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A REVIEW: EFFECT OF DIFFERENT MACHINING ENVIRONMENT ON TURNING

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ABSTRACT - In this study, it has been examined that cutting fluids are used in different machining operations to improve machining characteristics. The cutting fluids reduce tool wear, enhance surface quality of the work-piece and reduce cutting temperature. It also helps in carrying away the unwanted chips produced during machining. On another side, the cutting fluids have numerous harmful effects. These fluids causes skin and lungs disease to the operator and it is very difficult to dispose. Because of this kind of harmful effects, a lot of research work has been recently reported towards minimizing the use of cutting fluids or to totally avoid them. Recently, Minimum Quantity Lubrication (MQL) has come into existence as an alternative to conventional cooling. The process mainly focuses on the use of minuscule level of lubricants mixed with pressurized air and sprayed on to the cutting zone through the help of nozzle. This review paper shows the effect of MQL on the machining performance of different workpiece when contrasted with dry machining and flood cooling in terms of temperature, chip morphology, surface roughness and tool wear.

Keywords: Minimum Quantity Lubrication, cutting fluid, nano fluids, surface finish, tool wear.

I. INTRODUCTION

Cutting fluids are commonly employed in all manufacturing industries to reduce heat generated in tool work material interface. On another side cutting fluids have various toxic effects to human health. Most of fluids, which are deployed to lubricate for machining, comprises environmentally harmful chemicals. These fluids are not easily decomposed and cause health problem issues like lung disease and skin problems to the worker. In the recent years, great amount of work have done in dry and wet machining and now-a-days machining with MQL is believed to eco-pleasing features. In order to recede the quantity of cutting fluids, various investigators looked in the probability of employing MQL in various manufacturing processes. The reviews of the literature suggest that MQL have a lot of advantages in machining. The principle objective of the study is to examine the role of MQL on temperature, chip formation, surface roughness and micro structure in various machining applications at different cutting speed, depth of cut and feed rate. [1-4]

II. CUTTING FLUIDS

The sustainability of manufacturing industry is possible only if it manufacture the products of extreme quality at lower rates. However, many times tool replacements in the work place due to wear of tool enhances the total cost of the manufacturing product. Hence the decrease of tool wear is very important in machining work. Tool wear is frequently caused because of friction between tool and work material. High temperatures and cutting forces, emerging due to friction, enhance the tool wear and reduce the tool life [5]. In order to reduce the friction between tool and work piece which in result reduces the temperature and cutting force, cutting fluids are generally utilized. [6].

Cutting fluids serve as coolant machining industries. Metal working fluid or cutting liquid are employed in various machining operations to enhance tool life, lessen friction between tool and work piece, better surface finish and to wash away the cutting chips from cutting zone. The vital role of cutting fluid is to lower the temperature between tool and work piece interface. The selection of cutting fluid is prime importance in different machining operation depends upon several process parameters. In addition to cooling and lubricating effect, the cutting fluid is employed to protect the work material from chemical attack and flush away chips from the work piece [7, 8].

Cutting fluid can be divided into four different categories: straight cutting fluid, soluble cutting fluid, synthetic cutting fluid and semi-synthetic cutting fluid. Straight oil is also known as neat oil or cutting oil is the oldest class of metal cutting fluid. These types of fluids are derived from petroleum or animal origin. The application of straight oil is only with very light duty machining operations. Soluble or emulsifiable oil, in this type of oil droplets suspended in emulsifier agent. Normally these fluids are commonly used for high cutting speed with low pressure. Synthetic or chemical fluids are normally mixed with number of chemical agents in water. The chemical agent includes amines, nitrites phosphates, glycol and germicides. The use of chemical agent helps in improve lubrication and decrease surface tension. Synthetic fluids have best coolant properties but less lubrication properties in comparison to other cutting fluids. Semi- synthetic oil is a combination of small amount oil usually less than 30 percent and additives to improve lubricating properties. Sometimes 2 to 10 percent concentrations of chlorine, Sulphur or other additives are added to both synthetic and semi- synthetic fluids to induce extreme pressure as well as boundary lubrication effects. Hence these fluids are used in more difficult and tough machining and grinding applications [9].Comparison between different cutting fluids is shown in table (a)

