A Review on Minimum Quantity Lubrication

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ABSTRACT
In contrast to flood lubrication, minimum quantity lubrication uses only a few drops nanoparticles of lubrication (approx. 5 ml to 50 ml per hour) in machining. Today, the enormous cost-saving potential resulting from doing almost entirely without metalworking fluids in machining production is recognized and implemented by many companies, primarily in the automotive industry. While in the early 1990s small applications (sawing, drilling) were done "dry", today we are able to produce cylinder heads, crankcases, camshafts and numerous other components made of common materials – such as steel, cast iron and aluminium – using MQL in the framework of highly automated large volume production. The advantages of this new technology are clear. With respect to occupational safety, MQL offers numerous advantages over water-mixed metalworking fluids. This paper shows the overview of Minimum Quantity Lubrication (MQL) With respect to its need, types, application.

Keyword: - *MQL, Atomizer, Internal & External Feed, Lubrication.*

1. INTRODUCTION

In recent years, environmental pollution is very critical factor occurred due to industrial waste as well as its degradation directly impact on the environment. Also in the industrial area, the better surface finishing of product/work-piece is a very important factor towards customer point of view. By considering environmental pollution occurred due to industrial waste and good finishing of work-piece, new concept was introduced by a researcher called Minimum quantity lubrication (MQL).

Many researcher already did their research and they come with a possible solution in searching for the optimum lubrication system is minimum quantity lubrication (MQL), which is becoming increasingly important. This is an alternative between wet and dry machining. In the case of minimum quantity lubrication, the quantity of the applied lubricant is reduced to a minimum.

Minimum quantity lubrication (MQL) has increasingly found its way into the machining process such as metal cutting machining and, in many another machining, MQL has already been established as an alternative to conventional wet processing. As compare with flood lubrication, minimum quantity lubrication uses only a few drops of lubrication (approx. 5 ml to 50 ml per hour) in the machining operation.

Elimination of oil mist and coolant is only possible with dry machining but dry machining was found successfully with some material such as cast iron but loses its effectiveness when high production rates and machining efficiency is required. Also, for continuous high-speed machining of some material such as super alloys and titanium, cooling is necessary to minimize dimensional deviation and improve tool life and surface finish.

2. DEFINITIONS OF MQL

A definition of minimum quantity lubrication has not yet been specified in standards and guidelines. Based on numerous publications, the following definition has been established in practice:

- Minimum quantity lubrication (MQL) An average of not more than 50 ml of lubricant is used per processing hour and tool for the machining process. For certain operations, however, the process may well use more than 150 ml/h for short intervals.

- MQL term often used is “minimum quantity cooling lubrication” (MQCL).Reduced quantity lubrication (RQL) This refers to reducing the circulation quantity of today‘s metalworking fluid systems through the targeted supply of lesser quantities of metalworking fluids (up to 2 liters per processing hour). Reduced quantity lubrication is therefore not total-loss lubrication. An example of reduced quantity lubrication is supplying metalworking fluids via shoe-shaped nozzles when grinding; the quantity of metalworking fluid can be reduced by up to 90 % compared to conventional processing [2].

3. LITERATURE REVIEW

The main problem identified by researchers in the machining of aluminium alloys 6061 T6 is the cutting parameter which can be affect the material removal rate of the material using different cutting parametric condition. The researcher reviews different types of MQL systems, comparison of MQL coolant system with conventional coolant systems, applications and advantages of MQL coolant system. The use of MQL also decreases the production cost by reducing the coolant cost. Some of the researcher study given below in tabulated form,

