



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 4, April 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com



A REVIEW OF MINIMUM QUANTITY LUBRICANT ON MACHINING PERFORMANCE

V. Bala Sathya, R. Malarvizhi, S. Siva and S. Thanga Dhinesh

Department of Mechanical Engineering,
St. Mother Theresa Engineering College,
Vagaikkulam, Thoothukudi, India

ABSTRACT

This paper reviews the effect of minimum quantity lubricant (MQL) on machining performance. Minimum quantity of lubrication in machining is an established alternative to completely dry or flood lubricating system from the viewpoint of cost, ecology and human health issues. The effect of MQL, dry cutting and flooded coolant were reviewed with respect to cutting forces, surface roughness of the machined work piece and tool wear. Results from literatures indicated that the MQL leads to lower cutting forces, reduced surface roughness and tool wear. Therefore, it appears that MQL, if properly employed not only provides environment friendliness but also improve the machinability characteristics.

Keywords: minimum quantity lubricant, cutting forces, surface roughness, tool wear

INTRODUCTION

In recent years, energy consumption, air pollution and industrial waste have been the focus of special attention on the part of public authorities. The environment has become one of the most important subjects within the context of modern life, for its degradation directly impacts humanity. Driven by pressure from environmental agencies, politicians have drawn up increasingly strict legislation aimed at protecting the environment and preserving natural energy resources. These combined factors have led the industrial sector, research centers and universities to seek alternative production processes, creating technologies that minimize or avoid the production of environmentally aggressive residues. In high speed machining, conventional cutting fluid application fails to penetrate into chip-tool interface and thus cannot remove heat effectively (Dhar et al., 2000). Addition of extreme pressure additives in the cutting fluids does not ensure penetration of coolant at the chip-tool interface to provide lubrication and cooling (Boothroyd and Cassin, 1965). However, high pressure jet of soluble oil, when applied at the chip-tool interface, could reduce cutting temperature and improve tool life to some extent (Kubala et al., 1989). Due to several negative effects, a lot has been done in recent past to minimize or even

completely avoid the use of cutting fluids (Sokovic and Mijanovic, 2001). Dry machining is now of great interest and actually, they meet with success in the field of environmentally friendly manufacturing (Klocke and Eisenblatter, 1997, 1999). In reality, however, they are sometimes less effective when higher machining efficiency, better surface finish quality and severe cutting conditions are required. For these situations, semi-dry operations utilizing very small amount of cutting fluids are expected to become a powerful tool and, in fact, they already play a significant role in a number of practical applications (Sutherland, 2000; Suda et al. 2001; McCabe and Ostaraff, 2001).

Minimum quantity lubricant in machining is an alternative to completely dry or flood lubricating system, which has been considered as one of the solutions for reducing the amount of lubricant to address the environmental, economical and mechanical process performance concerns (Heinemann et al., 2006). MQL refers to the use of only a minute amount of cutting fluids typically at a flow rate of 50–500 ml/h. Many researchers have suggested the MQL technique in machining process (Rahman et al., 2001; Davim et al., 2006; Machado and Wallbank, 1997). Dhar et al. (2006) were used this technique in turning process and concluded that MQL has been shown to be better than flood cooling. Lugscheider et al., (1997) applied this technique in reaming process of grey cast iron and aluminium alloy with coated carbide tools. The significant reduction in tool wear and improvement in surface quality of the holes have been observed by using MQL when compared to dry cutting.

The drilling of aluminium-silicon alloys is one of those process where dry cutting impossible due to high ductility of the workpiece material (Braga et al., 1999). Without cooling and lubrication, the chip sticks to the tool and breaks it in a very short cutting time. Therefore, in this process a good alternative is the use of MQL technique (Rahman, 2004). Kelly and Cotterell (2002) were investigated the role of different coolant application methods in the drilling of a 30 mm aluminum alloy ACP 5080 plate with a brinell hardness of 85. Drilling was carried out on a Hurco BMC-20 three-axis computerized numerical control (CNC) machining centre using a 10 mm high speed steel twist drills. It was revealed that the MQL technique is preferable for higher cutting speeds and feed rates. This review reports on the effect of minimum quantity lubricant with respect on the tool wear, cutting forces and surface roughness produced during machining.