Table (a)
Comparison between different cutting fluids [9]

Straight oils	**Soluble oils**	**Semi-synthetics**	**Synthetics**
Advantages			
a) Good lubrication	a) Low viscosity	a) Good cooling	a) Nonflammable
b) Good rust and corrosion protection	b) Non- flammable and non-toxic	b) Good microbial control	b) Good corrosion control
Disadvantage			
a) Poor cooling rate	a) Low lubricity	a) Foam quickly	a) Low lubricity
b) Mist and smoke formation	b) Foul smell	b) Easily polluted by other machine fluids	b) Low cooling

The selection of metal cutting fluid is of utmost significance as it could influence machining performance and more importantly the health of worker. This causes the spontaneously inhaling of cutting fluid particles by the workers, thus causing drastic health related issues [10].

III. MINIMUM QUANTITY LUBRICATION (MQL)

The traditional system of applying the cutting fluid is flood cooling system in which substantial amount of cutting fluid is consistently impinged on the tool. This type of flood cooling system is very unproductive. First of all, a large amount of coolant is required. Second, the coolant is not able to reach tool chip interface. A few choices have been looked to decrease or even avoid the utilization of these traditional coolants in different machining operation. The researchers found that best alternative for flood cooling is Minimum Quantity lubrication (MQL). MQL is a technique that enables to decrease the quantity of cutting fluid. MQL machining comprises of a mixture of tiny droplets of oil and compressed air at certain pressure applied directly into the tool chip interface. In this method, the lubricating and chilling effects were accomplished by the oil and pressurized air respectively.

In order to restrict the production of heat generated during machining operations, large amount of cutting fluids have been used throughout the world. However the use of flood cooling is highly criticized. Hence the use of large amount of lubricant in cooling is not recommended so a technique called minimum quantity lubrication (MQL) has been originated in machining operations in a past couple of years. Because of the usage of less quantity of cutting fluid (below 500ml/h) the MQL can be considered as more sensible technique in comparison to traditional or flood cooling technique [11].

Minimum quantity lubrication (MQL) utilizes the lubricant in little amount i.e just around ten- thousandth of the amount of cutting fluid used in traditional or flood-cooling. The performance of this technique largely relies upon the kind of cutting fluid, work piece and machining process used. This technique comprises mixture of cutting fluids and compressed air, producing a spray mist which is impinged on the cutting zone of work material. MQL machining has been studied in various machining processes such as turning process, milling process, drilling process and grinding process. All these studies highlighted some of the advantages utilizing this technique in machining processes along with various lubricants. Regardless MQL machining using different grade of vegetable oil as lubricant is another concept and should be further researched so far [12].

IV. MACHINING USING MQL IN TURNING

Krishankant et al. [13] Turning is a process in machining that removes unwanted material from the work piece and changes it into desired shape with the aid of cutting tool insert. In turning operation commonly cylindrical work pieces are machined. The cutting tool employ in turning operation is a single point cutting tool. The turning process requires a work piece, which is cylindrical in shape; i.e is fixed into the fixture of turning machine or lathe machine. The process parameters selected for machining operations are cutting speed in rpm or m/min, feed in mm/rev and depth of cut in mm.

