An Experimental Investigation on Vegetable Oils as a Cutting Fluid under Minimum Quantity Lubrication: A Sustainable Machining Approach

Shrikant U. Gunjal[1*],Sudarshan B. Sanap[2], Nilesh C. Ghuge[3], Satish Chinchanikar[4]

[1*]*Research Scholar, MIT Art, Design and Technology University, Pune, India*
[2]*Professor, MIT Art, Design and Technology University, Pune, India*
[3]*Professor, Matoshri College of Engineering and Research Center, Nashik, India*
[4]*Profesor, Vishwakarma Institute of Information Technology, Pune, India*
[1]*shrikant.gunjal@mituniversity.edu.in*

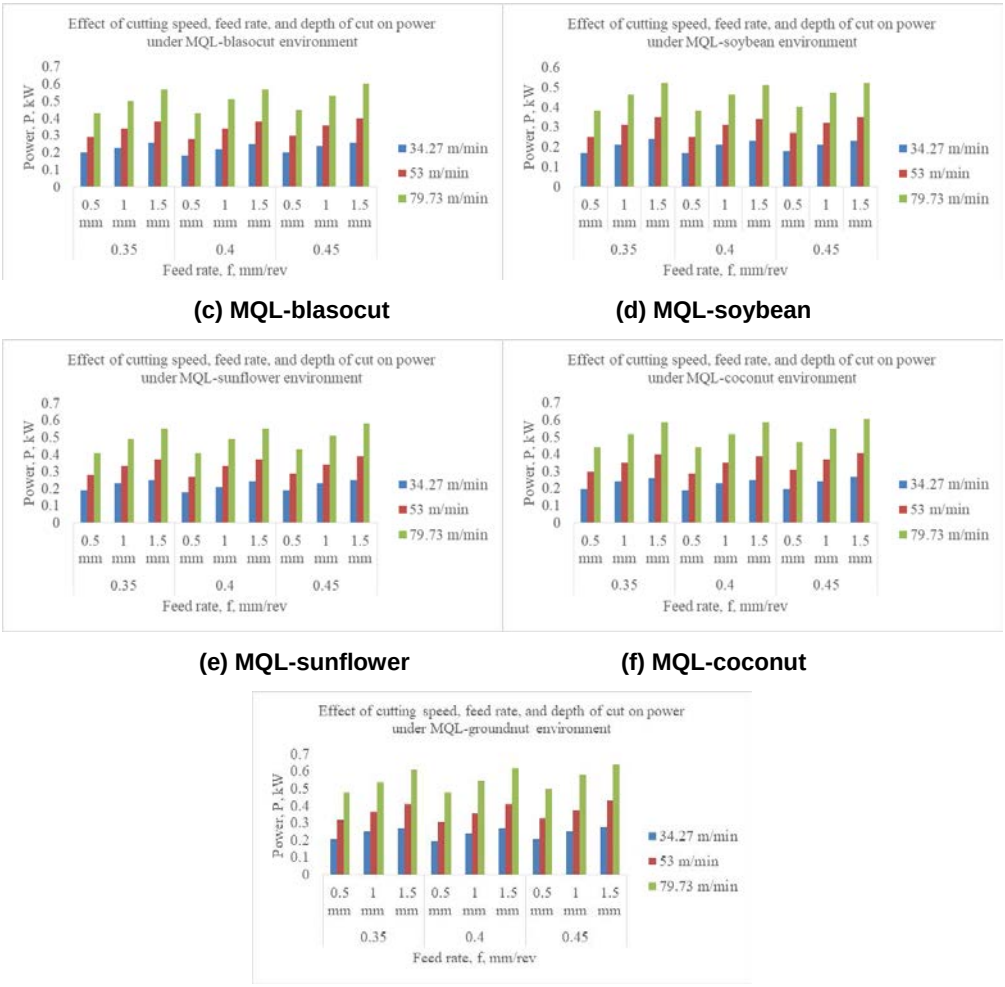
Abstract: *Cutting fluid is a vital part of the machining process. Cutting fluid is significantly applied to lower the friction and heat generated in the machining zone. It also helps in easy chip removal, protection against oxidation, tool life improvement, and an overall improvement in the quality of the product. The current industrial practices are majorly emphasized on mineral-based oil application under flood lubrication to achieve superior quality. However, these oils and techniques are toxic and environmentally unfriendly. Machining under dry or with minimum quantity lubrication (MQL) has been mostly preferred to eliminate the use of abundant oil. The current research work has established the promising potential for vegetable oils as a cutting fluid under MQL during turning of AISI 4130 steel. The results inferred that vegetable-based cutting fluids performed better over mineral-based cutting fluids in terms of lower values of machined surface roughness, tool wear, cutting forces, and chip-tool interface temperature. The MQL machining performance in terms of cutting forces, surface roughness and tool life has been observed better in comparison to machining under flood and dry cutting conditions.*

