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Experimental Analysis of Machining Parameters by Using Bio-Based Cutting Fluids

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ABSTRACT

Conventional metal cutting fluids, which are typically mineral oil-based or petroleum-based, have been widely used in the metalworking industry for decades. These fluids serve as coolants and lubricants during the machining process, improving the performance and durability of the cutting tools and workpiece. Conventional metal cutting fluids reduce heat build-up and friction, increasing cutting speeds and tool life, but pose potential health hazards to workers and can contaminate the environment. To address these concerns, sustainable and eco-friendly cutting fluids like vegetable-based or synthetic alternatives are becoming more popular.

The present study was aimed at investigating the impact of a bio-based cutting fluid on the machining parameters during the turning of MS AISI 1018 using minimum quantity lubrication (MQL). The experimentation involved varying the cutting parameters, such as cutting speed, feed rate, and depth of cut, while performing the turning process on a conventional lathe machine using a tungsten carbide cutting tool. A very easily available and economically feasible oil waste cooking oil blended with sea weed oil is chosen as the cutting fluid.

The results of the experimental analysis indicated that the utilization of the bio-based cutting fluid with MQL exhibited a favourable impact on the machining parameters. The bio-based cutting fluid was enhancing the surface finish quality, and minimizing the energy consumption during the machining operations. The optimal machining conditions for the bio-based cutting fluid with MQL were identified, and recommendations for future research were provided.

INTRODUCTION

MACHINING

The manufacturing industry is highly competitive and to remain relevant and profitable, it needs to run its operations effectively and efficiently. One way to achieve this is by maintaining the quality of its products to meet the demands of consumers. However, the industry must also consider environmental issues, safety, and health as important factors that affect business activity. With increasing public awareness and government regulations, it has become necessary for the manufacturing industry to operate with due regard to these factors.

Machining is a process used in the manufacturing industry to cut materials into the desired final shape and size. This process involves the removal of excessive material in the form of chips or flakes. To increase production rates and minimize machining time, alloys are machined at high speeds. However, the heat generated during this process can affect the quality of the workpiece, tool life, time taken for machining, surface roughness, tool wear, chip thickness, chip formation, power consumption, and chip breaking behaviour.

Using minimum quantity coolant has become a popular solution to the problems caused by cutting fluids. It involves using only the necessary amount of coolant during the machining process, reducing waste and minimizing the negative impacts on the environment and human health.

ROLE OF LUBRICANTS AND CUTTING FLUIDS IN MACHINING

Lubricants and cutting fluids play a critical role in machining operations. Their primary purpose is to reduce friction between the cutting tool and the workpiece, which helps to extend the life of the cutting tool and improve the quality of the machined part. Here are some of the key roles that lubricants and cutting fluids play in machining operations: 1.Reducing friction, 2.Cooling and 3.Chip removal.

WASTE COOKING OIL: Waste cooking oil (WCO) is a by-product generated from the use of vegetable oils for cooking and frying. Instead of discarding WCO, it can be collected and processed for reuse in various applications such as biofuels, soaps, and lubricants. Understanding the properties of WCO is essential for determining its suitability for different applications.

SEAWEED OIL : Seaweed oil is an oil extracted from different species of seaweed, which are marine algae that grow in oceans and other bodies of saltwater. It is commonly used in cosmetics, skincare products, and dietary supplements due to its unique properties.

Seaweed oil is rich in vitamins, minerals, and antioxidants, making it highly beneficial for the skin. It contains high levels of omega-3 fatty acids, which help to nourish and moisturize the skin, reducing dryness and flakiness. It also has anti-inflammatory properties, which can soothe and calm irritated or sensitive skin. Seaweed oil, also known as algae oil, is an oil extracted from various types of seaweed or algae. It has a unique set of properties that make it a popular ingredient in the cosmetics, food, and pharmaceutical industries.

