A Comprehensive Study of Minimum Quantity Lubrication System in Oil Hole Drilling Machine in Crankshaft Manufacturing Process

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Abstract— In today's era CNC machines have totally changed the face of the machining process, but a need for a better cooling system has always been sensed. Minimum Quality Lubrication (MQL) system has the potential to be the perfect cooling and lubricating system for Computer Numeric Control (CNC) machines by replacing the conventional wet type cooling and lubricating method. This paper talks in detail how MQL system can be implemented in Oil Hole Drilling Machine in Crankshaft production process and its advantages over the conventional wet type cooling and lubricating system.

Key words: MQL, CNC, Oil Hole Drilling Machine, Crankshaft Production

I. INTRODUCTION

Crankshaft is one of the most important components for an internal combustion engine which is responsible for the conversion of linear (reciprocating) motion caused by the piston to the rotary motion which is further delivered to the wheels of the vehicle through the transmission system. Crankshaft, as a whole is very complex part, has gone through many different machining processes like turning, facing, drilling, milling, etc. All the machining processes require for making a finished product have to be very precise and accurate as the crankshaft rotates at very high speed during engine's operation and unbalanced crankshaft can cause the high amount of vibration and decrease the overall efficiency of the engine. High vibrations induced due to the unbalanced crankshaft is one of the main reason leading to shortened life-cycle of the engine.

There are various bearings and connecting rods that are associated with the crankshaft. Bearings are connected to the smooth rotation of the crankshaft and connecting rods are connected for the transfer of linear (reciprocating) motion from the piston to the crankshaft. For proper functioning and movement of bearing and connecting rod proper amount of lubrication has to be provided. The lubricating oil from the engine swamp is provided to connecting rod and bearing through various holes drilled in the crankshaft. Holes are drilled in crankshaft using Oil Hole Drilling Machine.

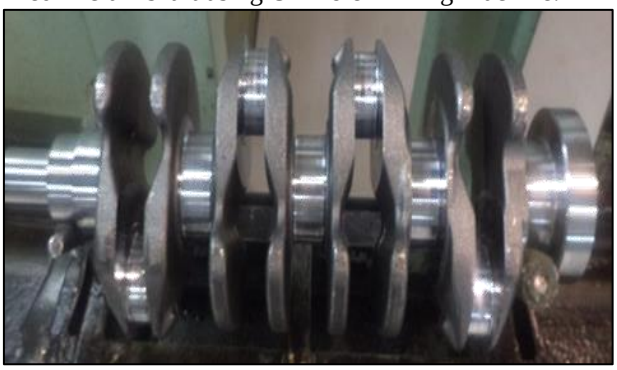


Fig. 1: Importance of Oil Hole Drilling Machine

Oil Hole Drilling Machine is a CNC machine whose main purpose is to drill fine holes at various different positions of the crankshaft where bearing or connecting rod has to be connected. Oil Hole Drilling Machine provides passage to the lubricating oil to flow through the crankshaft to the position where bearings and connecting rods are attached thus providing lubrication for bearing and connecting rods.

A. Current Scenario

During drilling process in Oil Hole Drilling Machine the temperature of both workpiece and drilling tool increases to a great extent thus affecting the precision of drilling. The abnormal increase in temperature can also lead to breakage or deformation in the cutting tool.

Currently to keep the temperature under control various kinds of coolants and lubricants are being used depending upon nature of the working piece. For soft metal and metal which doesn't require high-speed machining synthetic, vegetable, mineral or animal oil can be used as a coolant.

Soluble emulsions are chemicals that are mixed with water and are used as coolants. These are better than natural oils in providing lubrication and cooling to the working tool and workpiece.

The third type of coolants is synthetic coolants that have high cooling capabilities. These are generally used for high-speed machining for hard metals.

Problems with wet cooling methods

1) Costly Affair

These types of coolants available in the market are quite costly. The amount of coolant generally required in the wet method is very large as most of the time the workpiece is kept submerged in the coolant.

2) Difficult to Recycle

Once the coolant has been used it is very difficult to recycle as the used coolant contains chips of the workpiece and other impurities like sand and dust particles which may have been brought along with the workpiece. It is very difficult to remove chips from the coolant thus it becomes unfeasible for a company to segregate chips in order to recycle them. If not segregated properly it causes a problem especially in operation of chip compressor machine; which is used for compressing chip and making a small cylindrical shape of chips so that it can be stored in the small confined area and can be sent for recycling in more economical manner. If the chip is not completely coolant free and dry it causes a problem for the internal machinery of chip compressor machine.

