Environment Friendly Machining of Different Engineering Materials: A Review

Tauseef Uddin Siddiqui, Vaibhav Chait
Department of Mechanical Engineering, F.E.T, M.J.P. Rohilkhand University, Bareilly, Uttar Pradesh 243006 (INDIA)
***Email*: tauseefuddin.siddiqui@mjpru.ac.in, vaibhav1chait@gmail.com**
Received 09.02.2021 received in revised form 11.12.2021, accepted 17.01.2022

DOI: 10.47904/IJSKIT.13.3.2023.44-46

Abstract- **Due to several regulations imposed by the National Green Tribunal (NGT) on dangerous emissions from industrial waste, environmentally friendly machining is becoming essential ingredient among industrial sector in a sustainable manner. This machining process is capable of significant reduction in waste by remanufacturing, reuse and recycling. This machining process covers an in-depth overview of these operations and practices which are most environmentally sustainable. In the paper different machining operations with applications of minimal quantity lubrication (MQL) are discussed for different engineering materials. This paper also enlighten on energy conservation during machining with useful data and results obtained under these Environment-friendly sustainable machining operations.**

Keywords-Environmentally friendly machining, Minimal quantity lubrication, Surface finish, Tool life, Tool Wear

1. INTRODUCTION

Machining is most useful industrial operation in current practice. The removal of material takes place by virtue of plastic deformationof workpiece. Heat is generated due to friction at tool-workpiece interface etc. Heat generated will make negative impact on tool life and workpiece surface characteristics etc. Therefore, removal of this heat is necessary during maching operation. Several ways have been adopted for dissipation of this heat at machining interface. Various organic coolants have been used for this purpose but they have adverse effect on the environment and operator's health. Therefore, some noval ways are under progress to eliminate this problem of environment contamination which is mentioned below:
-Dry machining
-Cryogenic cooling
-Coated tools
-MQL

There all techniques are in use at R&D stage and have some advantages and limitations as well as. Out of these methods, MQL technique is more users friendly and in practice to achieve eco-friendly sustainable manufacturing environment [18, 19, 20]. The objective of this paper is to explore the different applications of MQL techniques in machining of different engineering materials.

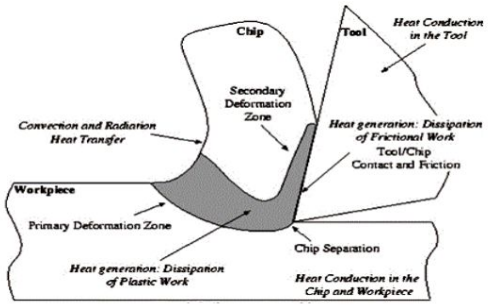

Fig. 1: The zones of heat generated during machining [1]

2. REVIEW STUDIES

Sachin and Nilesh (2018) conducted machining of M2 Steel using MQL. Non-edible oil is used as cutting fluid prepared using aloevera gel and cotton seed oil. Surface roughness and tool wear decreases by 6.7% and 0.14% respectively as compared to conventional cutting fluid as shown in Figure 2. There is reduction in amount of air pollution found as compared to conventional organic mineral oil.

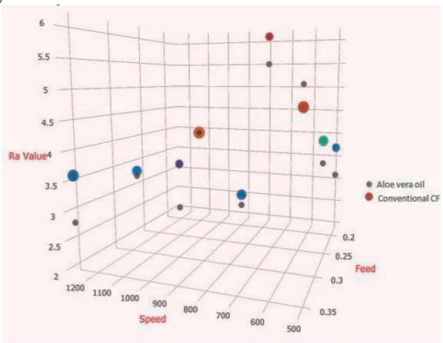

Fig. 2: Comparison of R_a vs. speed and feed for Aloe vera oil and conventional CF [1]

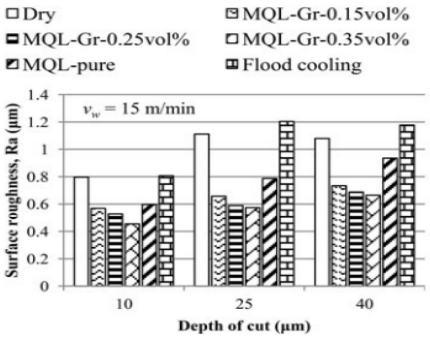

Fig. 3: Surface roughness across the grinding direction vs. depth of cut at different cooling conditions [6]

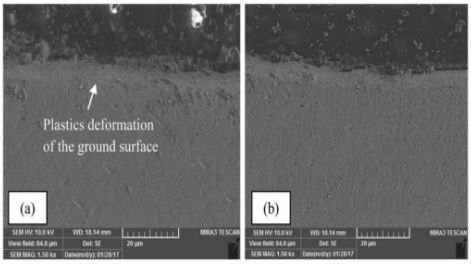

Fig. 4: SEM images of cross-section of ground surfaces; (a) Flood cooling and (b) 0.35 vol. % graphite nanofluid MQL grinding [6]

Mirsadegh et al. (2019) has performed grinding of Hardened AISI 1045 Steel using graphite nanofluid MQL. Significant reduction of 60 and 66.7% in grinding temperatures is obtained in comparison to flood and dry grinding. Surface roughness decreases by 49.93% and 34.56% in comparison to the flood cooling in grinding.