Table 1.1 Properties of mineral oil

Flash Point(°**c)**	150-300
Fire Point (° **c)**	>200
Viscosity Index	80-120
Density (kg/m)	800-1000
Kinematic Viscosity at 40°**C (cSt)**	10-100
Kinematic Viscosity at 100°**C (cSt)**	2-30

Table 1.2 Properties of waste cooking oil mixed with seaweed oil

Flash Point(°**c)**	325
Fire Point (° **c)**	358
Viscosity Index	205
Density (g/cc)	0.911
Kinematic Viscosity at 40°**C (cSt)**	43.20
Kinematic Viscosity at 100°**C (cSt)**	9.26

By considering the above properties the combination of waste cooking oil and seaweed oil extracted from seaweed is taken as a cutting fluid and also by comparing the combination of waste cooking oil and seaweed oil parameter values are comparatively equal with mineral oil.

METHODOLOGY

SELECTION OF RAW MATERIAL FOR MACHINING

AISI 1018 grade mild steel is chosen as our material for machining. AISI 1018 is a low carbon steel grade that is often referred to as mild steel. It is a versatile grade of steel that has a wide range of applications, from machine parts to construction components. AISI 1018 is known for its excellent weldability, machinability, and strength.

Mild steel (AISI 1018)

SELECTION OF COOLANT FOR MACHINING

Waste cooking oil with a blend of seaweed oil has been chosen as a coolant for the machining process. Waste cooking oil possesses similar properties to that of conventional coolants, while being a more cost-effective alternative with non-toxic and highly biodegradable properties. Seaweed oil, which is a naturally available and renewable resource, is incorporated due to its high levels of omega-3 fatty acids, antioxidants, vitamins and minerals. Being environmentally sustainable, seaweed oil is a viable alternative to other types of oils commonly used in machining processes.

Mixture of waste cooking and sea weed oil

WORKING OF MQL SYSTEM: The internal venture system within the spraying mechanism of the machine creates a spraying action when air flows from the interior air nozzle to the exterior spray nozzle. As a result, the liquid is aspirated through the siphon tube and flows through the distributor block to the nozzle block via nylon tubes. The recommended operating pressure for the machine is between 3Kg/cm2-5Kg/cm2, with the nozzles being constructed out of brass.

Working of MQL

SETTING THE NOZZLE OF MQL MACHINE NEAR THE TOOL OF LATHE MACHINE

In order to ensure effective Minimum Quantity Lubrication (MQL) operation, proper nozzle positioning is crucial. The position of the nozzle significantly impacts the MQL operation. The nozzle is placed on the cross slide of the Lathe machine to direct the coolant towards the tool bit of the machine. A magnetic stand is used to hold the nozzle in a particular position to ensure optimal functioning. The nozzle position is verified by performing a trial run to confirm that the coolant is directed towards the tool tip. Once all conditions are confirmed, the nozzle position is fixed, and the stand position is marked to ensure the location is maintained in case of any disturbances.

Fig 3.6 Nozzle Setting

PERFORMING TURNING OPERATION ON THE LATHEMACHINE HAVING TOOL DYNAMOMETER

PROCEDURE: A workpiece of 30mm diameter and 180mm length made of MS AISI1018 round bar is placed between the jaws of a lathe machine (MTT 1440). Machining parameters such as speed, feed, and depth of cut are set manually before the turning operation. The MQL setup is turned on, and the required air pressures are maintained. The MQL nozzle is activated by turning it one turn counter clockwise. Tool dynamometer readings are taken manually during the turning operation to confirm the resulting data. The lathe machine is started, and the turning operation is performed using various machining parameters. Tool dynamometer readings are taken for each cutting parameter that is changed.

Turning Operation

CUTTING FORCES MEASUREMENT

During a turning operation, a lathe tool dynamometer is utilized to measure the cutting forces that occur between the cutting tool and the workpiece. The tool dynamometer provides real-time display of the cutting forces on its screen. To obtain accurate results, the cutting forces are manually recorded during the turning operation and compared to the final results after the operation is completed. By comparing these two sets of values, a more precise assessment of the cutting forces and overall machining performance can be obtained.