Sharma et al. [2] studied that during turning operation, cutting liquid plays very significant part in removal of chips and also provide cooling and lubrication between the tool-work material interface. However both human health and environment get badly affected by using the access amount of cutting oil. For the past few years, nanofluids have captured the consideration of researchers because of its better heat conductivity and heat drawing capability. In this study, new nanofluid was formed by mixing aluminum oxide nano particles in traditional cutting fluids with varying concentrations. Then this newly formed nanofluid was described for its heat conductivity at all nano particle concentrations. Also its machining execution was observed for AISI 1040 STEEL using MQL method. The outcomes were also contrasted with that of MQL machining employing traditional cutting fluid. The experimental investigation confirmed that the execution of Al_2O_3 nanofluid in terms of chip morphology, tool wear, cutting force and surface quality of workpiece was significantly more promising when compared to dry and wet machining.

Dhar et al. [3] examined the role of MQL on surface roughness and tool wear in machining operation of AISI-4340 steel at different cutting speed and feed combination by carbide insert. The outcomes were quite encouraging that include lessen in surface roughness and wear rate by near dry machining mainly by decrease in the cutting temperature and significant alteration in chip tool work piece interactions.

Jagdeep and Balwinder et al. [4] investigated the impact of NDM and dry on steel workpiece by utilizing an eco amicable vegetable oil in order to eliminate other toxic lubricant for machining operation. AISI D2 workpiece material was machined at different speed and feed combination by utilizing carbide insert. The outcomes revealed that near dry machining indicate better results over dry cutting in terms of cutting temperature and surface roughness. Hence it was suggested that machining with vegetable oil give environment friendliness and can likewise help in enhancing machinablity qualities up to a certain level.

Behara et al. [11] prepared the mixture of powder type form of alumina and silver nanoparticles with water in order to form the nanofluid of various concentrations. The nanofluid formed was utilized in accordance with MQL during turning of nickel alloy. The outcomes so obtained were compared with biodegradable emulsion and dry machining. It was also observed that less contact angle, greater spreadability and small droplet size of powder type alumina provide lesser cutting force and tool wear during machining. The study additionally demonstrated that nano ball bearing effect of silver (Ag) nanofluid give rise to improved surface finish and reduction in abrasive wear.

Sreejith [14] investigated the impact of three different types of machining environment when workpiece material aluminium alloy 6061 was machined with coated carbide insert. The machining environment dry, MQL and flooded were studied on different output responses. Then comparison between three types of environment was made and it was obtained that minimum quantity lubrication proved to be a better technique over wet machining. So it was clearly revealed that if MQL perfectly utilized it can take the place of flood machining which is currently now a day's utilized in majority of the machining application. Consequently it will not just made machining eco friendly yet in addition it will lead to improvement of machining characteristics.

Yazid et al. [15] investigated the impact of input process parameters and machining environment on surface integrity during turning operation. In this case machining environment selected were dry and MQL with two varying flow rate 50ml/hr and 100ml/hr. Machining operation performed on Inconel 718 by using titanium aluminium nitride tool having hardness more than inconel. The result of this study revealed that surface finish in case of 50ml/hr was better than that of dry cutting and MQL at100ml/hr.

Dhar et al. [16] led the experimentation to study the role of MQL on temperature, formation of chips and product quality produced during turning operation on AISI 1040 workpiece steel. The outcomes have been compared for dry cutting and cutting with soluble cutting fluid as coolant. Experimental study revealed that MQL reduces temperature and improves dimensional accuracy relying on the level of feed and cutting speed. Consequently, it is quite evident that proper utilization of minimum quantity lubrication gives eco friendly environment as well as enhance machinability quality of product.

Abhang et al. [17] conducted the study on machining input parameters of steel. Experimentation performed by employing factorial method in order to examine the effect of input parameters such as cutting speed, nose radius, depth of cut and flow rate of lubricant on output response such as surface roughness while machining EN-31 steel. The analysis of outcomes have been made by using the variance method and statistical F-test , revealed that input process parameters have significant effect on measured surface finish during machining of steel.