Sr No	Year	Author's Name	Material	Input Parameter	Output Parameter	Most Significant	
	2018	Firdaus Shazriq Mohd Fadzil, Nur Izzati Khoirunnisa Ismail , Nurrina Rosli	Aluminium Alloy 6061	Nozzle distance(5, 20, 35) mm in horizontal direction, Feed rate(230, 270, 310) mm/min, Spindle speed(1200, 1400, 1600) rpm, Cutting tool Coated carbide End mill	Surface roughness	Nozzel direction and Distance	Feed
	2018	Swaraj Samanta, Sumit Kumar, Souram Guha, Sonal Kr. Singh	Aluminium alloy 6061	Speed (500, 1000, 1500) rpm,Feed (50, 75, 100)mm/min, DOC (0.5, 1, 1.5)mm, Coolant (Water, Coconut Oil, Mustard Oil)	Material Removal Rate, Surface Roughness	DOC,Water Cooling	Feed
	2017	Mahendra Singh, Amit Sharma, Deepak Juneja, Anju Chaudhary	Aluminium alloy 6351	Speed (500, 800, 1100) m/min, DOC (0.20, 0.25, 0.30)mm, Feed(0.10, 0.20, 0.30)mm/rev	Material Removal Rate, Surface Roughness	Feed	DOC, Speed
	2016	Himanshu Sonar, Vishudha Saxena, Vivek Kshirsagar, Shraddha P Deshpande	Aluminium Alloy 6061 T6	Speed (800, 1200, 1600) rpm, Feed(80, 120, 160)mm/min, DOC (0.2,0.3,0.4)mm, Tool Used- T1: Alumina K10 Coating layer- uncoated T2: Taegutech TT8020 Coating type- PVD Coating layer- TiCN T3: Taegutech TT5100 Coating type- CVD Coating layer-TiCN-Al2O3-TiN	Material Removal Rate, Surface Roughness	Surface RoughnessT 2: Taegutech TT8020 Coating type- PVD Coating layer- TiCN	MRR : T3: Taegutech TT5100 Coating type- CVD Coating layer -

							TiCN-Al2O3-TiN
	2015	Ranganath M. S, Vipin, R. S. Mishra, Prateek, Nikhil	Aluminium alloy 6061	Speed (1600,1900, 2200) rpm, DOC (0.25,0.50,0.75)mm, Feed(0.12, 0.18, 0.24)mm/rev	Surface Roughness	Speed	DOC
	2015	Deepak D, Rajendra B	Aluminium alloy 6061	Speed (308, 369, 429) m/min, DOC (1, 1.5, 2) mm, Feed(0.05, 0.1, 0.15)mm/rev, TWO Machining Condition- Dry Machinig & With Coolent, Tool: Silicon Carbied Insert	Material Removal Rate	Feed	DOC
	2013	Ranganath M. S, Vipin, R. S. Mishra	Aluminium alloy 6061	Speed (1700, 1900, 2100) rpm, DOC (0.2,0.3,0.4)mm, Feed(0.10, 0.125, 0.15)mm/rev, Tool used : Cemented Carbide Insert Type	Surface Roughness	Feed	DOC
	2012	L B Abhang, M Hameedullah	EN-31Steel Alloy	Feed(0.12, 0.18, 0.24)mm/rev,DOC (0.2,0.4,0.6)mm, Lubricant Temperature (10, 30, 50) °C	Surface Roughness	Lubricant Temperature	Feed
	2009	M. M. A. Khan, M. A. H. Mithu, N. R. Dhar	Low Alloy Steel - AISI 9310 Alloy	Speed (223, 246, 348, 483) m/min, Feed(0.10, 0.13, 0.16, 0.18)mm/rev, DOC (1.0)mm,Dry, Wet, MQL Condition	Tool Wear, Surface Roughness	MQL Condition	Feed
	2007	P.S. Sreejith	Aluminium Alloy 6061	Tool: Diamond coated, Cooling-Dry condition, flooded condition and MQL condition and apply two type of flow rate 50 and 100ml/hr., DOC- 1.Omm, Feed -o.15 mm/rev and Spped- 50 to 400 m/min	Tool wear, Cutting forces and Surface quality	coolant	Cutting Speed

4. WHY MQL?

- Cost related to Cutting fluid is several time larger than cutting tool cost, an overall cost of production. Also handling capacity of lubricant, disposal of it also major problem. Also flood cutting increases causes of health problem to employers and may create problem to environment
- In flood cutting, because of lubricant there is problem of disposal and more maintains and it is expensive process.
- Internally MQL is a conversion of production process from wet to dry machining help to motivate Personnel; externally it contributes a better corporate image.
- Chip removal also one of the major problem in machining, MQL is solution for it [4].

5. FACTORS GOVERNING MQL

According to king et al (2001) cost of cutting fluid is near about 7% to 17% of total production cost that is more than cost of cutting tool. So Dry and MQL is an option for it but where high surface finish and greater productivity require there is no use of dry cutting methods. So Minimum Quantity Lubrication is better solution for all problem. MQL System is used to overcome the disadvantages of Flood and Dry, cutting. In MQL system very small quantity of lubricant is used. In India there is unaware of MQL system High cost is major concern of it. So objectives of this study is to obtain simple MQL system, reducing cost, making aware of this system to people and investigate its performance in comparison with Dry and Flood cutting.