Cutting forces measurement

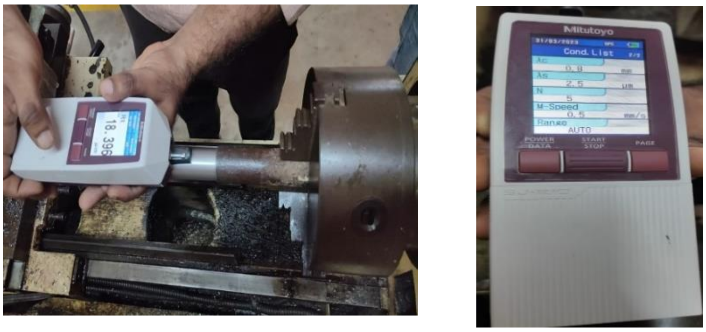
TOOL TIP TEMPERATURE MEASUREMENT

During the turning operation, the Fluke 561 IR thermometer was utilized to measure the temperature of the tool tip. To obtain more accurate results, the temperature of the tool tip was measured concurrently with the tool travel. The recorded temperature readings were then tabulated for analysis.

Temperature Measurement

SURFACE ROUGHNESS TESTING

The Mitutoyo 178-561-02A SJ-210 surface roughness tester was employed to determine the surface roughness values of workpieces. The device functions by utilizing a stylus to measure the surface roughness of a material. The stylus is connected to the device and placed on the surface of the material being examined. As the stylus traverses the surface, it detects and records the height variations and irregularities, which are subsequently analysed to ascertain the surface roughness and waviness.



Surface Roughness Measurement

RESULTS AND DISCUSSIONS

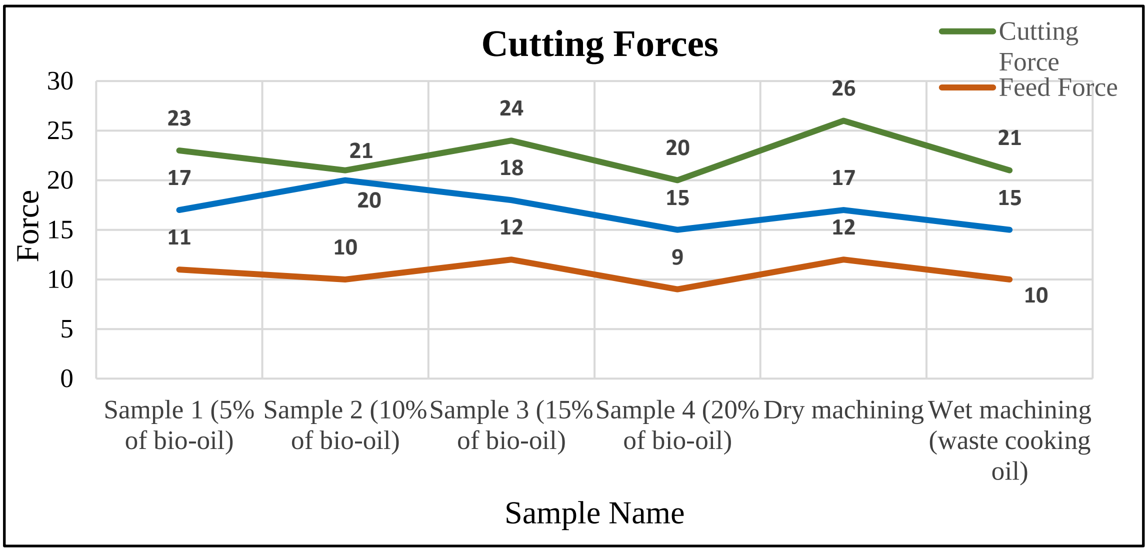
The observed coolant discharge from the nozzle during MQL operation at 2 bar pressure and an opening of 1 turn was determined to be **2.014×10^{-7} m^3/sec**.

RESULTS OF CUTTING FORCES MEASUREMENT

Cutting forces measurement results provide valuable information to optimize machining operations and ensure the quality and efficiency of manufacturing processes.