WORKING PRINCIPLE OF MQL SYSTEM

The MQL needs to be supplied at high pressure and impinged at high speed through the nozzle on the cutting zone. Considering the conditions required for the present research work and uninterrupted supply of MQL at a constant pressure of around 6 bar over a reasonably long cut, a MQL delivery system was designed, fabricated and used. The typical schematic view of the MQL set-up is shown in Figure 1 (Khan et al., 2009). In this system, a compressor was used to supply air at a high-pressure of 10 bar. This high- pressure air from the compressor entered into two chambers like fluid chamber and mixing chamber at two different but pre-selected pressures of 10 and 6 bar respectively. The fluid chamber was connected to the mixing chamber at the bottom by very small diameter flexible tube. This tube was passed through a roller-type flow controller to permit a little amount of fluid to flow under high pressure. The compressed air entering into the inlet port created pressure to cause the fluid to flow continuously to the mixing chamber through controller at a constant rate. The air and the vegetable oil were mixed in the mixing chamber so that the mixture of vegetable oil and air impinged at a high



velocity through the nozzle on the chip–tool interface. During experimentation, the thin but high velocity stream of MQL was projected at the tip of the cutting tool along the auxiliary cutting edge making an angle 15° with it. Consequently, the coolant reached as close to the chip–tool and the work–tool interfaces as possible. The MQL jet was used mainly

to target the rake and flank surface and to protect the auxiliary flank to enable better dimensional accuracy. The typical photographic view of the experimental set-up is shown in Figure 2.

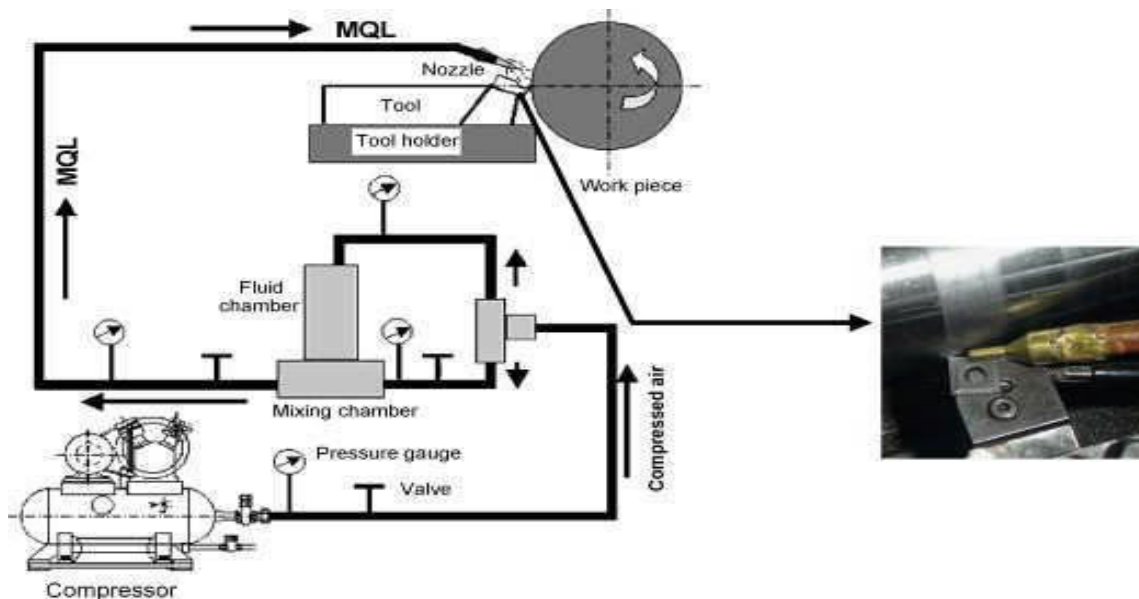


Figure 1: Typical schematic view of MQL unit (Khan et al. 2009).

