MQL - An Efficient Alternative for Dry and Flood Lubricant Conditions in Machining of 304 Stainless Steel

K.Nimel Sworna Ross
Department of Mechanical Engineering
DMI College of Engineering,Chennai,India

D.S.Ezhumalai
Department of Mechanical Engineering
Loyola Institute of Technology,Chennai,India

A.Anbazhagan
Department of Mechanical Engineering
Loyola Institute of Technology,Chennai,India

Abstract- In the current world scenario the use of new high strength alloys is increasing, owing to the fact that these alloys are difficult to machine due to high temperature generated during machining. In our current work a detail analysis of the effect of dry, minimum quantity lubrication (MQL), and flood coolant/lubrication conditions were made with respect to the parameters like, cutting force, depth of cut and surface roughness by milling 304 stainless steel. It has been found that MQL condition is a very good alternative to flood and dry machining condition and the same can replace the dry and flood coolant/lubrication environment which is presently employed in most of the cutting and machining applications. Moreover, this machining technique is environmental friendly and it will surely improve the machinability characteristics.

Keywords – Milling,304 stainless steel,MQL

I. INTRODUCTION

In simple terms, MQL is a technique which sprays small amount of cutting fluid (in the range of approximately 10 – 100 ml/h) to the cutting zone area with the aid of compressed air. The overall performance result of which was better than dry and conventional wet milling, which is beneficial for environment. [1,2]. AISI 304, due to its good corrosion resistance and biocompatibility, is used in the medical field for implant material nevertheless it is still prone to pitting corrosion. Their low thermal conductivity leads to bad heat conduction at the tool tip and locally to very hot points [3,4]. Austenitic stainless steels were found to have a widespread use in the nuclear industry due to their desirable mechanical properties and resistance to corrosion in aqueous solution environments [5]. However, there are inherent difficulties in machining AISI 304 steels. Their low heat conductivity, high ductility, high tensile strength, and high work hardening rate usually generate a series of machining problems such as build-up edge formation which ultimately deteriorates the surface quality of the finished surface [6, 7]. To this end, the use of coolant can generally limit the amount of resulting surface damage [8]. Surface integrity plays a vital in the design of components for the nuclear industry, since it directly influences corrosion and fatigue resistance [9]. Surface defects resulting from the milling process, such as cracks, are preferential sites for stress corrosion cracking (SCC) and can ultimately lead to the premature failure of the component when coupled with high residual tensile stresses [10].

Keeping all the above facts in mind we have developed a new technique MQL in machining of 304 stainless steel. Further various machinability characteristics have also been analysed and reported in our present work.

II. EXPERIMENTAL SETUP

Generally, milling operation is carried out in order to characterize the response of surface integrity to different cutting parameters. The specification of the milling process has been summarized below in Table 1.

Table-1 Specification of the milling machine

spindle speed range	45 to 2000 rpm
spindle motor power	5.5 KW or more .
vertical movement	70 mm or more
No of speeds	12 or more.

The elemental composition and the various mechanical properties of 304 stainless steel have been tabulated in Table 2 and Table 3 respectively.

Table-2 Material properties

Grade	C	Mn	Si	P	S
304	0.08%	2.0%	0.75%	0.045%	0.030

Table-3 Mechanical properties

Tensile strength MPa	Yield strength MPa	Elongation (% in 50 mm)min	Hardness Rockwell HRB max	Hardness Brinell HB max
515	205	40	92	201

A special type of fixture has been designed to fix the work piece as shown in the Figure 1. The dimension of the work piece material has been fixed as 50x50x30 mm as shown in Figure 2**.**

Figure 1.Workpiece holder

Figure 2.Workpiece

The tool used in this project is End mill cutter. Material is HSS, with helix angle 30º, shank 12mm diameter and flute length of 30mm.

The following conditions were maintained during machining, which has been summarized in Table 3.