Keywords:**Turning, Cutting parameters, MQL, Vegetable Oils, Cutting force, Surface roughness**

1.Introduction

Manufacturing industries are striving to achieve superior product quality with minimumresource utilization. Aiming for higher productivity is closely associated with higher material removal rate which results in extreme heat generation. The heat generated at the machining zone leads to an adverse effect on the machining process in terms of uneven surface quality and abrupt tool failure in certain cases. Cutting fluids are the source of limiting the heat generation during machining attributed to their cooling and lubrication characteristics. However, the current practices of mineral-based cutting fluids and flood lubrication technique resulting in a threat to the environment and operational safety, as the exposure of mineral-based cutting fluids for a longer time could result in dermatological and respiratory issues even [1, 2]. Concerning the same, many environmental protection agencies (EPA) have insisted long back to eliminate the application of mineral-based cutting fluids projecting their carcinogenic nature subsequent issues like disposal and recycling [3-5]. The rising ecological threat concerning the mineral-based cutting fluids and flood lubrication technique enforce to find the alternative for sustainable development. Dry machining was potentially projected as the method to eliminate the use of cutting fluids leading to a green manufacturing approach therein [6]. However, the certain limitations of dry machining were exposed especially at higher cutting speed as increased wear rate was noted as the major concern [7]. Thus, the industries are looking forward to environment-friendly machining which would have a long-term sustainable approach and a potential alternative to flood and dry technique. Near-dry machining which is also termed as minimum quantity lubrication or micro lubrication emerges in the same regard [8].

Minimum quantity lubrication (MQL) uses a cutting fluid in the range of 50-150 ml/hr which is significantly low as compared to the flood lubrication system (1-10 ltr/min), so it is appropriately termed as micro lubrication or near-dry machining [9]. The mixture of compressed air and cutting fluids is applied at the machining zone through the nozzle for precise penetration. The minimum attributed cutting oil usage avoids the



(c) MQL-blasocut **(d) MQL-soybean**

(e) MQL-sunflower **(f) MQL-coconut**

(g) MQL-groundnut

Figure5.Variation of power consumption at different cutting conditions

Figure 5 represents the variation of power consumption at different cutting conditions underconsideration. As speed increases, demand for driving power also increases which results in maximum power consumption. The depth of cut and feed rate is proportionate to the power consumption which is attributed to more frictional resistance at the tool-work interface. Dry cutting incurred maximum power consumption as 5-10% more than flood cutting; whereas, MQL helps in reducing power consumption approximately by 10% overall. Soybean oil performs better comparatively against all the conditions and shows about 9% reduced power consumption as compared to mineral-based blasocut oil.

4. Conclusions

The present research work is carried out to evaluate the performance of various vegetable-basedcutting fluids under varying cutting environments concerning the measuring parameters; cutting force, surface roughness, temperature, and power consumption. Based on the comprehensive experimental investigation following conclusions and remarks could be drawn:

- Minimum quantity lubrication shows improved characteristics in all aspects. The cutting forces, temperature, surface roughness, and power consumption found reduced under the application of MQL as compared to the dry and flood lubrication technique. MQL is also useful in the consumption of the cutting fluid
- The vegetable oils under MQL shows significant performance improvement than that of blasocut oil.
- Soybean oil shows the lowest cutting forces as compared to blasocut, by 9%/
- Under the application of soybean oil, the surface roughness was noted to be

reduced by 4%, 8%, 15%, and 16% as compared to sunflower, groundnut, blasocut, and coconut oil respectively.

- The soybean oil is also reported for the lower temperature as compared to blasocut, sunflower, groundnut, and coconut oil by 3%, 7%, 12%, and 16% respectively.
- Power consumption under soybean oil application is reported to be lower as compared to sunflower, blasocut, coconut, and groundnut oil by 7%, 9%, 13%, and 19% respectively.
- The overall observations under all machining environments show that the depth of cut shows a significant effect on cutting forces, feed rate and depth of cut are found to be influential parameters affecting the temperature, and cutting speed are noted to be an influential parameter for the power consumption.
- The combined effect of cooling and lubrication under the application of MQL assisted vegetable oils has shown significant performance comparatively over the other environments. The outstanding performance of the soybean oil is attributed to its higher molecular weight resulting in fewer evaporation losses, and its highest unsaturated fatty acid content resulting in excellent lubrication properties comparatively.
- The soybean oil is less costly as well and based on the investigations it is proposed that the application of soybean oil under the MQL environment would be an excellent substitute for the mineral-based cutting fluids.