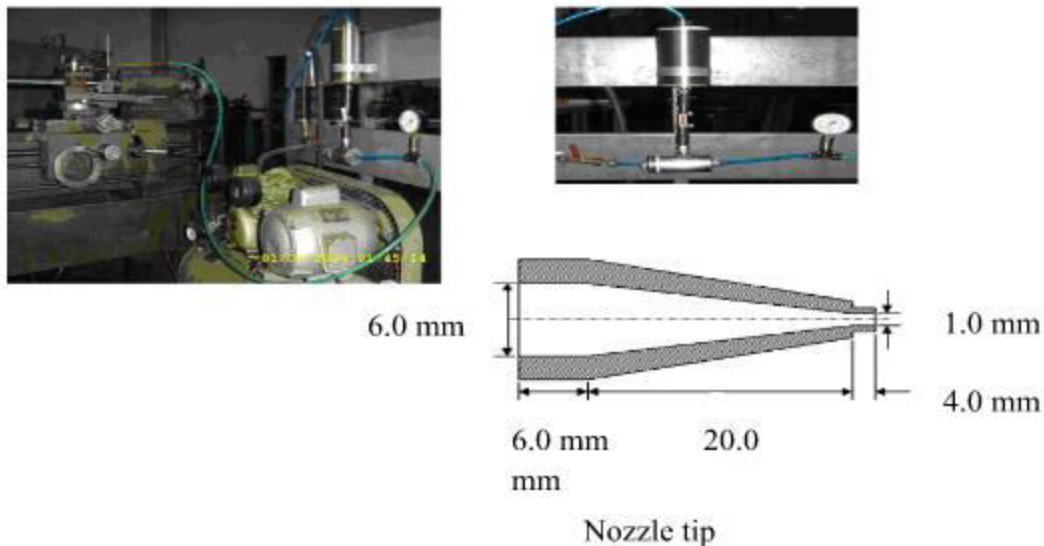


Figure 2: Photographic view of the experimental set-up (Khan et al. 2009).

Two different mixing methods can be used in application of MQL which are mixing inside nozzle and mixing outside nozzle. Using the mixing inside nozzle equipment, pressurized air and lubricant are mixed into the nozzle by a mixing device, as shown in Figure 3a. The lubrication is obtained by the lubricant supplied by the system, while a minimal cooling action is achieved by the pressurized air that reaches the cutting surface. Several advantages derive applying this method. Mist and dangerous vapours are reduced and the mixture setting is very easy to control. In the mixing outside nozzle method as shown in Figure 3b, the mixture is obtained in a mixing device

positioned in a specific tank. Also, in this case lubrication between workpiece and tools can be achieved. As already seen, MQL provides a cooling action that often is negligible. But is it necessary to cool workpieces and tools. Nowadays there are several cutting operations where cooling is undesirable, because the induced thermal shock could cause tool failure. An example is the finish machining of hardened steel using cubic bore nitride (CBN) or polycrystalline diamond (PCD) tools, where dry cutting is mainly performed. In these cases, MQL is said to provide several advantages in terms of tool wear reduction. Other MQL advantages (depending on the low lubricant quantity) are chip, workpiece and tool holder have a low residue of lubricant and their cleaning is easier. During machining the working area is not flooded so, if necessary, the cutting operation can be readily observed. On the other hand, the main limit of the MQL method is its inability to cool the cutting surface. This means that MQL is not able to furnish advantages, if it is applied in a cutting operation where cooling action is strongly required, like in grinding. In these cases it is very important correctly to define the conditions that allow the MQL technique to be applied with real benefits.

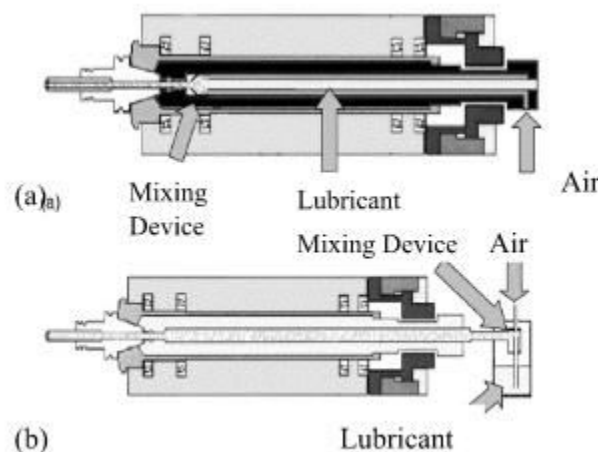


Figure 3: Mixing methods: (a) inside and (b) outside nozzles.