Kinovic et al. [18] investigated the role of MQL (mixture of oil and water) on input turning parameters and cutting forces while performing MQL machining of St 52-2 carbon steel. The influence of factors such as quantity of oil ranges from 10 to 50 ml/h and water ranges from 0.3 to1.7ml/h and nozzle position were investigated. The results revealed the presence of least cutting forces during machining operation with 1.7 liter per hour of water and 10 milliliter per hour of oil. It was likewise seen that the cutting forces were seventeen percent lesser than the similar ones during turning operation without coolant and oil lubricant.

Khan et al. [19] examined the comparison of MQL on the machining performance of AISI 9310 steel with flood and completely dry cutting for finding temperature, tool wear and surface finish. The outcomes revealed that the execution of MQL turning was far superior to dry cutting and the flood cooling because of generous cutting area temperature which enables the great chip formation and tool chip interaction. The study additionally revealed that great deal of reduction in tool wear enhances tool life and lessen the surface roughness. Also MQL gives lesser utilization of lubricant to make environment friendliness thereby avoiding health related issues due to fumes and gases and further more helps improving machinability characteristics.

Vasu et al. [20] performed experiments for three distinct ecological conditions completely dry, MQL machining and MQL with inclusion of aluminium oxide nanoparticles and results were plotted. It was examined that the cutting temperature and surface finish get raised with varying fraction of AL_2O_3 nanoparticles. The study also revealed less cutting force, wear rate and also decrease in negative ecological effects, owing to AL_2O_3 nanoparticles inclusion to MQL in turning nickel based Inconel 600 alloy.

Ali et al. [21] investigated the impact of MQL by oil on various output parameters such as tool wear, cutting force and tool wear in machining carbon steel at different cutting speed, feed and depth of cut. The outcomes showed the decrease in tool wear of carbide insert, improved surface roughness and dimensional accuracy of carbon steel using MQL as compared to dry cutting. The results also revealed that MQL can significantly enhance profitability, quality of machined product and over all machining characteristics.

Behara et al. [22] studied the tool wear of physical layer deposition of titanium nitride coated carbide inserts during machining of two alloys nickel based Nimonic 90 and titanium based Ti -6Al-4V.The turning operation had been done under completely dry cutting and MQL mode in order to fulfill the sustainability criteria. The uniquely prepared fine dispersion of minute droplets of sunflower oil with water was used as lubricant to increase the effectiveness of MQL. It has been observed that high nose wear was caused during turning of nickel alloy Nimonic 90. Greater strength of nickel alloy when compared with titanium alloy brought about high nose wear over the inserts during machining. Furthermore, the MQL technique utilizing biodegradable emulsion made better outcomes for Ti -6Al-4V. The properties like excellent weldability and immense penetration resulted in minor rake and flank wear during turning of Titanium based alloy under MQL environment. The experimental findings showed that the controlled wear during machining of Ti-6Al-4V resulted in lesser cutting forces as compared to Nimonic 90.

Kumar et al. [23] investigated the role of MQL method in surface finish in machining of AISI 4340 work piece with cubic boron nitride tool. The process variable chosen during machining operation were cutting speed in rpm, feed rate mm/rev and nose radius in mm with five different levels. The model of surface roughness was devised utilizing regression analysis. The results obtained by Analysis of Variance showed that MQL helps in enhancing the surface quality when differentiated with completely dry and flood cooling.

Prasad et al. [24] examined the utilization of nano graphite particle suspended in cutting oil for turning operation of AISI 1040 steel by high speed steel and carbide tool. The nano materials were developed using nano technology technique by spreading them in the oil which improved the performance of the oil and hence graphite powder is chosen of size 80 micro meter in distinct proportion. Experimentation was done at distinct flow rates with nano graphite particles suspended cutting oil together with dry cutting, flood machining. The results were quite fruitful demonstrating reduction in temperature, flank wear and surface roughness.

Amrita et al. [25] compared the performance of dry cutting, wet cutting and mist of soluble oil with mist of nano graphite particle soluble oil in turning of AISI 1040 workpiece. The performance was eventually studied by measuring the temperature, cutting forces and tool wear. The outcomes demonstrated that by employing mist supply nano graphite soluble oil had immensely enhanced the cutting conditions by lowering the temperature, forces and tool wear too.