The enormous reduction in the quantity of lubricant compared to the circulated quantities of conventional metalworking fluid systems is the key feature of MQL. In contrast to conventional flood lubrication, minimum quantity lubrication uses only a few milliliters (ml) of lubrication per hour for the machining process [2].

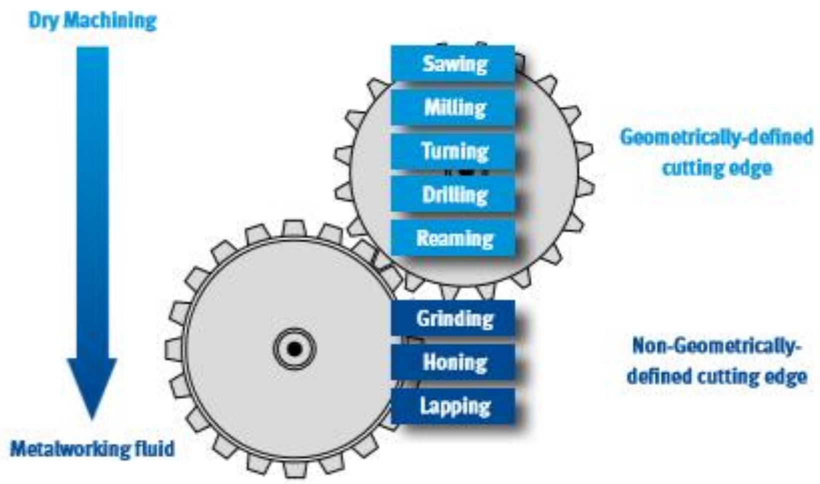

Fig-1 Application of MQL system

Fig 1 shows how MQL can be implemented for different kinds machining processes and how much worth is it to implement the process. Fig shows that MQL can be best implemented for the applications such as grinding, honing, and lapping. These operations are the applications where non geometrically defined cutting edges are present.

Minimum quantity lubrication greatly reduces health hazards due to emissions of metalworking fluids on the skin and in the breathed-in air of employees at their workplaces [2].

The cost-inflating factors of conventional flood lubrication are done away with when MQL is used.

This results in:

- Reduction of metalworking fluid quantities in use
- Decrease in the work required for monitoring and metalworking fluid maintenance
- No need to prepare and dispose of used metalworking fluids
- Decrease in the work required for cleaning the processed pieces and
- Easy recycling of the nearly dry chips due to less oil soiling.

The lubricant is either applied from outside as an aerosol using compressed air or it is “shot” at the tool in the form of droplets or it targeted towards toll chip interface. Another possibility is internal lubricant feed through the rotating machine tool spindle and the inner channels of the tool. [2]