EFFECT MQL ON TOOL WEAR

Tool wear, which results in tool substitution, is one of the most important economical penalties to take into account during cutting. Thus it is very important to improve tool life, minimizing the wear and



optimizing all the cutting parameters and factors: depth of cut, cutting velocity, feed rate, cutting fluids and cutting fluids application. In cutting operations fluids play an important role. They must mainly guarantee lubrication and cooling, secondly protect workpiece and tool from corrosion and promote the chip evacuation. During machining, at all cutting environments, work material adhered to the edges of the tool, but the quantity adhered material varied with the type of coolant environment. Lugscheider et al. (1997) applied this technique in reaming process of grey cast iron and aluminium alloy with coated carbide tools. The significant reduction in tool wear and improvement in surface quality of the holes have been observed using MQL technique when compared to dry cutting. Wakabayashi et al. (1998) in their turning process investigations were found that the flank wear rate with MQL application of a mineral oil-based agent at 2 ml/h (two nozzles: one directed at the rake-face, and the other at the flank) was comparable to that with conventional flooding, and superior to that with dry cutting, during turning of AISI 4340 steel with coated carbide tools at high cutting speeds (400 m/min).

The lubricating action of the oil was credited with achieving this improvement over dry cutting, and the use of MQL agents with moderately reactive EP constituents was recommended. Another important tool wear criteria is average auxiliary flank wear, V_s , which governs the surface finish on the job as well as dimensional accuracy. Irregular and higher auxiliary flank wear leads to poor surface finish and dimensional inaccuracy (Klocke and Eisenblatter, 1999). The growths of average auxiliary flank wear, V_s with time of machining of the steel under dry, wet and MQL conditions have been shown in Figure 4. The nature of growth of V_s matches with that of V_b expectedly. The application of MQL has reduced V_s , which is expected to provide better surface finish.

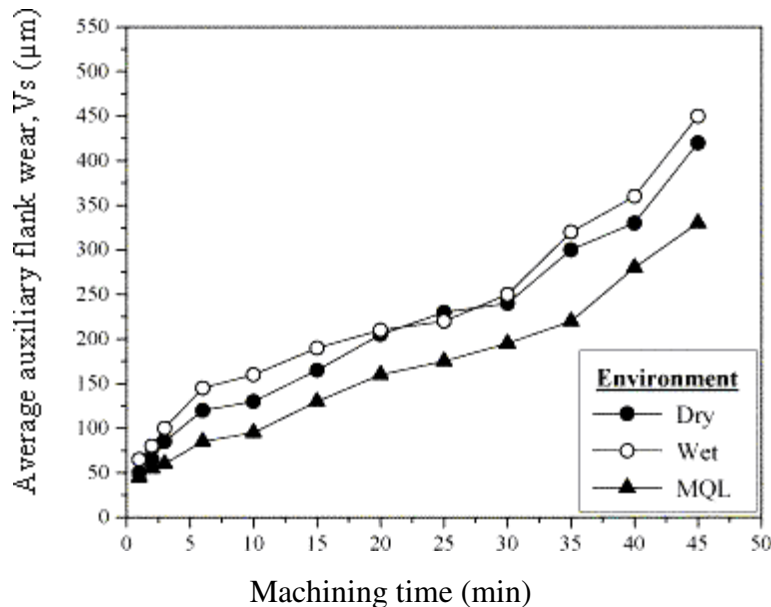


Figure 4: Growth of average auxiliary flank wear, V_s with time under dry, wet and MQL conditions.

In addition of that, Diniz et al. (2003) were found that during turning of hardened 52100 steel with cubic boron nitride tools at moderate cutting speeds (110 m/min), dry cutting yielded the lowest flank

wear, while directing a compressed air jet at the cutting zone caused the highest flank wear. The proposed explanation for this observation was that lack of any cooling action under dry condition enhances thermal softening of workpiece material, thus making cutting easier, whereas the cooling action of an air jet causes the reverse effect by promoting strain hardening in the work material. MQL was found to perform slightly better than plain compressed air, and this was explained to be occurring because the lubricating effect of the oil partly mitigated the increased forces (arising from lack of thermal softening) due to the compressed air jet of the MQL supply. A similar hypothesis was suggested for the case of conventional flooding, which ranked intermediate to MQL and dry in terms of flank wear. Dhar et al. (2006) were reported that the growth in average flank wear, V_B , on the main cutting edge under dry, wet (conventional cooling with 1:20 soluble oil) and MQL conditions (Figure 5). The gradual growth of V_B , the predominant parameter to ascertain expiry of tool life, observed under all the environments indicates steady machining without any premature tool failure by chipping, fracturing, etc. establishing proper choice of domain of process parameters.

