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COMPARATIVE STUDY OF CONVENTIONAL AND MINIMUM QUANTITY LUBRICATION (MQL) DURING MACHINING 17-4PH STAINLESS STEEL

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Abstract
In the recent years, 17-4PH martensitic stainless steel has assumed considerable significance in strategic applications primarily in the field of aerospace engineering. It is typically used to manufacture heavy load components such as fasteners, valves, gears, aircraft fittings, coupling, hydraulic actuators, rocket & missile components, jet engines, parts of nuclear reactor, the shafts and blades of steam turbine etc. Therefore, this material has strong potential to replace more costly titanium alloys. However, some of its properties such as low thermal conductivity, high toughness, tendency to strain harden make it difficult to machine. Heat generation during cutting is, therefore, a common problem necessitating extraction of heat using cutting fluid. However, use of cutting fluid is not a very environment-friendly option for which it is essential to determine if minimization of usage of cutting fluid can yield satisfactory results. The current study, therefore, investigates the use of minimum quantity lubrication (MQL) during turning of 17-PH stainless steel and compares its performance with that of conventional wet (flood) cooling. Variation of machining parameters such as cutting velocity (40–105m/min), feed (0.08 –0.2mm/rev) and depth of cut (0.5 – 1mm) has been investigated on cutting force, surface roughness, chip reduction coefficient and chip morphology. The experimental results indicate that MQL causes decrease of surface roughness with increase in depth of cut and cutting velocity when compared with flood cooling. It was also noted that chip reduction co-efficient for MQL is lower than flood cooling. Therefore, it appears that MQL, if properly used, not only provides environment friendliness but can also improve the machinability characteristics

Keywords: Minimum quantity lubrication (MQL), 17-4PH stainless steel, surface roughness, cutting forces, chip morphology.

1. Introduction

The increasing need for higher productivity, product quality in the manufacturing fields requires higher material removal rate and long life and high stability of the cutting tools. Higher productivity is achieved by increasing the parameters like depth of cut, feed and cutting velocity, but these are associated by high cutting temperature and large amount of heat. This high temperature not only affects the tool life but also destroy the surface integrity of the final product. The conventional coolant application fails to penetrate the chip tool interface, which cannot efficiently remove the heat generated during machining [1, 2]. Moreover this cutting fluid has so many adverse effects too, such as it may pollute water resources and soil affecting the environment. On the shop floor, operators may get affected by skin and breathing issues due to repeated contact with cutting fluids [3].

In order to minimize this problem a new technique has been developed known as Minimum Quantity Lubrication (MQL). As the name indicates MQL uses a minute amount of cutting fluid—normally a flow rate of 50–500 ml/h which is nearly three to four orders of magnitude lesser than the quantity normally used in flood cooling condition [7]. MQL system of lubrication includes mixture of high pressurised air (6 bar) with oil which is being used as the lubricant in machining. Air at high pressure is mixed with the oil in the mixing chamber and is directly supplied to the machining zone through nozzle, this high pressurized air ensures penetration of coolant onto chip tool interface to provide cooling and lubrication, and this oil will get evaporated by absorbing the temperature generated at the machining zone.

Many researchers have tried to find out the benefits of minimum quantity lubrication in machining processes.MQL method has been used for turning of AISI 1040steel [4]. Their outcomes of study showed that MQL machining is superior than conventional flood cooling method. Machado et al. [6] conducted an experiment on turning AISI 1040 using this method and concluded that ,in cases of chip thickness, force variation and surface finish.MQL affected all these responses positively compared to results obtained with the flood coolant. The benefit over flood cooling condition is obtained by reducing the cutting temperature. From the earlier works surface roughness was found to be less in case of minimum quantity lubrication environment compared to flood cooling [4,5].
The present work experimentally investigates the role of minimum quantity lubrication on cutting force, chip reduction coefficient and surface roughness in plain turning of 17-4PH stainless steel at different speed, feed and depth of cut combinations by uncoated carbide insert and compares the effectiveness of MQL with that conventional cutting fluid.

2. EXPERIMENTAL SETUP .

For the experiment 17-4PH steel of length 620mm and diameter 42mm was used, and turned in a heavy duty lathe machine (Maker: Hindustan Machine Tools (HMT) Ltd.) The turning experiment was conducted for conventional cooling conditions and MQL system conditions. The tool used for the experiment is uncoated cemented carbide insert.

