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Binayak Sen,[1,2] Sunil Kumar Kothapalli,[3] Raman Kumar,[4,5] Manjunath C,[6] Irsyad Abdullah,[7] Gurpartap Singh,[8] and A. Johnson Santhosh[9,a)]

AFFILIATIONS

[1] Centre for Computational Modeling, Chennai Institute of Technology, Chennai 600069 Tamil Nadu, India
[2] Department of Mechanical Engineering, Chennai Institute of Technology, Chennai 600069 Tamil Nadu, India
[3] Department of Mechanical Engineering, SRKR Engineering College, Bhimavaram, Andhra Pradesh 534204, India
[4] School of Mechanical Engineering, Rayat Bahra University, Kharar, Punjab 140103, India
[5] Faculty of Engineering, Sohar University, P.O. Box 44, Sohar PCI 311, Oman
[6] School of Engineering and Technology, JAIN (Deemed to be University), Bangalore, Karnataka, India
[7] Management and Science University, Shah Alam Selangor, Malaysia
[8] Department of Mechanical Engineering, Chandigarh Engineering College, Chandigarh Group of Colleges, Jhanjeri, Mohali, Punjab 140307, India
[9] Faculty of Mechanical Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia

[a)] **Author to whom correspondence should be addressed:** johnson.antony@ju.edu.et

ABSTRACT

The imperative shift toward sustainability has driven contemporary scholars to explore the lubricating and cooling properties of vegetable oils in traditional metal-cutting processes. Palm oil, as an environmentally conscious derivative, emerges as a preferable option for the base fluid in Minimum Quantity Lubrication (MQL). However, its high viscosity impedes fluidity, limiting industrial applicability. In contrast, sunflower oil offers superior lubricating qualities and flowability. Consequently, efforts have been directed toward enhancing the lubricating efficacy of palm oil. Six blends of palm and sunflower oils (ranging from 1:0.5 to 1:3) were utilized as MQL fluids, followed by evaluations of machining outcomes, including average surface roughness, specific cutting energy, and tool wear. In addition, an integrated Shannon's Entropy-based Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) framework was employed to determine the optimal volume ratio of the palm–sunflower oil blend. The TOPSIS analysis confirmed that the 1:2 ratio yielded the most favorable outcomes. Subsequent comparative analysis demonstrated that this optimal blend resulted in reductions of 16.79% and 14.92% in surface roughness, 11.82% and 10.98% in specific cutting energy, and 10.19% and 8.45% in tool wear compared to pure palm and sunflower oil media, respectively. Finally, sustainability assessments of various cooling media revealed that a minimal quantity of the blended bio-lubricant-based medium outperforms both compressed air and flooded media.

I. INTRODUCTION

Due to their corrosion resistance, high strength-to-weight ratio, and excellent creep-rupture strength at elevated temperatures, Inconel alloys are extensively utilized in aerospace, nuclear reactors, and fluid mechanics.[1–3] However, the poor machinability of Inconel alloys leads to elevated cutting temperatures and consequent tool damage.[4,5] In addition, chips tend to adhere to the tool surface, forming a build-up edge,[6,7] resulting in severe surface damage, reduced tool lifespan, and decreased productivity during machining.[2,8–11] Flood cooling is a fundamental solution to mitigate the heat generated between the Inconel workpiece and the tool. Nevertheless, conventional cutting fluids used in flood cooling are non-biodegradable and environmentally unfriendly,[12,13] posing significant hazards if mishandled and potentially harming soil and water resources.[14,15] Hence, the handling and disposal of cutting fluids must adhere strictly to environmental protection regulations.[16]