Rough cutting results

SET 1	**SPEED (rpm)**	**FEED (mm/rev)**	**DEPTH OF CUT (mm)**	**CUTTING FORCE**	**FEED FORCE**	**THRUST FORCE**
Sample 1 (5% of bio-oil)	755	0.75	0.7	23	11	17
Sample 2 (10% of bio-oil)	755	0.75	0.7	21	10	20
Sample 3 (15% of bio-oil)	755	0.75	0.7	24	12	18
Sample 4 (20% of bio-oil)	755	0.75	0.7	20	9	15
Dry machining	755	0.75	0.7	26	12	17
Wet machining (waste cooking oil)	755	0.75	0.7	21	8	9



Cutting Forces (Rough cutting)

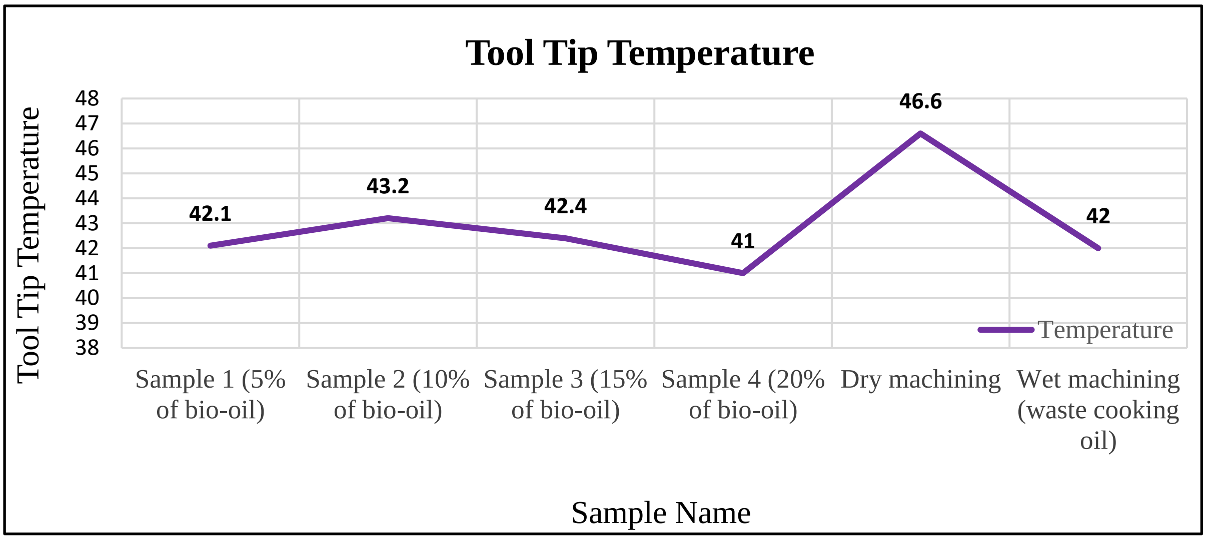
The results of the experiment indicate that the minimum values of the three cutting forces were observed at sample 4, which corresponds to a concentration of 20% bio-oil.

RESULTS OF TOOL TIP TEMPERATURE MEASUREMENT

Results of tool tip temperature measurement provide critical information about the performance of cutting tools and help to optimize machining processes.

Rough cutting temperatures

SET 1	SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	TOOL TIP TEMPERATURE (^{0}C)
Sample 1 (5% of bio-oil)	755	0.75	0.7	42.1
Sample 2 (10% of bio-oil)	755	0.75	0.7	43.2
Sample 3 (15% of bio-oil)	755	0.75	0.7	42.4
Sample 4 (20% of bio-oil)	755	0.75	0.7	41
Dry machining	755	0.75	0.7	46.6
Wet machining (waste cooking oil)	755	0.75	0.7	42



Tool tip temperature (Rough cutting)