3) Thermal Stability

Many times the excess amount of coolant is used and sometimes wrong type of coolant is used which doesn't match

with the nature of the workpiece and thus it disturbs the thermal stability of the workpiece as a whole.

4) Working Environment Degradation

As in dry method a large amount of coolant is used. Thus there is always a probability of spillage and leaking which generates the problem of cleanliness and hygiene.

5) Storage

The storage of such fluids also needs special care as these fluids very easily react with the external working environmental contaminations like dust particles, food particles etc. Many studies have shown that due to the interaction of fluids with micro-organisms may result in a change of a various variety of fluid properties like density, viscosity and even change in the pH level of the fluid leading to rusting and corrosion of the storage tanks. The growth of anaerobic bacteria in the fluid leads to the production of various kinds of harmful gases which contaminates the working environment. Water-based fluids provide optimum breeding conditions for various types of bacteria and provide excellent nutritional sources and thus special care has to be taken while storing water-based fluids.

6) Oder and Harmful Flumes

In many cases when coolant comes in contact with the hot cutting tool or workpiece it generates an unpleasant smell and flumes. These flumes are not only unpleasant but many studies have shown that continuous exposure to these flumes may cause many health problems like breathing disorders.

7) Health Risks

Many studies have shown with prolonged exposure to these fluids have a lethal effect on human lungs causing respiratory problems like Hypersensitivity pneumonitis and Asthma which are acute respiratory problems.

8) Problem of Proper Disposal

Proper disposal of coolant is also a crucial activity if not disposed of properly it can pollute the nearby environment. Proper disposal of metal coolant and lubricating fluid is a costly affair which includes various segregation processes in order to make the fluids less volatile and reactive to the environment.

II. MINIMUM QUANTITY LUBRICATION SYSTEM

Also commonly known as MQL system it is a type of lubricating system. Since the last few years MQL system has gained a lot of popularity due to its advantage of consuming a negligible amount of lubricant as compared to wet lubrication system. In the wet lubrication system, the whole workpiece is submerged in coolant while in the case of MQL system a mist of lubricating fluid is used which is just sufficient to lubricate and reduce friction between both workpiece and cutting tool. MQL system is most appropriate for machining processes like drilling, milling, and cutting. After being implemented in industries MQL system has shown much better results in terms of accuracy and machining quality as compared to the old wet type lubricating system. The performance of MQL system is also efficient while machining hard metals. This system is found to be equally good under wet conditions.

A. Advantage of MQL System in Crankshaft Production: (Case Study)

MQL system has completely revolutionized the crankshaft production in the automobile industry by making high precision drilling and milling process possible.

Earlier high amount of efficiency was not achieved due to excess use of lubrication during the machining process but after the introduction of MQL the problem of excessive use of lubricant has been solved as MQL system provides the machine with minimum amount of the lubricating oil which is necessary for reducing unwanted friction between the cutting tool and work-piece.

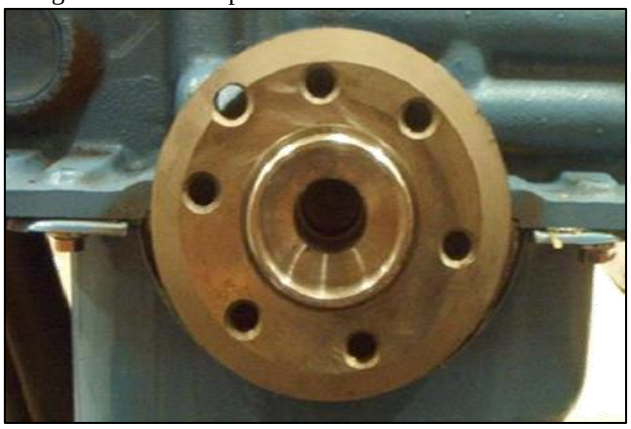


Fig. 2: The Picture of Part of Crankshaft before Implementation of MQL System

Fig. 3: The Picture of Part of Crankshaft after Implementation of MQL System

From the above two photos, one can easily conclude that crankshaft made without using the MQL system had some extra rubbing and poor finishing due to improper distribution of lubricant inside the machine during the machining process.(Shown in blue box).