The most promising approach to addressing these concerns is Minimum Quantity Lubrication (MQL), which involves applying a minimal amount of cutting fluid (6–100 ml/h) directly to the cutting zone.[17] Over recent decades, extensive research has been conducted on MQL milling. For instance, Sun *et al.* investigated cutting forces during end milling of titanium under three cutting conditions, demonstrating that MQL-assisted cooling significantly enhances tool life and reduces cutting forces due to improved lubrication and cooling effects.[18] Li *et al.* examined tool wear and cutting forces in milling Inconel 718 with coated carbide inserts, identifying flank wear as the primary failure mode reducing tool life, with quicker wear propagation observed in up-milling compared to down-milling.[19] Da Silva *et al.* conducted a comparative study on the influence of three machining environments, concluding that MQL is highly effective in machining hardened materials, minimizing thermal cracks, and achieving greater material removal rates.[20] Liu *et al.* explored machining titanium under MQL conditions, observing significant effects on the cutting temperature and force with variations in parameters such as spray pressure, nozzle angle, and lubricant flow rate.[21] Furthermore, Cai *et al.* found that increasing the fluid flow rate up to 10 ml/h was effective in reducing the surface roughness and cutting force but had insignificant effects beyond that threshold.[22] Zhang *et al.* noted that MQL extends tool life compared to dry machining due to its lubricating effect, resulting in lower cutting forces and chip lengths.[23] Kasim *et al.* investigated the influence of cutting parameters on surface roughness during MQL milling of Inconel 718, demonstrating a superior surface finish compared to conventional methods.[24] Finally, Hassanpour *et al.* studied surface roughness, micro-hardness, and white layer thickness in MQL milling of AISI 4340, highlighting the significant reduction in surface defects with higher cutting speeds.[25]

Numerous scholars have undertaken a plethora of experimental investigations utilizing vegetable oil as the foundational fluid within the Minimum Quantity Lubrication (MQL) system. These oils, derived from non-toxic renewable sources and available at a low cost, exhibit commendable lubricating properties due to their high content of fatty acids and carboxyl groups.[26–29] Among these, palm oil emerges as a viable candidate for lubricating purposes within the machining domain, given its widespread availability and documented superior lubrication characteristics when employed as a base fluid in the MQL system. However, despite its favorable attributes, palm oil suffers from high viscosity and poor flowability, thereby limiting its practical application in industrial settings.[30–32] Consequently, enhancing the lubricating performance of palm oil holds significant importance from the perspective of sustainable manufacturing practices. Several years ago, Wang *et al.* evaluated the lubricating properties of various vegetable oils in the machining of GH4169. Their findings indicated that sunflower oil exhibits notable lubrication capabilities and improved flow characteristics.[33] Building upon these insights, the present study endeavors to assess the lubricating efficacy of palm oil when combined with sunflower oil at varying volume ratios (ranging from 1:0.5 to 1:5). In addition, the research seeks to identify the optimal palm-sunflower oil volume ratio for MQL milling of Inconel 718. To facilitate this determination, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) has been employed, utilizing weights derived from Shannon's entropy to ascertain the most effective palm–sunflower volume ratio in the MQL milling process. In light of these objectives, this study seeks to advance the existing body of literature by conducting a comprehensive analysis of the machining behavior exhibited by blended vegetable oils, focusing on surface topography, specific cutting energy, and tool wear characteristics.

II. MATERIALS AND METHODS

A. Blending of bio-lubricants

In the blending procedure of palm and sunflower oil, a volume ratio ranging from 1:0.5 to 1:3 is typically employed, depending on desired properties and end-use applications. First, both oils are carefully measured using precise volumetric equipment. Then, a container, preferably a clean and dry vessel, is chosen for blending. The palm oil, being thicker and more viscous, is often poured first into the container, followed by the sunflower oil. To ensure homogeneity, the oils are mixed thoroughly using a mechanical blender or agitator, operating at a moderate speed to prevent excessive foaming or emulsification. The blending process continues until a uniform consistency is achieved, visually confirmed by the absence of distinct layers or streaks. Finally, the blended oil is transferred to suitable amber-colored storage containers to protect against light-induced oxidation, ready for further application in MQL-assisted milling operation.