6. EXTERNAL FEED AND INTERNAL FEED LUBRICATION

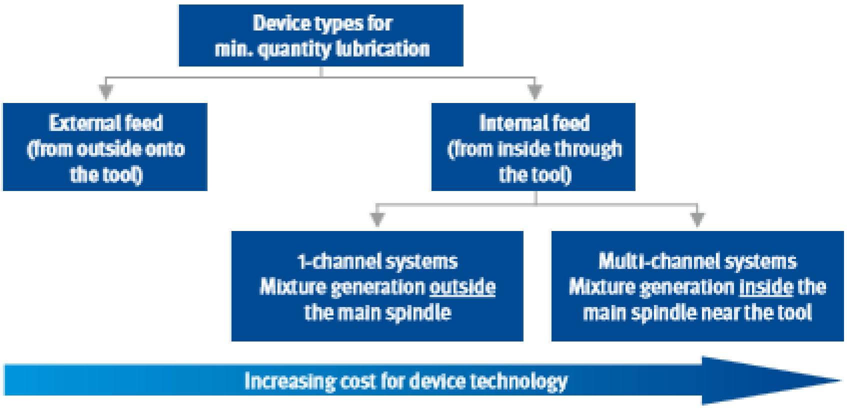

Fig-2 Systems of MQL

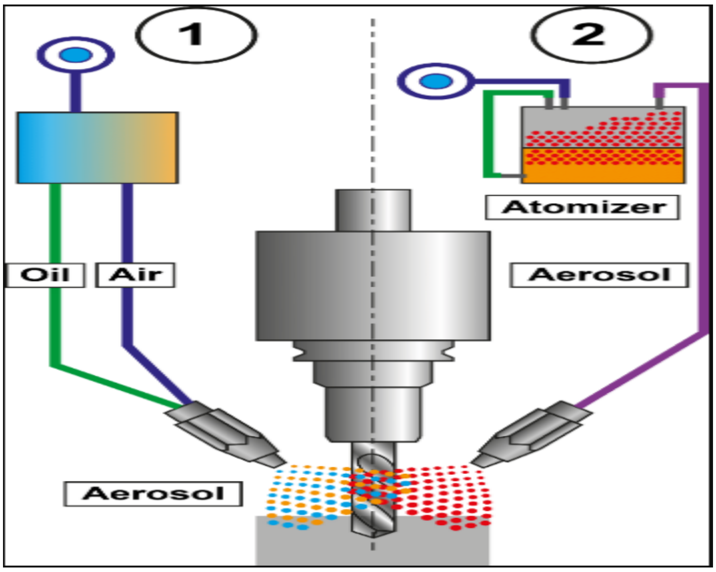

Fig-3 Working Principal of Minimum Quantity Lubrication
Adapted from: Astakhov, V. P. (n.d.). Ecological Machining: Near-dry Machining. Machining, 195–223.

6.1 EXTERNAL FEED:

For standard processes MQL systems for external feeds are suitable for retrofitting machine tools because the required spray nozzles can be easily installed on the spindle head. This system is especially suitable for simple standard processes, e.g. sawing, drilling, milling and turning. This type of lubricant supply, however, is limited by the different tool lengths and diameters as well as by limited accessibility to the tool cutting edge, e.g. when deep hole drilling [2].

Advantages	Disadvantages
Simple adaptation	Limited adjustment options for the nozzles due to different tool lengths and diameters
Low investment costs	Possible shadowing effects of the spray jet when machining
Little work required to retrofit conventional machine tools	Possible shadowing effects of the spray jet when machining
Rapid response characteristics	
No special tools required	

Table-1 External feed

6.2 INTERNAL FEED

For demanding processes Using MQL systems with internal feeds enables precise aerosol supply directly to the contact point through the tool. The lubricant is continually available at the critical points during the entire processing sequence. This makes it possible to drill very deep holes and use very high cutting speeds. Because the medium has to be fed through the machine spindle, converting to this system may be costly. Some systems can be controlled directly by the machine tool control system; lubrication system settings for the required oil quantity and compressed air values can then be performed automatically when there is a tool change. For these lubrication systems in automated production, setting system parameters manually is not required.

Advantages	Disadvantages
Optimal lubrication at the cutting point (for each tool, even for inaccessible points)	Special tools required
No scattering or spray losses (see external feed)	High investment costs
Optimized lubricant quantity for each tool	Suitability of the machine is required

Table-2 Internal feed

Table 2 provides an over- view of the advantages and disadvantages of internal feed. General requirement the main task of the MQL systems is the targeted supply of an appropriate Lubricant to the contact point of the tool (cutting edge). A number of different devices for various requirements are available for this purpose.

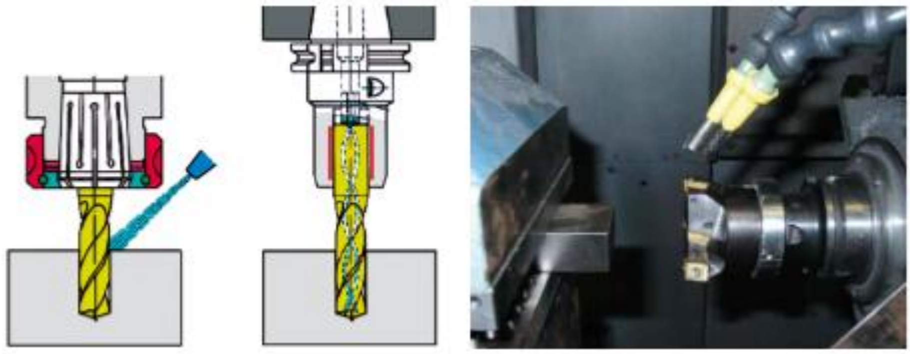

Fig-4 Internal and External feed MQL

For single-purpose machines, e.g. broaching, sawing and shaping, simple, manually controllable MQL devices with internal and external feeds with different functional modes are normally used. They are usually systems

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with pressure tanks and metering pumps. Modern flexible production systems require very demanding MQL device technology. For this purpose, complex MQL systems have been developed that have integrated components for regulation, control and monitoring. Depending on the accessibility to the cutting edge, different requirements apply to the devices in use. For this reason, a differentiation is made between external and internal feed of the lubrication medium, which makes a noticeable difference to the cost of the device technology [8].