To study more about the difference between machines with MQL system and without MQL system two same machines were selected and the same model of crankshaft was machined in the two machines and at the end of the day rejection amount from both the machines were compared to study the effectiveness of MQL system in increasing the efficiency of machine.

Machine	Number of defected/rejected parts
With MQL System	2
Without MQL System	7

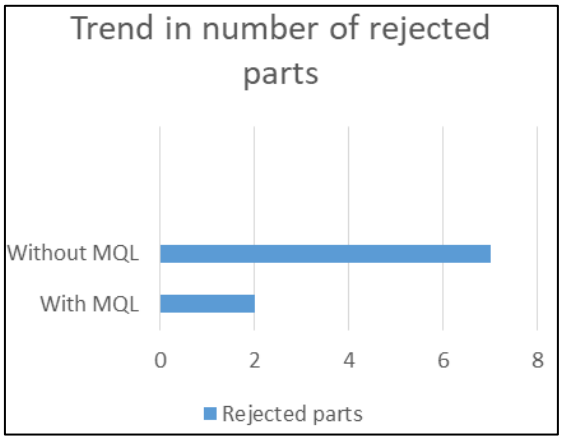


Fig. 4: Trend in Number of Rejected Parts

From the above table and graph, it is clear that the number of rejected parts due to machining defects is high on the machine without MQL unit. The MQL system has not only helped in the reduction in the number of rejected produced parts but has also helped in the reduction in overall cost of production by a considerable amount.

As we are aware that the amount of lubricating fluid used in the machine without MQL system is very high as compared to the machine with MQL system. To study and know the real amount of difference between the consumption of lubrication oil an experiment was conducted.

Two oil hole drilling machines were considered- one with MQL unit and the other without MQL unit. Both the machines were operated for approximately 18 hours and the amount of lubrication oil used was noted.

A machine with MQL unit consumed 0.29 liters of lubricating fluid per hour.

A machine without MQL unit consumed 4 liters of lubricating fluid per hour.

B. Calculation

The cost of MQL lubricating fluid was Rupees 720 per liter. Machine with MQL unit: 0.29*720= Rupees 208.8. A machine without MQL unit: 4*720= Rupees 2880. Difference=2880-208.8= Rupees 2671.2 Running the machine with MQL unit costs the company Rupees 208.8 per hour while the machine without the MQL unit costs the company Rupees 2880 per hour with a considerable difference of Rupees 2671.2 per hour.

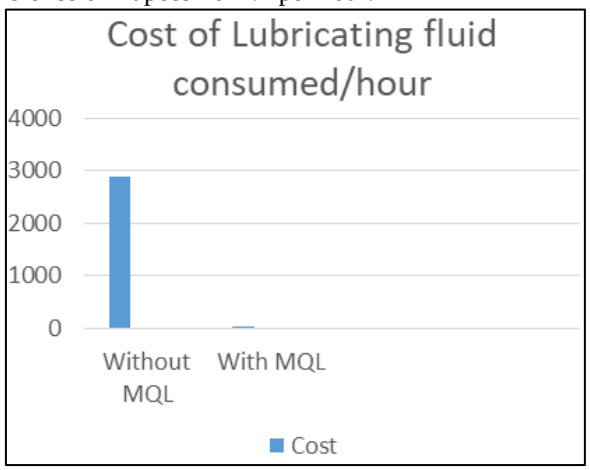


Fig. 5: Cost of Lubricating Fluid Consumed/Hour

C. Implementation of MQL System

An MQL System Contains Following Elements

1) Compressed Air Tank.
2) Oil Tank.
3) Mixing Tank.
4) Pressure Control Valve.
5) Flow Control Valve.

1) Compressed Air Tank

It is undoubtedly one of the most important parts of the MQL system. It is responsible for storing compressed air which is used by mixing tank for creating required oil mist.

Fig. 6: Compressed Air Tank

2) Oil Tank

It is the tank that holds the lubricating oil. It is generally a cylindrical tank having a capacity of about 5 liters. The tank has marking indicating the maximum and the minimum level. The tank also comes with a chart depicting all kinds of oils and its grades that are safe to use with that MQL unit.

3) Mixing Tank

It is the tank where oil and compressed air mixes with each other. Due to the high pressure of air as soon as the air enters the mixing tank it creates a swirling motion. In that motion of air-oil drops are released slowly and the oil mixes with air producing mist. That mist is used for lubricating the workpiece and cutting tool.