TABLE I. The physical, mechanical, and thermal properties of Inconel 718.

Property	Value
Physical properties	
Density	8.19 g/cm^3
Melting range	1260–1336 °C (2300–2438 °F)
Modulus of elasticity	200 GPa (at 20 °C)
Poisson's ratio	0.29
Electrical resistivity	1.29 μΩ·m (at 20 °C)
Mechanical properties	
Tensile strength (ultimate)	965 MPa (140 ksi)
Tensile strength (yield)	550 MPa (80 ksi)
Elongation at break	12%–25%
Hardness (rockwell C)	36–44
Fatigue strength	400 MPa (58 ksi)
Thermal properties	
Thermal conductivity	11.4 W/m·K (at 20 °C)
Specific heat capacity	435 J/kg·K (at 20 °C)
Thermal expansion coefficient	13.0 μm/m·K (20–100 °C)

TABLE II. Key machining and MQL parameters.

Parameters	Values
Machining parameters	
Cutting speed	100 m/min
Feed	0.25 mm/tooth
Depth-of-cut	1.0 mm
MQL parameters	
Flow rate	60 ml/h
Nozzle distance	30 mm
Nozzle angle	45°
Air pressure	0.8 MPa

B. Experimental details

In this study, Inconel 718 was selected as the workpiece material, with dimensions measuring 90 × 30 × 20 mm^3. The physical, mechanical, and thermal properties of Inconel 718 are outlined in Table I for reference. Machining operations were carried out using an uncoated carbide tool with a diameter of 6 mm, mounted on an MTAB CNC-assisted three-axis milling machine. Key parameters such as speed, feed, depth-of-cut, the flow rate of MQL, and nozzle inclination angle were maintained as fixed variables, as detailed in Table II. The focus of the experimentation lay in varying only the volume ratio of the palm–sunflower oil mixture. The surface finish quality was assessed using Arithmetic Average Surface Roughness, calculated as the average height of roughness irregularities from the mean line within a specified sampling length. The surface roughness values were obtained from diverse positions on the workpiece using a 3D profilometer, with the mean value derived from five individual measurements for each cut. The cutting forces were measured using a dynamometer affixed to the workpiece, supported by a charge amplifier and signal conditioning apparatus. The cutting forces were categorized into normal, axial, and tangential components, represented as F_x, F_y, and F_z, respectively, along the x, y, and z axes. The resultant cutting force was determined using an equation accounting for these major cutting components, providing insights into the machining behavior of Inconel 718. Following that, a thorough inspection of the tool's flank was carried out utilizing an optical microscope. Given the presence of irregular wear patterns across the flank surfaces, the focal point for assessment shifted toward the maximum flank wear rather than relying on average flank wear measurements. Figure 1 presents a schematic of the experimental setup employed in this study.

C. Entropy-coupled TOPSIS model

TOPSIS, pioneered by Hwang and Yoon in 1981, stands as a prominent methodology for resolving multi-criteria decision-making (MCDM) challenges. It delineates alternatives' rankings by deriving compromise indices, which hinge on their proximity to both the positive ideal solution (PIS) and the negative ideal solution (NIS). Employing TOPSIS necessitates two essential types of user input: the decision matrix detailing alternatives against performance criteria and the relative importance of these criteria.[33–37]

Mathematically, this involves:

* A set of alternatives $\{A_1, A_2 \ldots A_m\}$.
* A set of criteria $\{C_1, C_2 \ldots C_m\}$.
* A criteria weight vector $W = (w_1, w_2 \ldots w_n)$.

The alternatives' evaluations are summarized in a decision matrix $D = [d_{ij}]$, where d_{ij} represents the performance of alternative A_i against criterion C_j.