Figure 5 also clearly shows that flank wear, V_B particularly its rate of growth decreased by MQL. The cause behind reduction in V_B observed may reasonably be attributed to reduction in the flank temperature by MQL, which helped in reducing abrasion wear by retaining tool hardness and also adhesion and diffusion types of wear which are highly sensitive to temperature. Because of such reduction in rate of growth of flank wear the tool life would be much higher if MQL is properly applied.

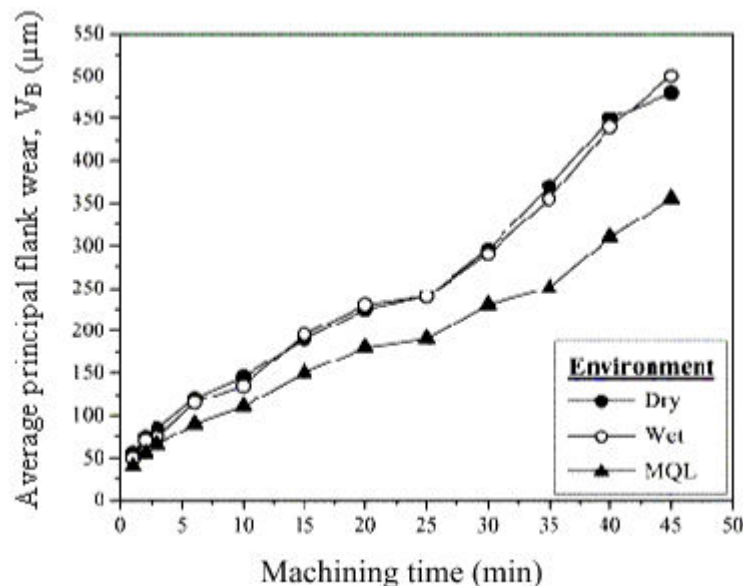


Figure 5: Growth of average principal flank wear, V_B with machining time under dry, wet and MQL conditions.

Besides that, Srejith (2008) was conducted investigations in turning process of aluminium alloys stated that the speed of machining increased from 50 to 400 m/min, the adhesion between the tool and the chip also increased correspondingly. This could be due to the increase in thermal softening of the chip



as the temperature increased with the increase in cutting speed. The adhesion of the work material to the tool was observed to be having the highest rate during dry cutting. The material adhesion was seen all over the tool surfaces like flank, rake and clearance surfaces especially when the speed of machining was increased from 250 to 400 m/min. The quantity of the adhered material reduced considerably with flooded coolant compared to the dry cutting operation. During MQL machining, the amount of material adhered was seen to be more compared with flooded coolant and less compared to dry machining. As the quantity of the lubricant was increased from 50 ml/h to 100 ml/h during MQL, there was not any considerable reduction in the adhered material. The larger amount of adhered material during MQL conditions may be due to the tool geometry.

Khan et al. (2009) were carried out experiments by plain turning alloy steel using lathe machine stated under all the environments, abrasive scratch marks appeared in the flanks. There were some indications of adhesive wear in the insert. Severe groove wear at the flank surfaces were found in insert under dry and wet conditions. Some plastic deformation and micro chipping were found to occur under dry machining. Effective temperature control with MQL by vegetable oil almost reduced the growth of groove wear on the main cutting edge as well as auxiliary cutting edges. Further, Figure 6 clearly shows reduced average principal flank wear the predominant parameter to ascertain expiry of tool life, observed under all the environments indicates steady machining without any premature tool failure by chipping, fracturing etc. establishing proper choice of domain of process parameters, and average auxiliary flank wear under MQL by vegetable oil condition.

Khan et al. (2009) were extended discussion stated the significant contribution of MQL jet in machining the low alloy steel by the carbide insert undertaken has been the reduction in flank wear, which would enable either remarkable improvement in tool life or enhancement of productivity (MRR) allowing higher cutting velocity and feed. Such reduction in tool wear might have been possible for retardation of abrasion, decrease or prevention of adhesion and diffusion type thermal sensitivity wear at the flanks and reduction of built-up edge formation that accelerates wear at the cutting edges by chipping and flaking. Minimum quantity lubrication reduces deep grooving, which is very detrimental and may cause premature and catastrophic failure of the cutting tools.