To conduct the turning experiment using minimum quantity lubrication (MQL) technique set up was developed, shown in Fig.3. Highly compressed air is supplied into the air filter from a compressor through a solenoid valve. All the impurities are filtered that may present in the supplied air to keep it clean and dirt free. During this process oil control valves guided the oil to the mixing chamber. In mixing chamber the oil and the filtered air mixed to form oil-mist. The prepared oil-mist mixture is supplied to the cutting zone through a nozzle to target dimensional accuracy. The experimental design was based on Taguchi L9 orthogonal array, the turning process was carried by varying the parameters cutting velocity, feed and depth. The turning of 17-4PH stainless steel was carried out under the following experimental conditions as summarised in Table.1. MQL is expected to provide some favourable effects mainly through reduction in cutting temperature.

Fig.1: Experimental setup for flood cooling

The parameters varied during the machining are cutting velocity, feed of cut and depth of cut. During the experiment cutting forces are measured with help of a dynamometer, and surface roughness was measured after the experiment with a profilometer (maker: Taylor Hobson: Sutronic). For each experiment chips were chips were collected and chip thickness is measured with the help of digital Vernier calliper thus determining chip reduction coefficient. The photographic view of both type experimental setup is shown is shown in Fig.1 and Fig.2.

Fig.2: Experimental setup for MQL

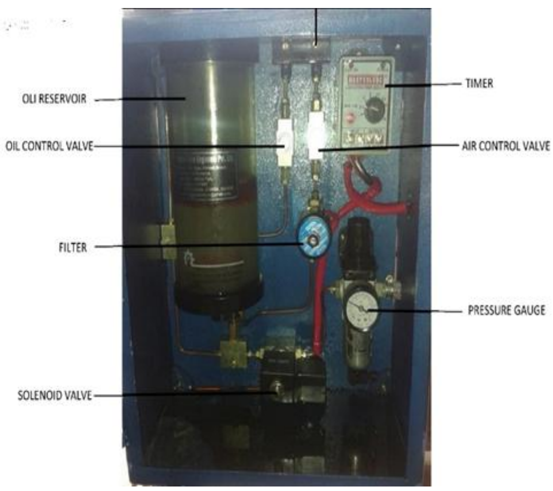


Fig.3: Set-up for Mixing Air and Oil

Table.1: Experimental conditions for turning operation

Workpiece Material	17-4PH stainless steel
Tool Insert	Uncoated cemented carbide insert
Cutting velocity(m/min)	47,61,103
Feed(mm/rev)	0.08,0.14,0.20
Depth of cut(mm)	0.5,1.0,1.5
Length of cut(mm)	15
Environment	MQL

3. EXPERIMENTAL RESULTS

During the machining of ductile materials, heat is generated at the (i) primary deformation zone due to plastic and shear plastic deformation, (ii) tool-chip interface due to sliding and secondary deformation and (iii)tool-work interfaces cause by rubbing. These heat sources create high temperature at the tool-chip interface, which considerably influence the cutting forces, chip formation mode and tool life [10]. With increasing cutting velocity, cutting force decreases both under flood cooling and MQL.This reduction is related to decrease in chip tool interface friction and increase in cutting temperature thus softening the work material. It is important to note that MQL technique is somewhat effective in reducing cutting force, particularly under low and moderate velocity. However the same technique was not beneficial due to difficulty in penetration of atomized fluid into machining zone under high cutting speed. Obvious increase in cutting force with feed and depth of cut is also noted, both the cases Minimum Quantity Lubrication environment effectively reduce the cutting force. A maximum reduction of 9.17% of have obtained for current study. Main effect plot for cutting force (FZ) as a function of different cutting parameter under MQL and flood cooling condition has been shown in Fig.4

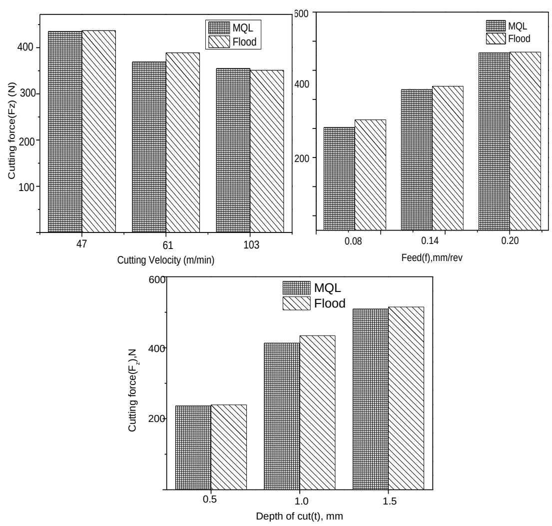


Fig.4 Main effect plot for cutting force(F_z) under flood cooling and MQL environment

The major sources behind development of surface roughness in continuous machining processes like turning, particularly of any ductile metals are (i) regular feed marks left by the tool tip on the machined surface, (ii) uneven deformation of the auxiliary cutting edge at the tool-tip due to wear, fracturing and chipping, (iii) vibration in the machining system, and (iv) built-up edge(BUE) formation.