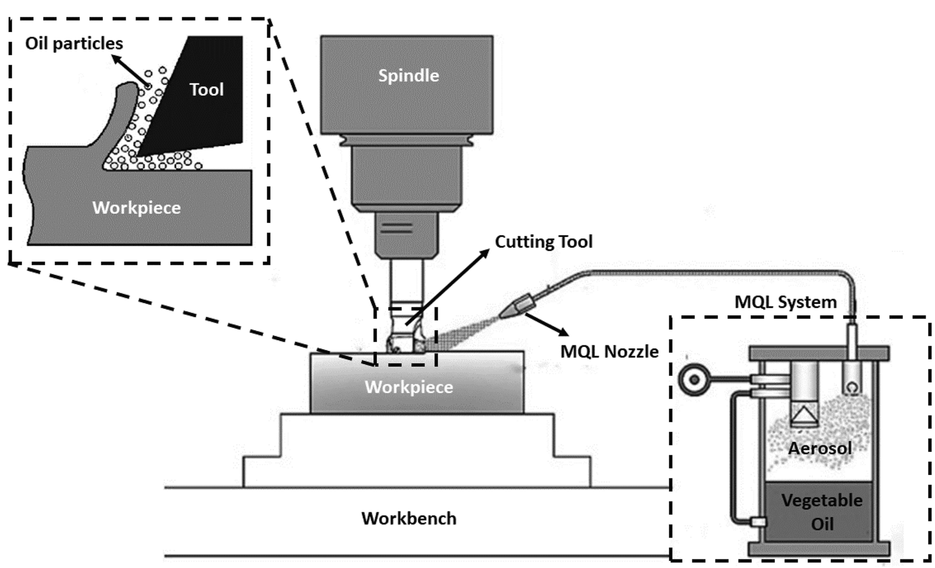

FIG. 1. The schematic illustration delineating the experimental setup.

TOPSIS with entropy weight estimation proceeds as follows:

(a) ***Normalization of the Decision Matrix:*** Normalize D to facilitate inter-criteria comparison, yielding a normalized decision matrix $R = [r_{ij}]$.

(b) ***Weight Information Determination:*** Weights can be subjective (based on the decision maker's preferences) or objective (derived from the decision matrix). This study uses the entropy-based objective approach, where entropy measures the uncertainty of a probability distribution.[38] The entropy E_j and diversification degree d_j of criterion C_j are calculated, leading to the criteria weights w_j.

(c) ***Weighted Normalized Decision Matrix:*** Compute the weighted normalized decision matrix $V = [v_{ij}]$.

(d) ***Positive and Negative Ideal Solutions:*** Determine *PIS* and *NIS*:

$$PIS = \{v_1^+, v_2^+, \ldots, v_n^+\},$$

$$NIS = \{v_1^-, v_2^-, \ldots, v_n^-\}.$$

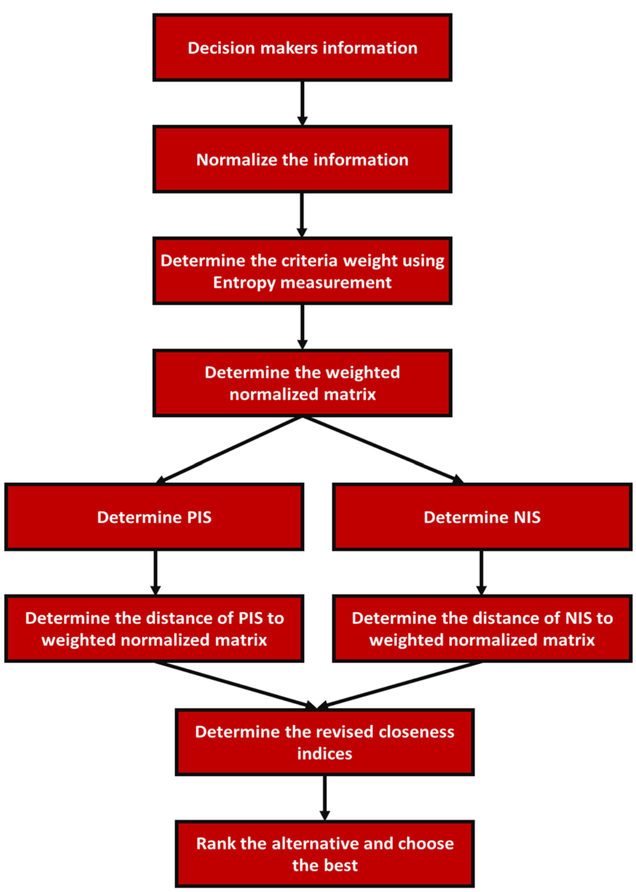

FIG. 2. The steps involved in Entropy-TOPSIS method.

(e) ***Separation Measures:*** Compute the separation of each alternative from *PIS* and *NIS*:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2},$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}.$$

(f) Relative ***Closeness Coefficient:*** Calculate the relative closeness coefficient C_i for each alternative:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}.$$

(g) ***Ranking Alternatives:*** Rank alternatives based on their C_i values, with higher values indicating better ranks. The steps involved in determining the best alternative are shown in Fig. 2.

III. RESULTS AND DISCUSSION

A. Impact of bio-lubricants on machining responses

Surface roughness stands as a pivotal gauge of the geometric integrity of a workpiece, shaped by the interaction between the tool material and the workpiece surface. Reduced surface roughness values not only bolster fatigue strength, corrosion resistance, and abrasion resistance but also ensure heightened precision in component assembly.[39–41] The surface roughness values for various palm–sunflower oil mixtures were: 0.395 μm for a 1:0.5 ratio, 0.361 μm for 1:1, 0.359 μm for 1:1.5, 0.342 μm for 1:2, 0.351 μm for 1:2.5, and 0.374 μm for 1:3. Specific cutting energy epitomizes the energy demanded to eliminate a unit volume of material from the workpiece, reflecting the energy expenditure during machining and often serving as an efficiency metric for machining processes.[42,43] Experimental data revealed that the specific cutting energy peaked at 0.411 N/mm^2 for a 1:0.5 palm–sunflower oil ratio. Subsequently, a downward trend was observed, culminating in a minimum of 0.345 N/mm^2 for the 1:3 mixture. Finally, tool wear—the gradual deterioration of the cutting tool due to non-stop friction—was also significantly affected by the use of palm–sunflower oil mixtures. The measured tool wear values for various mixtures were: 0.416 mm for a 1:0.5 ratio, 0.374 mm for 1:1, 0.361 mm for 1:1.5, 0.379 mm for 1:2, 0.401 mm for 1:2.5, and 0.411 mm for 1:3. Figure 3 illustrates the machining performance metrics under different volume fractions of palm–sunflower oil.

B. Results of Entropy-TOPSIS

In this investigation, a 6 × 3 decision matrix was formulated in accordance with the experimental findings, where n = 6 represents the number of experimental runs using different volume fractions of palm–sunflower oil, and m = 3 denotes the number of performance parameters. Each experimental run is considered an alternative, and its analogous output serves as the output measurement criteria (Fig. 4). Notably, all performance measurement