Table-3 Machining Condition

Dry	Wet	MQL
No coolant	Soluble oil with water, ratio 1:20	Mustard oil and compressed air, 4 ml/min

III. RESULT AND DISCUSSIONS

a) Surface Roughness

The surface roughness (Ra) values of the work piece have been measured parallel to the feed direction. The feed given was 0.5m, 0.8m and 1.0m. MQL method gave better surface finish than dry and flood coolant condition. The Ra value was found to increase at a higher cutting speed. From the graph (Fig.3), it is very clear that the roughness of the surface decreased with the application of coolant. Soluble oil used in the wet condition and in MQL condition, mustard oil is mixed with pressurized air from the compressor. The outlet pressure from the nozzle is 4ml/min in MQL setup.

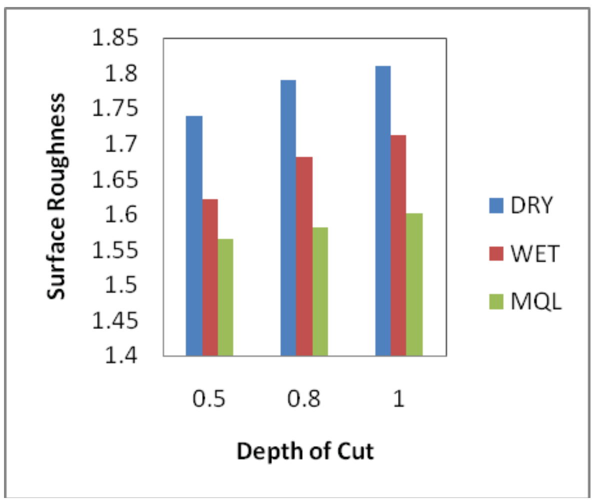

Figure 3. Surface Roughness

b) Material Removal Rate

The Material Removal Rate has been observed in different environmental conditions (Fig 4.). The time taken in MQL is lesser when compared to wet and dry conditions. Depth of cut taken is 0.5cm, 0.8cm and 1.0cm. The spindle speed is 325 rpm. The time taken in MQL is 40sec, 46sec and 51sec for the above mentioned depth of cuts. In dry condition Material Removal Rate takes more time for machining because of no lubrication and cooling.

$$MRR = \frac{Vol.\ Removed}{CT} = \frac{L*W*t}{CT} = W*t*f_m$$

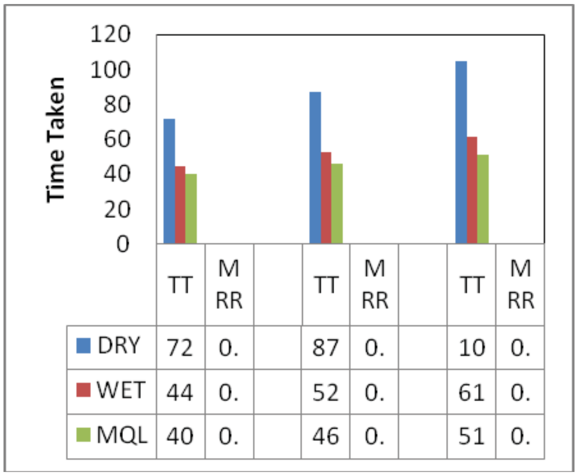

Figure 4. Material Removal Rate

C) Chip recycling

Metal chip processing is a common practice in manufacturing to collect and treat metal wastes (eg. chips) for recycling revenue from chip re-melting is often a significant component of a plant's operating budget. In web machining, chips typically must be dried before transport to a remelter to avoid contaminating roadways. Chip drying is expensive as it requires energy and floor space.

During MQL machining, the metal chips produced are nearly dry and virtually clean. The near dry chips do not require drying and thus bring more net revenue to the plant.

d) Tool wear

During machining, at all cutting environments, it was found that the material adhered at the edges of the tool. But the quantity of material adhered at the tool vary from types of environments (Fig.5). In dry cutting process, the adhesion of work material to the tool was very high. The adhesion of material was seen all over the tool surface. The adhesion of material reduced in flood coolant condition, when compared to dry process. In MQL condition, depending upon the amount of flow, adhesion varies. Amount of flow used in this process was 4 ml/min at 0.5mm, 0.8mm and 1.0mm depth of cuts.