Gaitonde et al. [26] determined the optimum quantity of flow rate and the most suitable cutting speed and feed by performing turning operation on brass workpiece utilizing carbide tool. The experiments were conducted by applying Taguchi's method with each trail performed at various conditions of flow rate, cutting speed and feed-. The optimal level of input parameters was determined by Analysis of Variance (ANOVA) and Analysis of Mean (ANOM). The results obtained by optimization technique showed that flow rate of 200ml/h, feed rate of 0.05 mm/rev and cutting speed 200m/min were essential to reduce both cutting force and surface roughness.

Ramana et al. [27] investigated the optimization of input parameters in lathe turningof Titanium alloy under various machining environment utilizing Taguchi methodology on tool wear rate. The process parameters selected were machining environment, cutting speed,feed, depth of cut and type of tool material. From Analysis of Mean, it was observed that minimum quantity lubrication and uncoated cutting tool performed better thereby lowering the tool wear rate. By utilizing ANOVA the impact of each process parameters on tool wear observed to be important and the involvement of cutting speed is more trailed by cutting tool material, feed rate, coolant and depth of cut with a specific goal to reduce tool wear.

Bagherzadeh and Budak [28] studied different kind of cooling strategies performed on hard machining on nickel and titanium alloys. Types of strategies used were carbon dioxide delivery system, modified carbon dioxide nozzle, combination of carbon dioxide and MQL and CMQL technique to optimize response parameters which were surface roughness, tool wear and temperature. After comparing the outcomes for various techniques study revealed that the CMQL is welcoming techniques that enhance tool life up to sixty percent and furthermore increase the surface quality in contrast with other lubrication systems.

Hadad and Sadeghi [29] performed machining operation on steel workpiece AISI 4140 and studied the effect of cutting parameters and nozzle position under dry, wet and MQL machining**.** The Ester oil lubricant is utilized in MQL machining and water mixable in a 10% concentration for wet turning. MQL flow rate was 30 ml/h at a pressure of 3 bar. The turning process was carried out at three different cutting velocity 50.2, 100.4 and 141.4 m/min, depth of cut 0.5, 1 and 1.5 mm and feed 0.09 and 0.22 mm/rev to obtain the values of output parameters surface roughness, cutting force, and temperature. It was accounted that nozzle position of MQL system plays an important role in MQL turning process. In contrast with dry cutting and flood machining all the machining forces extraordinarily decreased in MQL condition when oil impinged to the rake face. Surface roughness also improved in MQL conditions at 0.09mm/rev feed rate and 141.4m/min cutting velocity. Present study also revealed that the tool-chip temperature in machining steel by supplying of oil mist is approximately 350°C less in comparison to dry machining.

V. CONCLUSION

There is enough literature which clearly suggested that MQL provide better outcomes in comparison to dry and wet machining. MQL in which pressurized air at certain pressure mix with minute amount of lubricant directly to cutting/tool workpiece interface instead of using conventional flood coolant. MQL utilize less amount of lubricant which leads to economic benefits like saving of lubricant cost and machine cleaning time and it also minimizes environmental impact by significantly reduce fluid usage. This method significantly affects the machining characteristics such as improved surface quality; reduce tool wear and reduction in cutting force. Therefore, it is clear that MQL not only improve machining characteristics but also enhances environmental conditions. Thus, considering its machining characteristics, environment friendliness and economy it can be concluded that MQL is a possible alternative in future different machining operation in comparison to the traditional processes.