4. References

[1] M. Sokovic and K. Mijanovic, “Ecological aspects of the cutting fluids and its influence on the quantifiable parameters of the cutting processes,” Journal of Materials Processing Technology, Vol. 109, (2001), pp. 181-189.

[2] D. P. Adler, W. W.S. Hii, D, D. J. Michalek, and J. W. Sutherlamd, “Examining the role of cutting fluids in machining and efforts to address associated environmental/health concerns,” Machining Science and Technology, Vol. 10-1, (2006), pp. 23-58.

[3] Bennett EO and Bennett DL, “Minimizing human exposure to chemicals in metalworking fluids”, Lubrication Engineering, Vol.43-3, (1987), pp. 167-175.

[4] L. K. Low, J. R. Meeks, C.R. Mackere, “Health effects of alkyl benzenes II. Xylenes”, Toxicology and Industry Health, Vol. 5-1, (1989), pp. 85-105.

[5] Simpson AT, Stear M, Groves JA, Piney M, Bradley SD, Stagg S, Crook B, “Occupational exposure to metalworking fluid mist and sump fluid contaminants”, Annals of Occup. Hyg., Vol. 47, (2003), pp. 17–30.

[6] Klocke F. and Eisenblatter G, “Dry cutting”, Annals of the CIRP, Vol. 46-2, (1997), pp. 519-526.

[7] Dixit U.S, Sarma D.K, Davin J.P, “Environmentally friendly machining”, ISBN 978-1-4614-2308-9, Springer-Verlag New York, (2012), pp.1-100.

[8] P.S. Sreejith and B.K.A. Ngoi, “Dry machining-machining of the future”, Journal of Materials Processing Technology, Vol. 101,1-3, (2000), pp 289–293.

[9] T.F. MaClure, R. Adams, M.D. Gugger, “Comparison of flood vsmicrolubrication on machining performance”, http://www.unist.com/techsolve.html., (2001), pp. 4-5.

[10] N.R. Dhar, M. Kamruzzamman, M. Ahmed, “Effect of minimum quantity lubrication (MQL) on tool wear and surface roughness in turning AISI-4340 steel”, J. Mater. Process. Technol. Vol. 172-2, (2006), pp. 299–304.

[11] N. R. Dhar, M. T. Ahmed, S. Islam, “An experiment investigation on effect of minimum quantity lubrication in machining AISI 1040 steel”, International Journal of Machine Tools & Manufacture, Vol. 47, (2007), pp. 748-753.

[12] AhmadrezHosseiniTazehkandi, “On the feasibility of a reduction in cutting fluid consumption via spray of biodegradable vegetable oil with compressed air in machining of Inconel 706” Journal Of Cleaner Production, Vol. 104, (2015), pp.422-435.

[13] A.S. Varadarajan and P.K. Philip, “Investigations on hard turning with minimal cutting fluid application and its comparison with dry and wet turning”, International Journal of Machine Tools and Manufacture, Vol. 42-2, (2002), pp. 193–200.

[14] C. Ju, L. P. Keranen, K. R. Haapala, D. J. Michalek, J. W. Suthrland, “Issues associated with MQL

implementation: effect on peripheral milling process performance and impact on machining economics". Proc. of ASME Manufacturing Engineering Division, Orlando, Florida, 2005, (IMECE2005-79259) IMECE Paper -79259, (2005), pp.3-12.

[15] Attanasio , M. Gelfi, C. Giardini, C. Remino "Minimal quantity lubrication in turning effect on tool wear" Wear, Vol. 260, (2006), pp. 333–338.

[16] Y.S. Liao, H.M. Lin, Y.C. Chen, "Feasibility study of the minimum quantity lubrication in high-speed end milling of NAK80 hardened steel by coated carbide tool", International Journal of Machine Tools &Manufacture, Vol-47, (2007), pp. 1667–1676.