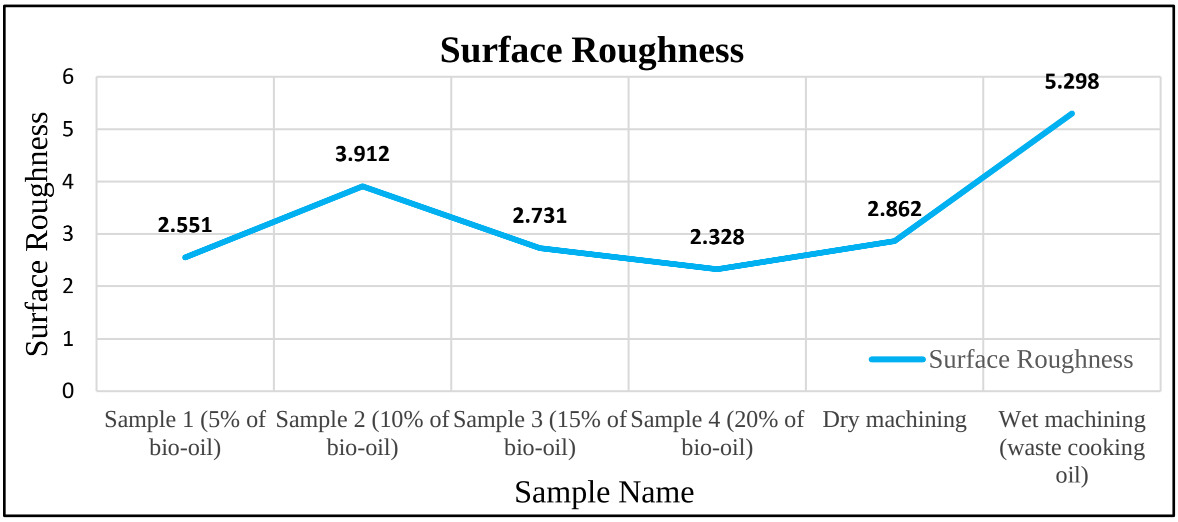
It has been observed that the lowest temperature was recorded at sample 4, which corresponds to a concentrations of 20% bio-oil.

RESULTS OF SURFACE ROUGHNESS TESTING

Results of surface roughness testing provide valuable information on the quality of a machined surface and can be used to optimize machining processes and ensure product functionality.

Rough cutting surface roughness

SET 1	SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	SURFACE ROUGHNESS (R_a)
Sample 1 (5% of bio-oil)	755	0.75	0.7	2.551
Sample 2 (10% of bio-oil)	755	0.75	0.7	3.912
Sample 3 (15% of bio-oil)	755	0.75	0.7	2.731
Sample 4 (20% of bio-oil)	755	0.75	0.7	2.328
Dry machining	755	0.75	0.7	2.862
Wet machining (waste cooking oil)	755	0.75	0.7	5.298



Surface roughness (Rough cutting)

The results of the experiment indicate that the minimum Ra value was observed at sample 4, which corresponds to a concentration of 20% bio-oil.

CONCLUSION AND FUTURE SCOPE

CONCLUSION

The experimental analysis of cutting parameters during turning operations using different cutting fluids, namely waste cooking oil and blends of waste cooking oil and sea weed oil, and minimum quantity lubrication (MQL) has yielded promising results. The use of MQL significantly reduces the amount of cutting fluid required while still maintaining high surface quality and minimizing tool wear.

The findings of the experimental investigation suggest that the use of waste cooking oil-blended cutting fluids can enhance machining performance in terms of surface roughness, cutting force, and tool wear. Compared to the use of waste cooking oil or synthetic cutting fluid, the waste cooking oil-sea weed oil blend (with a 20% volume ratio) demonstrated superior performance. These results indicate that blending waste cooking oil with sea weed oil can be a feasible alternative cutting fluid for machining operations, particularly in the context of sustainable machining practices.

FUTURE SCOPE

The experimental analysis of cutting parameters during turning operations by using different cutting fluids, waste cooking oil and blends of waste cooking oil and sea weed oil, using minimum quantity lubrication (MQL) has significant future scope for further research and development. Some potential areas for future exploration are:

Optimization of the blend ratio: The current study used a 20% volume ratio of sea weed oil in the waste cooking oil blend. Further studies can be conducted to optimize the blend ratio to achieve the best possible performance in machining operations.