Table (2b)
Comparison of different workpiece by using dry, flood and MQL

References no Year/	**Work material**	**Tool material**	**Cutting parameters**	**Machining environment**	**Output responses**	**Remarks**
[2]/2016	AISI 1040 Steel	Uncoated cemented carbide.	V_c=96.7m/min f= 0.1 mm/rev d.o.c= 1.0 mm P= 5 bar	Dry, wet, MQL conventional and Nanofluid with MQL	Cutting forces, Tool wear, Surface roughness and Chip sample	Cutting forces, Tool wear and Surface roughness improves in MQL nano cutting fluid, chip sample colour in dry

						was blue in wet was silver, in MQL was light golden and in MQL nano cutting was silver.
[3]/2016	AISI 4340 Steel	Uncoated carbide insert.	V_c=110m/min f=0.16mm/rev d.o.c=1.5mm P=7.0 bar	Dry, wet and MQL.	Tool wear and Surface roughness	Reduced tool wear and improves tool life, better surface finish compared to dry and wet.
[4]/2014	AISI D_2 steel	Tungsten carbide insert	V_c=79,96,130 m/min f= 0.5,0.10,016 mm/rev d.o.c= 1 mm	Dry and MQL machining.	Cutting temperature, surface finish and micro hardness.	Cutting temperature reduce by 50% in MQL, surface finish improves and micro hardness has no effect with mql but increase in dry cutting.
[11]/2016	Nimonic-90	Multilayer tungsten carbide insert	V_c= 60m/min f= 0.12mm/rev d.o.c= 0.5mm	Dry, wet and MQL	Cutting force, tool wear and chip morphology	Cutting force reduce, tribo layer formed of AL_2O_3 reduces tool wear.
[14]/2008	Aluminum 6061 alloy	Diamond coated carbide tool	V_c= 400m/min f= 0.15mm/rev d.o.c= 1.0mm	Dry, MQL and flooded cooling	Tool wear, surface roughness and cutting force.	Tool wear reduced increase tool life, surface quality improved and cutting force also lowered.
[15]/2011	Inconel 718	PVD coated TiAlN carbide tool.	V_c=90,120 150m/min f=0.10,0.15 d.o.c= 0.30,0.50 mm	Dry and MQL	Surface roughness, surface texture and microstructure. .	MQL at 50ml/hr produces better surface finish, smoother surface texture and change of microstructure of workpiece under MQL at 50ml/hr was less.
[16]/2006	AISI 1040 steel	Uncoated carbide insert.	V_c= 64,80,110,130 m/min f= 010,013,016,020	Dry, wet and MQL	Cutting temperature, chip reduction ratio	Cutting temperature reduced improve the

			mm/rev d.o.c= 1.0mm			chip tool interaction, Dimensional accuracy improved due to reduction of wear.
[17]/2014	En -31 steel	Diamond shape carbide tool.	V_c= 39,112,89 m/min f= 0.06,010,0.15 mm/rev d.o.c= 0.2,0.4,0.6 mm	Dry ,wet and MQL	Surface roughness	Surface roughness obtained in 10% boric acid mixed with SEA 40 base oil could be attributed due to retention of insert sharpness due to lower wear and plastic deformation at reduced cutting temperature.
[18]/2015	Carbon-St-52-3	Uncoated cemented carbide.	V_c= 95 m/min f=0.142mm/rev d.o.c=1.0 mm	Dry and MQL	Cutting forces	Less cutting force by 17% for MQL machining actually means less power consumption in terms of energy saving.
[19]/2009	AISI 9310 steel	Uncoated carbide insert	V_c=223,246,348, 483 m/min f= 0.10,0.13,0.16,0.18 mm/rev d.o.c= 1.0 mm	Dry, wet and MQL	Cutting temperature, chip pattern, tool wear and surface roughness.	Reduction in cutting temperature by 10%, ribbon type and tubular type chip at lower and higher feed rate, surface finish also improves due to reduction of wear, reduction in flank wear.
[20]/2012	Inconel 600 alloy	Coated carbide	V_c= 40,50,60 m/min f=0.08,0.12,0.16 mm/rev d.o.c= 0.4,0.8,1.2 mm	Dry, wet, MQL nano particle	Surface roughness, Temperature, Cutting force and tool wear	Surface quality improves, temperature and force reduce, tool wear reduce improve tool