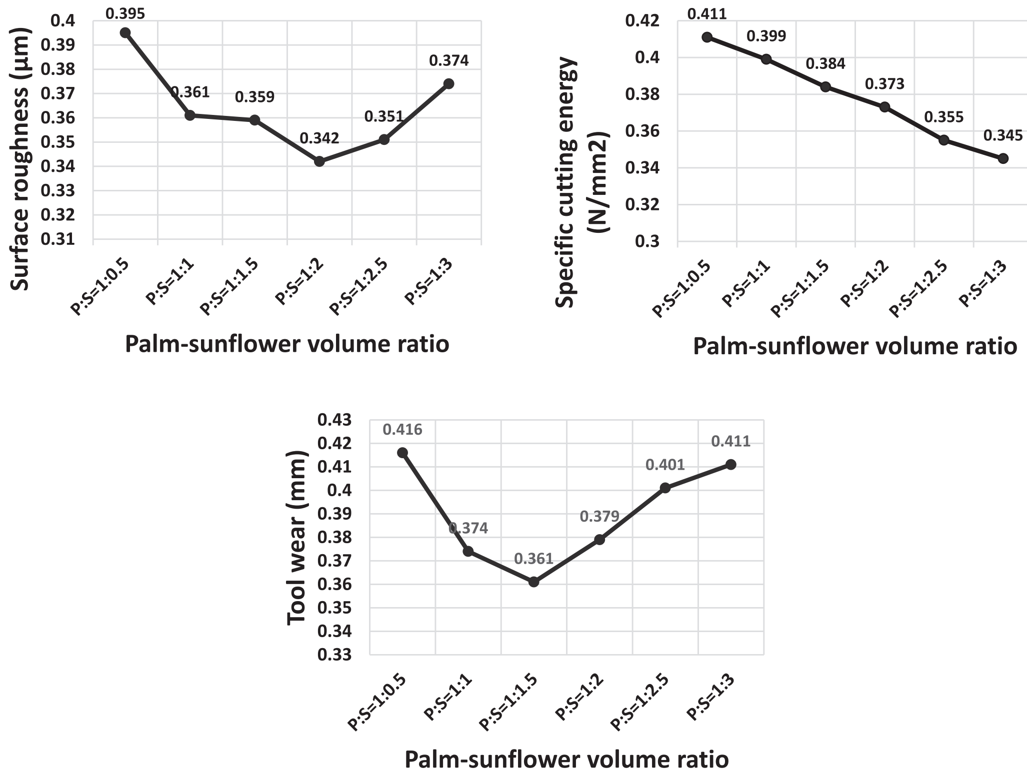

FIG. 3. Variation of machining responses with palm–sunflower volume ratio.

criteria fall into the cost category, implying that minimization is desired. To determine the optimal palm–sunflower oil volume ratio, minimization characteristics for machining responses were considered. Weight factors are typically involved in addressing MCDM problems. Shannon's entropy[43,44] measurement technique was employed to estimate the weight factors for each objective function. The calculated weight factors for surface roughness, specific cutting energy, and tool wear were 0.334, 0.333, and 0.333, respectively.