In the case of external feed, the lubricant is applied by means of spray nozzles around the circumference of the tool. This system is especially suitable for entrance-level implementation for standard processes (turning, milling, and drilling). With internal feed, the lubricant is transported through the spindle system of the machine and through the channels in the tool to the machining point. This system is used primarily when flexible processing centers and new machinery are in use as well as with high-speed cutting (HSC).The different device technologies and their purposes, as well as advantages and disadvantages, are described below [8].

Minimum quantity lubrication systems for external feed Devices for external feed transport the lubricant and the separate atomization air to near the contact point. This takes place in a coaxial or parallel pipework packet. At the end of the pipes, the lubricant is atomized with a spray nozzle and fed to the tool as an aerosol from outside [2]. Low cost, simple retrofitting and the option of deploying conventional tools are the key advantages of these systems. However, all of these systems have disadvantages that limit their use owing to the principle involved. The nozzles have to be manually adjusted or adjusted via supplementary positioning axes to the tool; there are also losses due to dispersion and shadowing effects. The most important areas of application use machine tools with a low level of flexibility and involve sawing, milling, broaching, shaping, drilling and threading processes [8].

7. PRINCIPLE AND CONSTRUCTION OF MQL

7.1 PRINCIPLE AND CONSTRUCTION OF MQL

Developed system based on simple principle shown in fig 3, Compressed air passed through pipe, and it control by adjusting konb means regulator. Oil siphoned from reservoir by air flow, is atomized into a fine spray .A typical system consist of reservoir, regulator, spray control valve with distributor nozzle, switches

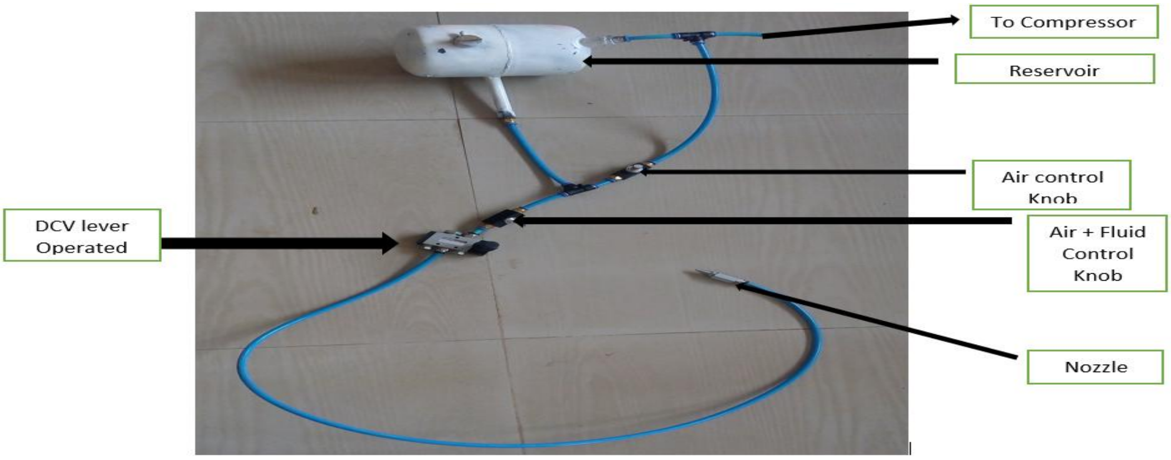

Fig-5 Minimum Quantity Lubrication Setup

The MQL system describe here with reference to size and distribution of lubricant drop, generate homogeneous aerosol with drop size approximately 0.5 µm. the oil drops are very light because of their small size , which in turns result in very low moment of Inertia. These small drop of oil can be transported over long stretch through lines & deflection without being deposited due to moment of inertia. Fig 6 explains the construction of MQL. Additionally transport of aerosol through spindles and tool is unproblematic. MQL system even at very high rotational speed, since effect of centrifugal force an oil drops in very low.The size & distribution of droplets of oil in the aerosol are very homogenous with lubrication MQL system since the aerosol is atomized under controlled condition. In Addition to high degree of surface wetting, extremely fine particle of lubricant also reach poorly accessible or hidden spots on work piece [4].