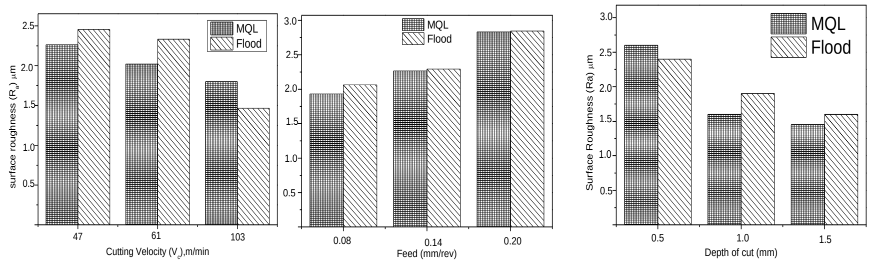


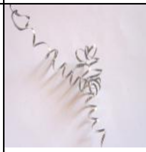
Fig.5 Main effect plot for surface roughness (Ra) under flood cooling and MQL environment

Main effect plot for surface roughness (Ra) as a function of different cutting parameter under MQL and flood cooling condition is shown in Fig.5. It was found that surface roughness improves with cutting velocity. At lower cutting velocity under MQL condition better surface finish is obtained, but at higher cutting velocity flood cooling gives better surface finish. At all values of feed rate surface roughness is found to be more in case of MQL when compared to flood cooling. For lower depth of cut MQL environmental machining conditions gave poor surface finish when compared with flood cooling environment. But at higher depth of cut s MQL environment became superior to the flood cooling when surface roughness property is considered. At high feed and depth of cut MQL appeared to be effective in reducing surface roughness, even though it is not much beneficial at high cutting speed. A maximum reduction in surface roughness of 35.69% has been obtained under current study. It is obvious that MQL improves surface finish depending upon the work–tool materials and mainly by controlling the deterioration of the auxiliary cutting edge by chipping, built-up edge formation and abrasion. The application of MQL has lowered auxiliary flank wear, which is predicted to provide better surface finish. The air-oil mixture could easily enter into the tool-chip interface forming a thin layer which prevent formation of BUE and abrasion wear [2]. Also lesser tool wear and reduction in machining temperature which prevent machining environment, it lowers the surface roughness [6]. Tool life get improved in MQL condition. In absence of chip breaker, length and uniformity of chips grows with the increase in ductility and softness of the work piece material,

Table.2: Chip morphology

CONDITION	FLOOD	MQL
Cutting Speed=47m/min Feed=0.20mm/rev Depth of cut=1.5mm		
Cutting Speed=61m/min Feed=0.14mm/rev Depth of cut=1.5mm		

tool rake

Cutting Speed=103m/min Feed=0.08mm/rev Depth of Cut=1.5mm		
Cutting Speed=47m/min Feed=0.14mm/rev Depth of cut=1mm		
Cutting Speed=61m/min Feed=0.08mm/rev Depth of Cut=1mm		
Cutting Speed=103m/min Feed=0.20mm/rev Depth of Cut=1mm		
Cutting Speed=47m/min Feed=0.08mm/rev Depth of Cut=0.5mm		
Cutting Speed=61m/min Feed=0.20mm/rev Depth of cut =.5mm		
Cutting Speed=103m/min Feed=0.14mm/rev Depth of Cut=0.5mm		

angle and cutting velocity unless the chip–tool contact is adverse causing rigorous friction and built-up edge generation. [4] Table.2 shows the photographs of chips collected after each run. It was found that almost in all cases chips formed are continuous. But the chips produced under high depth of cut and feed found to be discontinuous and of ‘C’ type.