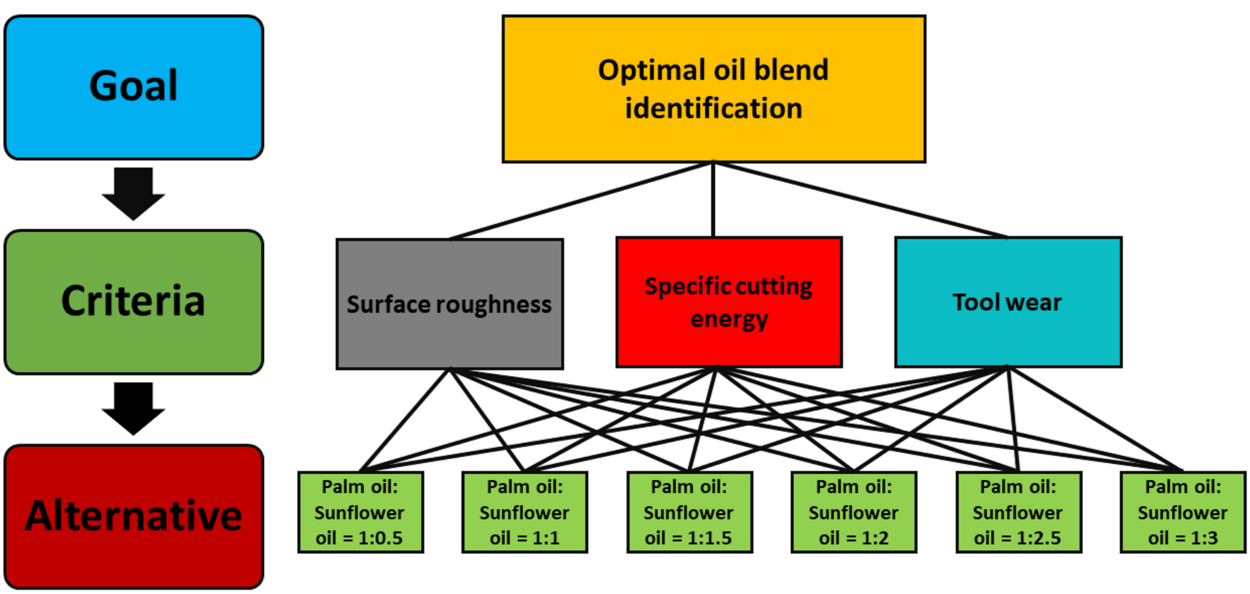

FIG. 4. The structure of the multi-criteria decision-making model.

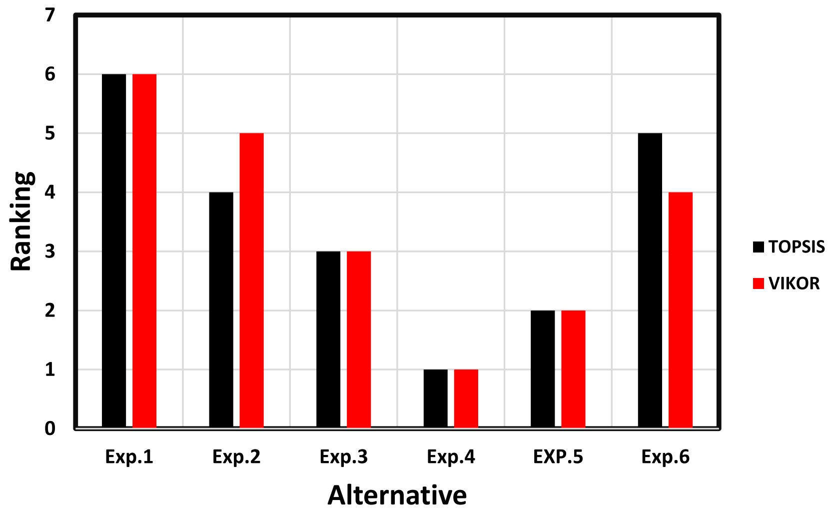

FIG. 5. Ranking of alternatives.

The optimal palm–sunflower oil volume ratio of 1:1.5 was identified using a TOPSIS and Shannon's entropy method. For validation, a comparative analysis using the VIekriterijumsko KOmpromisno Rangiranje (VIKOR) technique is also presented. The output ranking results of the Entropy-TOPSIS and Entropy-VIKOR methods are demonstrated in Fig. 5. The outcomes reveal that the best alternative identified through the Entropy-VIKOR method aligns with that discerned by the proposed Entropy-TOPSIS approach. This