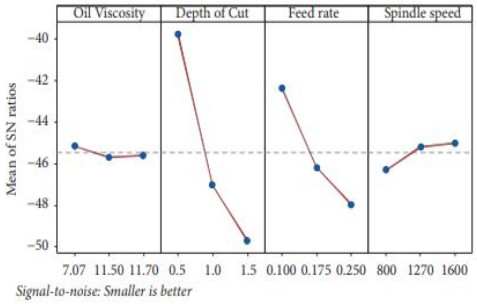

Fig. 5: Main effects plot for cutting force [2]

Xiao et al. (2012) conducted high speed end milling of Ti–6Al–4V alloy using MQL. Significant reduction is obtained in cutting forces and surface roughness. The coating of the tools also improves under MQL than flood coolant due to decrease in coating delamination. Mehmet et al. (2016) used hexagonal boron nitride (hBN) due to its superior lubrication behavior. Certain improvement found in tribological properties of tool and workpiece material etc. Jeevan and Jayaram (2018) conducted turning of AA 6061 alloy using Jatropha and Pongamia oil MQL. Significant improvements are obtained in cutting forces, flank wear and surface roughness in comparison to mineral oil. It was found from the S/N ratio (Fig. 5), Jatropha oil outperformed Pongomia oil and Mineral oil. Results obtained from main effect plot showed that Pongomia oil outperformed Jatropha oil and Mineral oil (Fig. 6).

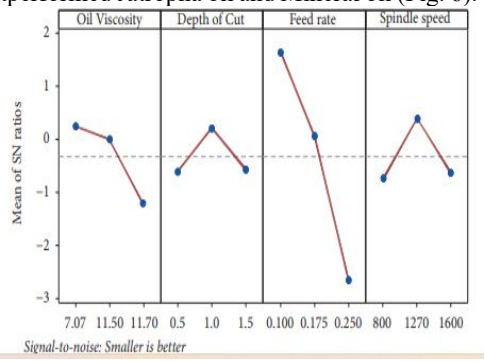

Fig. 6: Main effects plot for surface roughness [2]

Rahul et al. (2019) has discussed different aspects of green and sustainable grinding operation using different nanofluids. Significant improvement found in grinding performance due to better heat transfer properties of nanofluid MQL. Al_2O_3 nanofluid gives better lubrication performance in terms of lower surface roughness, specific grinding energy and grinding force ratio as compared to pure SiC nanofluid.

Sidik et al. (2017) discussed use of Al_2O_3, CNT, MoS_2, Diamond nanoparticles with different vegetable oils (Coconut/ Jatropha/ Soyabean) during different machining operations. It was found that these nanofluids are very useful in enhancing heat transfer and cooling rate during machining. They also reduce friction and wear at machining interface. But there are some problems associated with them such as poor stability and high production cost. Some new prospects of hybrid nanofluids were also discussed.

Suresh and Amitava (2019) conducted an experimental investigation to study behavior of Sunflower Oil in MQL in End Milling of AA1050. Sunflower oil is attempted because of its good wettability and lubrication characteristics. The coefficient of friction decreases from 0.5 to 0.1. The uncoated carbide end mill showed better results as compared to diamond coated tools under dry and MQL conditions. The surface roughness by MCD coated tool was higher as compared to other tools. Pereiraa, et al. (2015) used the hybrid CO_2+MQL in end milling operation. It was found that at higher cutting, lubrication is done effectively in the machining zone. CO_2+MQL hybrid cooling method found more sustainable and environment friendly alternative as compared to other

lubrication methods used during machining operations.

Aqilah et al. (2021) conducted the machining of AISI 4340 steel using green lubrication techniques. Significant improvement obtained in tool wear, cutting force, surface roughness and chip formation. It was found that increase in material removal rate results in reduced machining cost. Certain improvements found in tool life in case of CM and HSM dry and MQL supply under different operating conditions (Fig. 7).

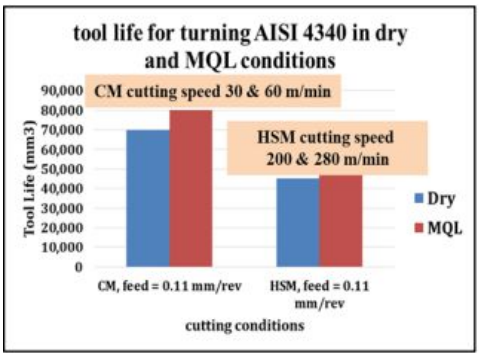

Fig. 7: Comparison of tool life between conventional machining (CM) and high-speed machining (HSM) under dry and MQL conditions [12]

Sharma et al. (2021) reviewed the different aspects of Environmental friendly machining in current scenario. Improvement in surface quality and tool life is obtained which results in improved machinability and productivity of the operation. By proper waste disposal, the cost effectiveness and efficiency of the operation can be enhanced.