Overall, the experimental analysis of cutting parameters using different cutting fluids and MQL has significant future scope for research and development, which can further contribute to the advancement of sustainable machining practices in the manufacturing industry.

REFERENCES

[1] Bhatt Y, Ghuman K, Dhir A. Sustainable manufacturing. Bibliometrics and content analysis. J Clean Prod 2020;260:120988. https://doi.org/10.1016/j.jclepro.2020.120988.

[2] Global Footprint Network. Ecological footprint. 2019 (accessed 6 May 2020), http s://www.footprintnetwork.org/our-work/ecological-footprint/.

[3] Huang A, Badurdeen F. Sustainable manufacturing performance evaluation: integrating product and process metrics for systems level assessment. Procedia Manuf 2017;8:563–70. https://doi.org/10.1016/j.promfg.2017.02.072.

[4] Malek J, Desai TN. A systematic literature review to map literature focus of sustainable manufacturing. J Clean Prod 2020;256:120345. https://doi.org/10.1016/j.jclepro.2020.120345.

[5] Gutowski TG. The carbon and energy intensity of manufacturing. 40th CIRP International Manufacturing Systems Seminar. Liverpool University; 2007.

[6] Abukhshim NA, Mativenga PT, Sheikh MA. Heat generation and temperature prediction in metal cutting: a review and implications for high speed machining. Int J Mach Tools Manuf 2006;46:782–800. https://doi.org/10.1016/j. ijmachtools.2005.07.024.

[7] Goindi GS, Sarkar P. Dry machining: a step towards sustainable machiningchallenges and future directions. J Clean Prod 2017;165:1557–71. https://doi. org/10.1016/j.jclepro.2017.07.235.

[8] Debnath S, Reddy MM, Yi QS. Environmental friendly cutting fluids and cooling techniques in machining: a Review. J Clean Prod 2014;83:33–47. https://doi. org/10.1016/j.jclepro.2014.07.071.

[9] Zhang JZ, Rao PN, Eckman M. Experimental evaluation of a bio-based cutting fluid using multiple machining characteristics. Int J Mod Eng 2012;12:35–44.

[10] Rao PN, Srikant RR. Sustainable machining utilizing vegetable oil based nanofluids. Proceedings of the International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials 2015:664–72. https://doi.org/10.1109/ICSTM.2015.7225495.

[11] Adler D, Hii W-S, Michalek D, Sutherland J. Examining the role of cutting fluids in machining and efforts to address associated environmental/health concerns. Mach Sci Technol 2006;10:23–58. https://doi.org/10.1080/ 10910340500534282.

[12] Anton S, Andreas S, Friedrich B. Heat dissipation in turning operations by means of internal cooling. Procedia Manuf 2015;100:1116–23. https://doi.org/ 10.1016/j.proeng.2015.01.474.

[13] Shashidhara YM, Jayaram SR. Vegetable oils as a potential cutting fluid-an evolution. Tribol Int 2010;43:1073–81. https://doi.org/10.1016/j. triboint.2009.12.065.

[14] Pusavec F, Kramar D, Krajnik P, Kopac J. Transitioning to sustainable production part - II: evaluation of sustainable machining technologies. J Clean Prod 2010;18: 1211–21. https://doi.org/10.1016/j.jclepro.2010.01.015.

[15] Shokrani A, Dhokia V, Newman ST. Environmentally conscious machining of difficult-to-machine materials with regard to cutting fluids. Int J Mach Tool Manuf 2012;57:83–101. https://doi.org/10.1016/j.ijmachtools.2012.02.002.

[16] Tsch¨ atsch H, Reichelt A. Cutting fluids (coolants and lubricants). In: Tschatsch ¨ H, editor. Appl Mach Tech. Springer; 2009. p. 349–52. https://doi.org/10.1007/ 978-3-642-01007-1_21.