6. Conclusion

The current work was undertaken comparatively to evaluate the performance of MQL condition and conventional cooling during the machining of 17-4PH stainless steel. The effect of various cutting parameters(cutting velocity, feed and depth of cut) on different machinability characteristics were studied with the help of Taguchi L9 orthogonal array method. The study resulted in the following conclusions

1. MQL was effective in bringing down the cutting force in low and medium cutting velocity, a maximum reduction of 9.17% have obtained in the current study.
2. MQL also obtained superior surface finish compared to flood cooling, surface finish has been improved

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to a maximum of 35.69% under t e current study. But under high cutting speed condition flood cooling provided better finish.

3. Due to superior chip to tool interface under MQL decrease in chip reduction coefficient has been noted in MQL, however no significant variation in macro morphology of chip was observed.

Therefore MQL is a promising technique during machining of difficult to machine materials like 17-4PH, reduction in productivity due to less cutting velocity can be compensated by high feed and depth of cut.

References

[1] M.C. Shaw et al,. "Effect of cutting fluid upon chip–tool interface temperature" Trans. ASME 71 (1951) 45–56.

[2] S. Paul et al,."Beneficial effects of cryogenic cooling over dry and wet machining on tool wear and surface finish in turning" AISI-1060 steel, in: Proceedings of the ICAMT- 2000, Malaysia, 2000, pp. 209–214.

[3] M. Sokovic et al,. "Ecological aspects of the cutting fluidsand its influence on quantifiable parameters of the cutting processes" J. Mater. Process. Technol. 109 (12) (2001) 181–189

[4] N.R. Dhar , M.W. Islama, S. Islama, M.A.H. Mithu"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 (2006) 93–99

[5]T. Tawakoli et al., "Influence of oil mist parameters on minimum quantity lubrication – MQL grinding process "International Journal of Machine Tools & Manufacture 50 (2010) 521–531

[6] A. R. Machado et al., "The effect of extremely low lubricant volumes in machining" International Journal on the Science and Technology of Friction, Lubrication and Wear, 210 (1997) 76-82

[7]N.R. Dhar ∗, M. Kamruzzaman, Mahiuddin Ahmed "Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel". Journal of Materials Processing Technology 172 (2006) 299–304

[8] J.Sharma et al., "Investigation of effects of dry and near dry machining on AISI D2 steel using vegetable oil". Journal of Cleaner Production 2014, 66, 619-623

[9]Rodrigues L.L.R et al., "Effect of Cutting Parameters on Surface Roughness and Cutting Force in Turning Mild Steel". Research Journal of Recent Sciences Vol. 1(10), 19-26, October (2012)

[10] Dhar, N. R., Ahmed, M.T. and Islam, S. "An experimental investigation on effect of minimum quantity lubrication in machining AISI 1040 steel". International Journal of Machine Tools & Manufacture 2007,47, 748–753

[11] Li, K. M et al., "Performance profiling of minimum quantity lubrication in machining". International Journal of Advanced Manufacturing Technology 2007, 35, 226–233.

[12]Kishawy, H.A et al., "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 & Manufacture 2005, 45, 219–227.

[13]M. M. A Khanet al., "Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid". Journal of Materials Processing Technology 2009, 209, 5573–5583.

[14]Hadad, Met al., “Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy”. Journal of Cleaner Production 2013, 54, 332-343.

[15]He, J., Pei, H., Chu, Y, Wang, S. and Wang, G. “MQL Application in high-speed turning bearing steel.” Applied Mechanics and Materials 2014, 490-491, 306-310.

[16]Rosemar Batista Da Silva. “Turning of Medium Carbon Steel with Vegetable-Based Oil delivered by MQL” 22nd International Congress of Mechanical Engineering (COBEM 2013)

[17]S.B.Kedare et al.,. “T. Effect of Minimum Quantity Lubrication (MQL) on Surface Roughness of Mild Steel of 15HRC on Universal Milling Machine”.3rd International Conference on Materials Processing and Characterization (ICMPC 2014)

[18]Kapil Sharma1, Dalgobind Mahto2 and S.S. Sen . “In metal turning, effect of various parameters on cutting tool: A Review ”International Journal of Application or Innovation in Engineering & Management (IJAIEM)Volume 2, Issue 8, August 2013

[19] Troy D. Marusich, “Effect of friction and cutting speed on cutting force.”Third Wave Systems, Inc Minneapolis, MN

[20] S. Thamizhmanii, Rosli, S.Hasan “A study of minimum quantity lubrication on Inconel 718 steel”. Achieves of material science and engineering, volume 39, issue 1 September 2009