[17] M.C.S. Alves, E.C, Bianchi, P.R. Aguiar, R.C. Canarim, "Influence of optimized lubrication cooling and MQL on the cutting force, on the geometric quality of the surfaces and on the micro structural integrity of hardened steel part", RevistaMateria, (Rio the Janeiro) , Vol. 16-3, (2011),pp.754-766.

[18] Hadad, M. and Sadeghi, B. "Minimum quantity lubrication-turning of AISI 4140 steel alloy", Journal of Cleaner Production, Vol.54, (2013), pp.332-343.

[19] Kedare S.B, Borse, D.R., Shahane P. T., "Effect of minimum quantity lubrication on surface roughness of mild steel of 15HRC on universal milling machine", Procedia Materials Science, ICMPC 2014, Vol.6, (2014), pp. 150-153.

[20] M.M.A. Khan., M.A.H. Mithu, N.R. Dhar, "Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil-based cutting fluid", Journal of Materials Processing Technology, Vol. 209, (2009), pp. 5573–5583.

[21] E. Kuram, B. Ozcelik, E. Demirbas, E. Sik, I. N. Tansel, "Evaluation of new vegetable-based cutting fluids on thrust force and surface roughness in drilling of AISI 304 using taguchi method", Materials and Manufacturing Processes, Vol. 26, (2011), pp.1136-1146.

[22] Khan M.M.A. and Dhar N.R, "Performance evaluation of minimum quantity lubrication by vegetable oil in terms of cutting force, cutting zone temperature, tool wear, job dimension and surface finish in turning AISI-1060 steel", Journal of Zhejiang University, Science, Vol. 7-11, (2006), pp. 1790–1799.

[23] M A. Islam and N.R. Dhar, "Effects of Minimum Quantity Lubrication by vegetable oil based cutting fluid on temperature, chip morphology and surface finish in grinding AISI 1060 steel", Proceedings of the 4th BSME-ASME International Conference on Thermal Engineering, 27-29 December (2008), Dhaka, Bangladesh, pp.861-866.

[24] Gunjal S. U. and Patil N. G, "Experimental investigations into turning of hardened AISI 4340 steel using vegetable based cutting fluids under minimum quantity lubrication." ProcediaManufacturing, 20, (2018), pp.18-23.

[25] S. U. Gunjal, S. B. Sanap, N. G. Patil, "Role of cutting fluids under minimum quantity lubrication: An experimental investigation of chip thickness", Materials Today: Proceedings, Volume 28-2, (2020), pp 1101-1105.

[26] Shrikant U. Gunjal and Sudarshan B. Sanap, "Experimental investigations and regression analysis based mathematical modelling for tool life under minimum quantity lubrication", International Journal of Mechanical and Production Engineering Research and Development, Vol. 10, (2020), pp 911-920.

[27] Y. M. Shashidhara and S. R. Jayaram, "Experimental determination of cutting power for turning and material removal rate for drilling of AA 6061-T6 using vegetable oils as cutting fluid", Advances in Tribology, Hindawi Publishing Corporation, Vol. 2013, (2013) Article ID 362931, pp.1-7.

[28] Manoj Kumar, JeewanSarda, AmitavaGhosh, "Potential of vegetable oils as micro lubrication/cooling medium for SQL grinding", 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014) December 12th–14th, IIT Guwahati, Assam, India 387, (2014), pp.1-5.

[29] Jagdeep Sharma and Balwinder Singh Sidhu, "Investigation of effect of dry and near dry machining on AISI D2 steel using vegetable oil", Journal of Cleaner Production, Vol. 66-03, (2014), pp. 619-623.

[30] Mohamed HindawiSaadElmunafi, D. Kurniawan, M. Y. Noordin, "Use of castor oil as cutting fluid on machining of hardened stainless steel with minimum quantity lubrication", Procedia CIRP, Vol. 26, (2015), pp. 408-411.

[31] Shrikant U. Gunjal and Sudarshan B. Sanap, "A bibliometric analysis of minimum quantity lubrication as a sustainable approach", Library Philosophy and Practices, (2020), 4772.

[32] Gurpreet Singh, Sehijpal Singh, Manjot Singh, Ajay Kumar, "Experimental investigations of vegetable & mineral oil performance during machining of EN-31 steel with minimum quantity lubrication", International Journal of Research in Engineering and Technology, Vol. 02-6, (2013), pp.1030-1037.

[33] O.O. Fasina and Z. Colley, "Viscosity and specific heat of vegetable oils as a function of temperature", International journal of food properties, Vol. 11, (2008), pp 738–74.