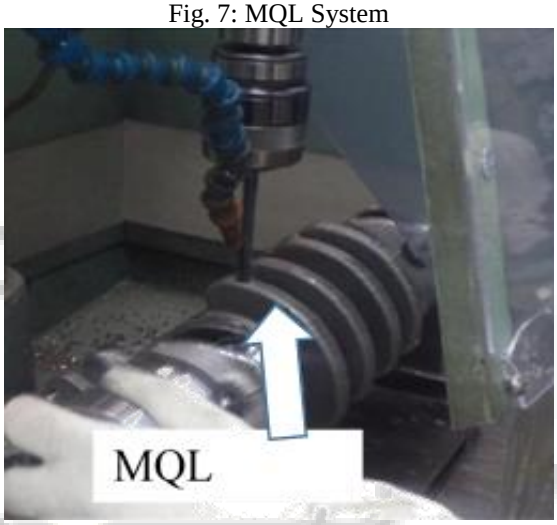
4) Pressure and Flow Control Valve

These valves are used for safety measures. The pressure valves are connected to the compressed air tank to regulate the pressure in the tank. If the pressure drops the required level the distribution of oil in the air won't be consistent and will lead to uneven concentration of oil in the air. It is also used to release any extra pressure in the tank in case of high air pressure in the tank as pressure higher than set value can damage the air pipes and can also be harmful for the air tank.

5) Flow control valve

It is connected to the mist nozzle of MQL system and is responsible for controlling the pressure and the flow of the mist coming out of the nozzle. It can be adjusted according to the requirement of the machining.

Fig. 7: MQL System



The unit shown in the above image is the outside unit of MQL system and is connected to the outer peripheries of the machine. It should be connected to an easily accessible place as it has oil tank attached which contain oil inside it which has to be refilled from time to time. The inner unit of MQL system contains the air pipe and a nozzle for delivery of mist from the air tank to the workpiece. The above picture shows the inner unit of MQL system which has a nozzle for delivering the oil and air mist.

D. Advantage of MQL System

The implementation of MQL system is comparatively cheaper than implementing the wet lubricating system. The latter has high initial implementation cost as it requires various machinery like filters for filtering the lubricating oil from the chips and also requires various types of other filters for the disposal of the fluid safe in the environment. On the other hand MQL system requires only an MQL external and internal unit which is comparatively cheaper and easier to implement and set up.

Additional Requirements of Wet Type Lubrication System

1) Filters

Wet type lubricating systems requires a lot of filters to

a) Separate lubricating oil from chips.
b) To separate lubricate concentrate from the water.

2) Chillers

Large chillers are required to cool the fluid coming from the machines as the fluid coming is generally very hot due to the machining process.

3) Chemical Processing Tanks

These are the tanks that are used for balancing the pH level of fluid. The pH level of the solution should be in neutral range otherwise it will be very dangerous for the environment.

E. Cost Comparison between MQL System and Wet Lubrication System

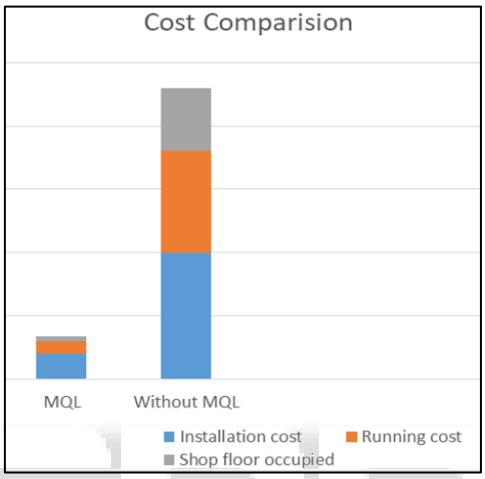


Fig. 8: Cost Comparison

III. Conclusions

After conducting various experiments it has been observed that MQL system is better than conventional wet type lubrication system as

1) It is highly cost effective for the industry to adopt in terms of both initial installation and long-term use.
2) MQL system occupies much less floor space as compared to wet type lubrication system.
3) MQL system is safer for environment.
4) MQL has no health effects on machine operators and on the people working in the industry.
5) Clean and dry chips are obtained after machining operation which makes the recycling and storage of chips easy.

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