3. CONCLUSIONS

Various researches have been reviewed in this paper to explore the application of different types of MQL fluids used to achieve Environment-friendly machining in a sustainable manner. This MQL will help to achieve reduction in surface roughness, tool wear and certain improvements in triboloical properties of workpiece material. Several techniques are used for preparation of different cutting fluids using either edible or non-edible oil.

This review paper will be effectively applied in generating knowledge and in-depth understanding of application of these eco-friendly lubrication techniques to resolve problems of environmental contamination in engineering materials.

4. REFERENCES

[1] Agarwal S. M, Patil N. G, "Experimental study of non edible vegetable oil as a cutting fluid in machining of M2 Steel using MQL", 2nd International Conference on Materials Manufacturing and Design Engineering (2018).

[2] Cai X J, Liu Z Q, Chen M, Long An Q, "An experimental investigation on the effects of minimum quantity lubrication oil supply rate in high-speed end milling of Ti–6Al–4V", Journal of Engineering Manufacture (2012).

[3] Chakule R, Chaudhari S., Talmale P, "Recent advances in green and sustainable manufacturing grinding process: A review", Journal of Nanoscience and Technology (2019).

[4] Iyappan S K, Ghosh A, "Small Quantity Lubrication Assisted End Milling of Aluminium Using Sunflower Oil", International Journal of Precision Engineering and Manufacturing-Green Technology (2019).

[5] O. Pereiraa, P. Catalab, A.Rodrigueza, T. Ostrac, J. Vivancosb, A. Riveroc, L. N. Lópezde-Lacalle, "The use of hybrid CO2+MQL in machining operations", The Manufacturing Engineering Society International Conference, MESIC (2015).

[6] Seyedzavvar M, Shabgard M., Mohammadpourfard M, Investigation into the performance of eco-friendly graphite nanofluid as lubricant in MQL grinding, Machining science and technology (2019).

[7] Sidik N A C, Samion S, Ghaderian J, Recent progress on the application of nanofluids in minimum quantity lubrication machining: A review, International Journal of Heat and Mass Transfer (2017).

[8] Upahdyay, N. Environmentally Friendly Machining: Vegetable Based Cutting Fluid, SAMRIDDHI, S-JPSET: 7 (2015).

[9] Gupta, K, "A Review on Green Machining Techniques", Procedia manufacturing, 51 (2020).

[10] Sen. B, Mia. M, Krolczyk. GM, Mandal. UK, Mondal. SP, "Eco Friendly Cutting Fluids in Minimum Quantity Lubrication Assisted Machining: A Review on the Perception of Sustainable Manufacturing", International Journal of Precision Engineering and Manufacturing-Green Technology, 8 (2021).

[11] Gokce Mehmet, Yapincak Goncu, Nuran AY, "Environmentally friendly material: Hexagonal boron nitride", BORON 1 (2), (2016), 66-73.

[12] Ahsana Aqilah Ahmad, Jaharah A. Ghani, Che Hassan Che Haron, "Green lubrication technique for sustainable machining of AISI 4340 alloy steel", Jurnal Tribologi 28 (2021), 1-19.

[13] T. P. Jeevan, S. R. Jayaram, "Performance Evaluation of Jatropha and Pongamia Oil Based Environmentally Friendly Cutting Fluids for Turning AA 6061", Advances in Tribology (2018), 9.

[14] K.M.Li, S.K. Liang, "Modeling of cutting force in near dry machining", International journal of machine tools and manufacturing (2007), 1292-1301.

[15] Y. M. Shashidhara, S.R. Jayaram, "Vegetable Oils as a Potential Cutting Fluid—an Evolution", Tribology International 43 (2010), 1073-1081.

[16] Lawal, S. A., Choudhury I. A., Nukman Y., "Application of Vegetable Oil-Based Metalworking Fluids in Machining Ferrous Metals—a Review", Int J Mach Tool Manu (2012) 52, 1-12.

[17] L.D. Lacalle, "Experimental and numerical investigation of the effect of spray cutting fluids in high speed millin". Journal of materials processing technology (2006), 172(11), 11-15.

[18] G.C. Nie, X.M. Zhang, D. Zhang, H. Ding, H., "An experimental study of the white layer formation during cryogenic assisted hard machining of AISI 52100 steel", Procedia CIRP 77(2018), 223-226.

[19] R. Sharma, B. K. Jha, V. Pahuja, "Impact of environmental friendly machining on machinability: A review", Materials Today: Proceedings (2020).

[20] Sharma, R. Jha, B K, Pahuja, V., "A Comprehensive Review on Evaluation of Environmental Friendly Machinability, Cutting Fluids and Techniques in Metal Cutting Operation", International Journal of Advanced Research (2021), 9(04), 223-235.