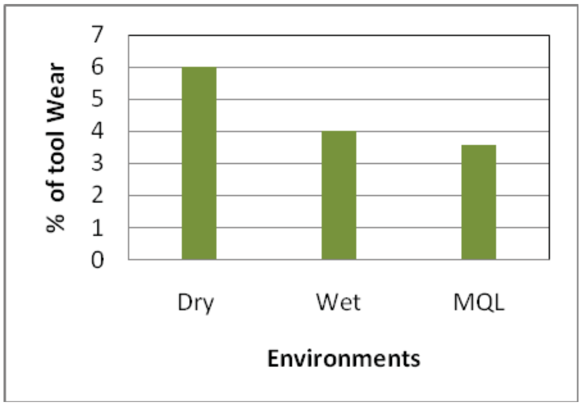

Figure 5. Tool Wear Percentage

IV. CONCLUSION

Upon summarizing, our current work developed using different conditions during machining. MQL technology which is still new. Moreover, it has been well documented that MQL were able to produce better results when comparatively with that of flood coolant conditions. It has been found that, the application of coolant does not necessarily reduce tool wear since at MQL condition the tool wear was found to be low. Further, the cutting performance of MQL has also been observed to be better than that of dry and conventional flood coolant machining. Hence, undoubtedly MQL provides the benefit of reducing the cutting temperature, which improves the chip tool interaction and maintains sharpness of the cutting edge.

REFERENCES

[1] Dhar, N. R., Kamruzzaman, M., and Ahmed, M. (2006). Effect of Minimum Quantity Lubrication (MQL) on Tool Wear and Surface Roughness in Turning AISI-4340 Steel, Journal of Materials Processing Technology. 172: 299–304.
[2] Byrne, G., Dornfeld, D., and Denkena, B. (2003).Advancing Cutting Technology, Annals CIRP 52: 483–507. Erence
[3] C. Maranhão, J. Paulo Davim, Finite Element Modelling of Machining of AISI 316 Steel: Numerical Simulation and Experimental Validation, Simulation Modelling Practice and Theory 18 (2010) 139–156. J. Van der Geer, J.A.J. Hanraads, R.A. Lupton, The art of writing a scientific article, J. Sci. Commun. 163 (2000) 51–59.
[4] P.J. Arrazola, I. Arriola, M.A. Davies, Analysis of the Influence of Tool Type, Coatings, and Machinability on the Thermal Fields in Orthogonal Machining of AISI 4140 Steels, CIRP Annals – Manufacturing Technology 58 (2009) 85–88.
[5] M.C. Bloom, C.N. Newport, W.A. Fraser, Journal of The Electrochemical Society, 111 (1964) 1343-1347.
[6] K. Tetal, Machining of Stainless Steels, in: ASM Handbook: Machining, Vol. 16 (Ed. by J.R. Davis), ASM International, USA, 1989, pp. 681-707.
[7] M.P. Groover, Fundamental of Modern Manufacturing-Materials Processes and Systems, Prentice-Hall, Englewood Cliffs, NJ, USA, 1990.
[8] F. Jiang, J. Li, L. Yan, J. Sun, S. Zhang, Int J Adv Manuf Technol, 51 (2010) 841-851.
[9] S. Ghosh, V. Kain, Journal of Nuclear Materials, 403 (2010) 62-67. [10] W. Li, Y.Guo, C. Guo, CIRP Annals – Manufacturing Technology, 62 (2013) 567-570.
[10] Mohammadjafar Hadad, Banafsheh Sadeghi Minimum quantity lubrication-MQL turning of AISI 4140 steel alloy, Journal of Cleaner Production 54 (2013) 332-343.