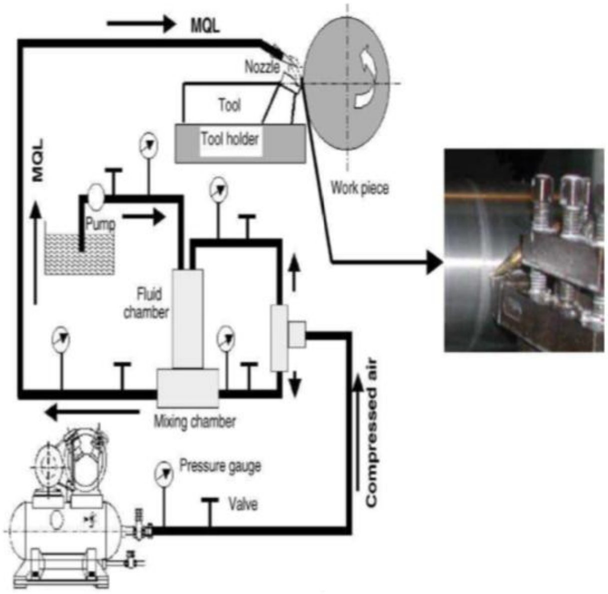

Fig-6 Construction of MQL
Adapted from: MQL an Emerging Cooling Technique IJRAT, Vol.3,
No.5, May 2015 E-ISSN: 2321-9637

Difficult through feed task with deflection of kind found in terms of turrets of turning machine can also be handled. Optimal lubrication during removal of chips in chip groove not only permits higher machining speeds but also results in much better work piece surface finish. A Fine aerosol with homogeneous particle size of 0.5 µm is produced in reservoir from a lubricant & compressed air with special nozzle system. Thanks to small particle size, the aerosol passes through the rotating spindle of machining centers ducts of turrets on modern turning centers without any de-mixing taking place route. A bypass system can be optionally integrated in aerosol feed to achieve shorter response time .The aerosol is directed is directed 3/2 way ball valve for this purpose [2]. Main Component of MQL construction consist of,

a) Spray Nozzle: Aerosol required at the process point is produced at nozzle outlet. The lubricant and require atomized air are fed through co-axial line from MQL to spray nozzle. The lubrication mixture is formed at a nozzle outlet by venturi principle .the purpose of the spray nozzle is to generate tint droplet of lubricant in the desired size.

b) Compressor: by means of compressed air, the aerosol generated inside the vessel is transported via one or several connected aerosol lines to supply connection at machine tool Compressed air Requirement valve. Maximum air admission pressure 8 bar minimum air admission pressure 4 bar. Maximum particle size 40 µm, Maximum particle density 10g/m3, Maximum pressure dew point temperature 70C, Maximum Lubricant concentration 25g/m3. The main air valve is closed before connecting the MQL system has an NG8 coupling socket for hoses with inside diameter 7.8mm for connection to compressed air supply [4].

8. ADVANTAGES OF MQL

- Cost merit- No need for cooling lubricant, No cost of disposal chip and cooling lubricant, No need of wash work piece, not requirement of device like lubricant filter, conditioning system.
- Chip removal- Chip removal is one of the major problem that should be considered in Construction of mass production large quantity of coolant is used to removal of chip but it is necessary to adopt less lubricant method to remove chip MQL.
- Improve productivity- Significant reduction of production time (30% to 50%) Higher efficiency Tool life increases by 300% Reliable control of production processes.

- Utilize a Technology Advantages – Solution for OEM's and retrofitter's Parallel use of wet & dry machining. No change in design is required [3].

9. CONCLUSION

The effects of Minimum Quantity lubrication over the other types were studied and found that the MQL systems produce better results in case of tool chip interface temperature, and the chips arising due to machining .The following are the observations recorded

- MQL technology is properly employed not only provides environment friendliness but also improve the machinability and is safe for both operators and the environment.
- MQL technology is cost saving and improves the overall performance of cutting operations related to cooling lubrication, dry machining and it leads to reduced surface roughness, delayed tool flank wear, and lower cutting temperature, while also having a minimal effect on the cutting forces.
- Minimum quantity lubrication today uses such precise metering that the lubricant is nearly completely used up. Typical dosage quantities range from 5 ml to 50 ml per process hour (tool cutting time).
- MQL reduce the risk of fire, lubricants with a flash point of at least 150 °C should be used, even the mist formation resulting from the spraying process itself does not form a hazardous explosive atmosphere.

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