CONCLUSION

Results from the previous research indicated that the use of minimum quantity lubricant (MQL) leads to lower cutting forces, reduce tool wear and decrease in surface roughness and since MQL conditions can be applied to the machining, it seems that this process has got economic advantage. Surface finish in MQL improves mainly due to reduction of wear and damage at the tool tip by the application of MQL. MQL also reduce the cutting forces by favorable change in the chip-tool interaction and retention of cutting edge sharpness due to reduction of cutting temperature seemed to be the main reason behind reduction of cutting forces by MQL. Besides that MQL jet provided reduced tool wear, improved tool life and better surface finish as compared to dry and wet machining and finally became powerful condition in order to enhance the machining performance.



ACKNOWLEDGMENT

This work has been funded by Universiti Malaysia Pahang under RDU090398. The authors are also grateful to the Faculty of Mechanical Engineering, Universiti Malaysia Pahang for laboratory facilities.

REFERENCES

- Boothroyd, G. and Cassin, C. 1965. Lubrication action of cutting fluids. *Journal of Mechanical Engineering Science*, 7(1): 67-81.
- Braga, D.U., Diniz, A.E., Miranda, G. and Coppini, N.L. 1999. Minimal lubrication in the drilling process of aluminum-silicon alloy-A356 (SAE 323). *Proceedings of the Third International Machining and Grinding Conference, USA*, pp. 683-697.
- Braga, D.U., Diniz, A.E., Miranda, G. and Coppini, N.L. 2002. Using minimum quantity of lubricant (MQL) and a diamond coated tool in the drilling of aluminum-silicon alloys. *Journal of Materials Processing Technology*, 122 : 127-138.
- Davim, J. P., Sreejith, P.S., Gomes, R. and Peixoto, C. 2006. Experimental studies on drilling of aluminum (AA0150) under dry, minimum quantity lubricant, and flooded-lubricated conditions. *Proc. ImechE. Part B: Journal of Engineering and Manufacturing*, 220: 1605-1611.
- Dhar, N.R., Ahmed, M.T. and Islam, S. 2007. An experimental investigation on effect of minimum quantity lubrication in machining AISI 1040 steel. *International Journal of Machine Tools and Manufacture*, 47(5): 748-753.
- Dhar, N.R., Kamaruzzaman, M. and Ahmed, M. 2006b. Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel. *Journal of Materials Processing Technology*, 172(2): 299-304.
- Dhar, N.R., S., Paul. and Chattopadhyay, A.B. 2000. Beneficial effects of cryogenic cooling over dry and wet machining on tool wear and surface finish in turning AISI 1060 steel. *Proceedings of ICAMT-2000, Malaysia*, pp. 209-214.
- Diniz, A.E., Ferreira, J.R. and Filho, F.T. 2003. Influence of refrigeration/lubrication condition on SAE 52100 hardened steel turning at several cutting speeds. *International Journal of Machine Tools and Manufacture*, 43(3): 317-326.
- Gaitonde, V.N., Karnik, S.R., and Davim, J.P. 2008. Selection of optimal MQL and cutting conditions for enhancing machinability in turning of brass. *Journal of Materials Processing Technology*, 204(1-3): 459-464.
- Heinemann, R., Hinduja, S., Barrow, G. and Petuelli, G. 2006. Effect of MQL on the tool life of small twist drills in deep-hole drilling. *International Journal of Machine Tools and Manufacture*, 4(1): 1-6.
- Islam, M.W., Dhar, N.R., Islam, S. and Mithu, M.A.H. 2006. The influence of minimum quantity of lubrication (MQL) on cutting temperature, chip and dimensional accuracy in turning AISI-1040 steel. *Journal of Materials Processing Technology*, 171(1): 93-99.
- Kelly, J.F.M. and Cotterell, G. 2002. Minimal lubrication machining of aluminium alloys. *Journal of Materials Processing Technology*, 120(1-3): 327-334.



Khan, M.M., A. Mithu, M.A.H. and Dhar, N.R. 2009. Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid. *Journal of Materials Processing Technology*, 209(15-16): 5573-5583.

Kishawy, H.A., Dumitrescu, M., Ng, E.G. and Elbestawi, M.A. 2005. Effect of coolant strategy on tool performance, chip morphology and surface quality during high-speed machining of A356 aluminium alloy. *International Journal of Machine Tools and Manufacture*, 45(2): 219–227.

Klocke, F. and Eisenblatter, G. 1999. Coted tools for metal cutting-features and application, *CIRP*, 48(2): 515-525.

Klocke, F., and Eisenblatter, G. 1997. Proceedings of the opening session of the dry cutting. *CIRP. Annals*, 46(2): 519-526.



INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.423



ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

9940 572 462 **6381 907 438** **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details