						life with 6% volume of AL_2O_3 nano particle MQL.
[21]/2011	Medium carbon steel	Uncoated carbide insert	V_c=68,95,133, 190,266 m/min f=0.10,0.12,0.14, 0.18,0.20 mm/rev d.o.c= 1.0 , 1.5 mm	MQL	Chip thickness ratio, cutting temperature, cutting force, tool wear and surface roughness.	MQL provide effective cooling at the shear zone which reduce temperature, reduction in flank wear improve tool life, surface finish improved. reduction in cutting zone temperature main reason behind reduction of cutting force by MQL.
[22]/2016	Nimonic-90 and Ti-6Al-4V	PVD coated carbide insert	V_c=60,120 m/min f= 0.15,0.25 mm/rev d.o.c= 0.5 mm	Dry and MQL	Flank and rake wear, cutting force.	Good wet ability behavior of Ti-6Al-4V under MQL provide less flank wear at high speed, due to high tool edge wear and notch wear very high and unstable cutting force are observed while machining.
[23]/2017	AISI-4340 steel	CBN tool	V_c=75,100,125, 150,175 m/min f=0.1,0.125,0.15, 0.175,0.2 mm/rev d.o.c= 0.2 mm	MQL	Surface roughness.	Surface quality improves 7 to 10% with MQL because in MQL convective as well as evaporative heat transfer occurs.
[24]/2013	AISI -1040 steel	HSS and cemented carbide tool	V_c=105 m/min. f=0.14 mm/rev d.o.c= 1mm	MQL nano particle	Cutting force and tool flank wear.	To reduce cutting force and tool flank wear 0.3% nano graphite particle

						inclusion at 15ml/hr can be taken as best combination.
[25]/2013	AISI 1040 steel	HSS and cemented carbide	V_c= 40.7 m/min f= 0.14 mm/rev d.o.c=1 mm	Dry, flooded, mist with nano graphite.	Cutting temperature, tool wear and cutting force	Minimum tool wear, temperature and cutting force were obtained at flow rate of 15ml/hr with 0.5 wt mist with nano graphite soluble oil.
[26]/2007	Brass	K10 –carbide	V_c= 100,200,400 m/min f= 0.05,0.10,0.15 mm/rev d.o.c= 2 mm	MQL	Surface roughness and specific cutting force	The optimum MQL of 200ml/hr, cutting speed of 200m/min and a feed rate of 0.05 mm/rev is necessary to minimize surface roughness and specific cutting force.
[27]/2017	Titanium alloy Ti-6Al-4V	Carbide tool	V_c=63,79,99m/min f=0.206,0.274, 0.343 mm/rev d.o.c=0.6,1.0, 1.6mm	Dry, flooded and MQL	Tool wear.	The optimum value of cutting speed of 63m/min, feed of 0.274, and depth of cut is 1 mm for minimum tool wear in MQL machining
[28]/2018	Ti-6Al-4V and inconel-718	Uncoated carbide insert	V_c=100,150m/min f=0.2mm d.o.c =1mm	CO_2 Cooling system , CO_2 +MQL, CMQL, Cryogenic CO2 cooling methods	Tool wear, surface roughness ,chip morphology, Cutting temperature.	CMQL method with fixed cooling rate increase tool life along with enhance surface quality, Temperature pointed out that CMQL results in higher heat removal efficiency

						compared to others.
[29]/2013	AISI 4140 steel	HSS tool steel	V_c =50.2, 100.4, 141.4 m/min, f= 0.09, 0.22 mm/rev, d.o.c= 0.5, 1, 1.5 mm	Dry, Wet, MQL	Force, temperature and surface roughness.	Surface finish improved mainly due to reduction of wear, cutting force and temperature were also reduced.

Here V_c, f and d.oc are the cutting speed, feed and depth of cut respectively.

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