[17] Caballero B, Finglas P, Toldra F. Encyclopedia of food sciences and nutrition. second ed. Elsevier; 2003.

[18] Singh AK, Gupta AK. Metal working fluids from vegetable fluids. J Synth Lubr 2006;123:167–76. https://doi.org/10.1002/jsl.19.

[19] Shokoohi Y, Khosrojerdi E, Shiadhi BR. Machining and ecological effects of a new developed cutting fluid in combination with different cooling techniques on turning operation. J Clean Prod 2015;94:330–9. https://doi.org/10.1016/j. jclepro.2015.01.055.

[20] Market Research Report. Metalworking fluids market size, share & trends analysis report by product (synthetic, bio-based), by application (near cutting, water cutting), by end use, by industrial end use, and segment forecasts, 2020-2027. 2020 (accessed 5 May 2020), https://www.grandviewresearch.com/indus try-analysis/metalworking-fluids-market.

[21] Rahim EA, Sasahara H. A study of the effect of palm oil as MQL lubricant on high speed drilling of titanium alloys. Tribolol Int 2011;44:309–17. https://doi.org/ 10.1016/j.triboint.2010.10.032.

[22] Zhang Y, Li C, Jia D, Zhang D, Zhang X. Experimental evaluation of MoS2 nanoparticles in jet MQL grinding with different types of vegetable oil as base oil. J Clean Prod 2015;87:930–40. https://doi.org/10.1016/j.jclepro.2014.10.027.

[23] Syahrullail S, Kamitani S, Shakirin A. Tribological evaluation of mineral oil and vegetable oil as a lubricant. J Teknol 2014;66:37–44. https://doi.org/10.11113/ jt.v66.2692.

[24] Masjuki HH, Maleque MA, Kubo A, Nonaka T. Palm oil and mineral oil based lubricants-their tribological and emission performance. Tribol Int 1999;32: 305–14. https://doi.org/10.1016/S0301-679X(99)00052-3.

[25] Krolczyk GM, Maruda RW, Krolczyk JB, Wojciechowski S, Mia M, Nieslony P, et al. Ecological trends in machining as a key factor in sustainable production - a review. J Clean Prod 2019;218:601–15. https://doi.org/10.1016/j. jclepro.2019.02.017.

[26] Kadirgama, K., Abou-El-Hossein, K., Ramasamy, D., & Noor, M. M. (2012). Performance of eco-friendly vegetable oil-based cutting fluids in turning AISI 1045 steel. Procedia engineering, 41, 1257-1264

[27] Ahmed, N., Khan, I., & Mithu, M. A. H. (2017). Experimental investigation of surface roughness and tool wear in milling AISI 1020 steel using sea weed oil as cutting fluid. Procedia engineering, 200, 152-160.

[28] Noordin, M. Y., Venkatesh, V. C., Sharif, S., Elting, S., Abdullah, A. G., & Rahman, M. N. A. (2010). Application of vegetable oil-based metalworking fluids in machining ferrous metals. Journal of materials processing technology, 210(3), 461-470.

[29] Khan, I., Ahmed, N., Mithu, M. A. H., & Hasan, M. M. (2020). Performance evaluation of seaweed oil as a cutting fluid in machining of aluminium alloys. Materials Today: Proceedings, 27, 2730-2736.

[30] Bhattacharya, S., et al. (2018). "Experimental investigation on machining performance of waste cooking oil as cutting fluid." Journal of Manufacturing Processes, 33, 144-153.

[31] Singh, R. K., et al. (2019). "Experimental investigation of waste cooking oil and sea weed oil blend as a cutting fluid in turning of AISI 1018 steel." International Journal of Precision Engineering and Manufacturing, 20(4), 633-644.

[32] Muthuvel, S., et al. (2021). "Experimental analysis of cutting parameters on machining AISI 1018 steel with waste cooking oil and a blend of waste cooking oil and seaweed oil-based cutting fluids." Journal of Materials Research and Technology, 10, 1532-1542