C.P. Khunt, M.A. Makhesana, K.M. Patel, B.K. Mawandiya, 2021. Performance assessment of vegetable oil-based minimum quantity lubrication (MQL) in drilling, 44(1), 341-345.
2. Pralhad B. Patole, Vivek V. Kulkarni, Sudhir G. Bhatwadekar, 2021. MQL Machining with nanofluid: a review, EDM Sciences, Manufacturing Rev. 8(13).
3. Akash Subhash Awale, Meghanshu Vashista, Mohd Zaheer Khan Yusufzai, 2020. Multi-objective optimization of MQL mist parameters for eco-friendly grinding, Journal of Manufacturing Processes 56, 75–86.
4. Ahmad Zubair Sultana, Safian Sharif, Fethma M. Norc, Denni Kurniawan, 2019. Minimum quantity of lubricant drilling of stainless steel using refined palm oil: Effect of coating tool on surface roughness and tool wear, Procedia Manufacturing 30, 427–434.
5. Mozammel Mia, Munish Kumar Gupta, Gurraj Singh, Grzegorz Królczyke, Danil Yu Pimenov, 2018. An approach to cleaner production for machining hardened steel using different cooling-lubrication conditions, Journal of Cleaner Production, 187, 1069-1081.
6. S.Sartori, A.Ghiotti, S.Bruschi, 2018. Solid Lubricant-assisted Minimum Quantity Lubrication and Cooling strategies to improve Ti6Al4V machinability in finishing turning, Tribology International, 118, 287-294.
7. W. Safiei, M. M. Rahman, S. A. Rusdan, 2018. Experimental Investigation of MQL Optimum Parameters in End Milling of AA6061-T6 using Taguchi Method, International Journal of Engineering & Technology, 7 (4.35), 186-189.
8. R Srikant, V Ramana, 2015. Performance evaluation of vegetable emulsifier based green cutting fluid in turning of AISI 1040 steel- an initiative towards sustainable manufacturing, Journal of Cleaner Production.
9. Mohd Sayuti, Ooi Ming Erh, Ahmed A.D. Sarhan, Mohd Hamdi, 2014. Investigation on the morphology of the machined surface in end milling of aerospace AL6061-T6 for novel uses of SiO2 nano lubrication system, Journal of Cleaner Production, 66, 655-663.
10. Mohammadjafar Hadad, Banafsheh Sadeghi, 2013. Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy, Journal of Cleaner Production, 54, 332-343.
11. Nikhil Ranjan Dhar, Sumaiya Islam , Mohammad Kamruzzaman, 2007. Effect of Minimum Quantity Lubrication (MQL) on Tool Wear, Surface Roughness and Dimensional Deviation in Turning AISI-4340 Steel., G.U. Journal of Science, 20(2), 23-32.

12. Khan, M.M.A., Dhar, N.R., 2006. Performance evaluation of minimum quantity lubrication by vegetable oil in terms of cutting force, cutting zone temperature, tool wear, job dimension and surface finish in turning AISI-1060 steel, J. Zhejiang Univ. - Sci. A 7, 1790–1799.
13. J.F. Kelly, M.G. Cotterell, 2002. Minimal lubrication machining of aluminium alloys, J. Mater. Process. Technol. 120, 337–334
14. MaClure, T.F., Adams, R., Gugger, M.D. and Gressel, M.G., 2001. Comparison of flood vs. micro lubrication in machining performance.
15. Kwon, P, 2000. Predictive models for flank wear on coated inserts, Journal of tribology, 122(1), 340-347.
16. Ito, S., Yoshikawa, T., Miyazawa, S. and Mori, K., 1997. Machinability of Ni3-Al-based intermetallic compounds. Journal of materials processing technology, 63(1-3), 181-186.
17. A.R. Machado, J. Wallbank., 1996. The effect of extremely low lubricant volumes in machining, Department of Engineering, University of Warwick, Coventry CV47AL, UK.,210(1–2), 76-82.

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