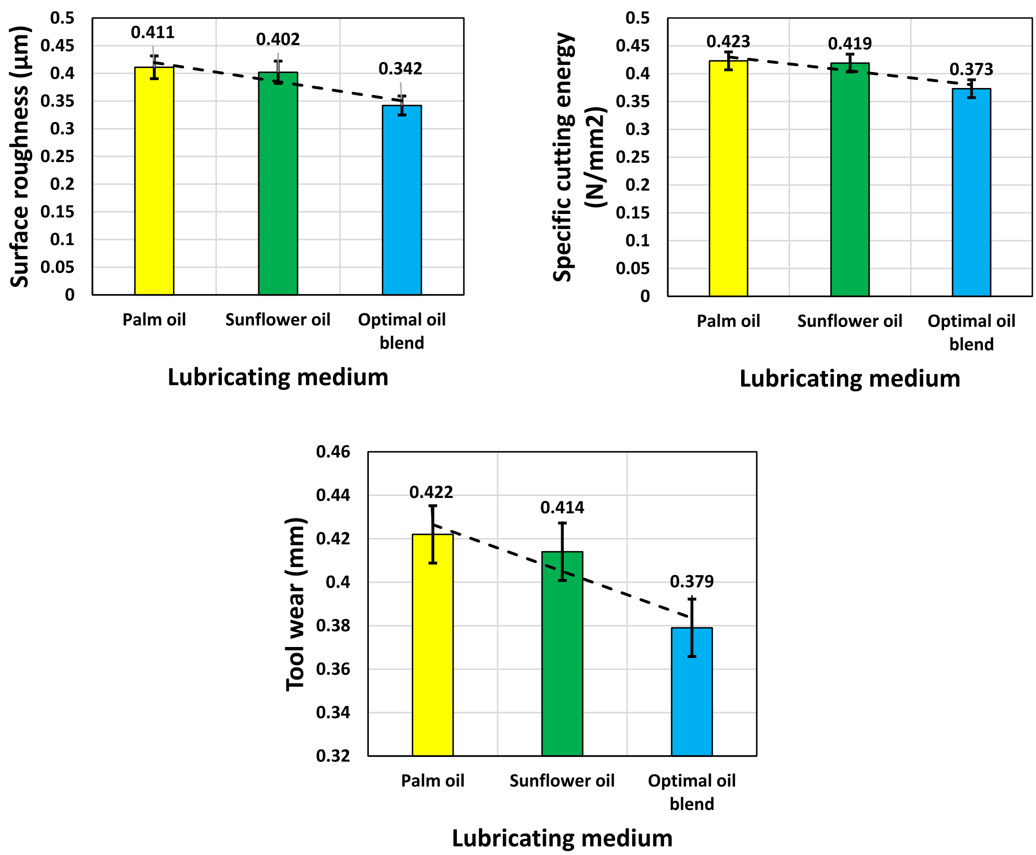

FIG. 6. Comparing the performance of palm oil, sunflower oil, and optimal oil blend.

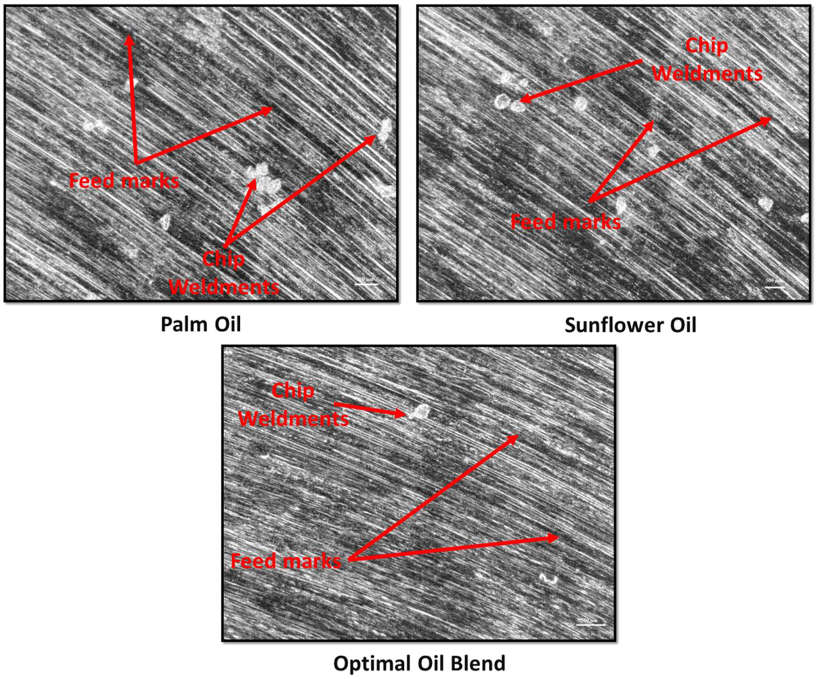

FIG. 7. Microscopic images of the machined surfaces using different lubricating oils.

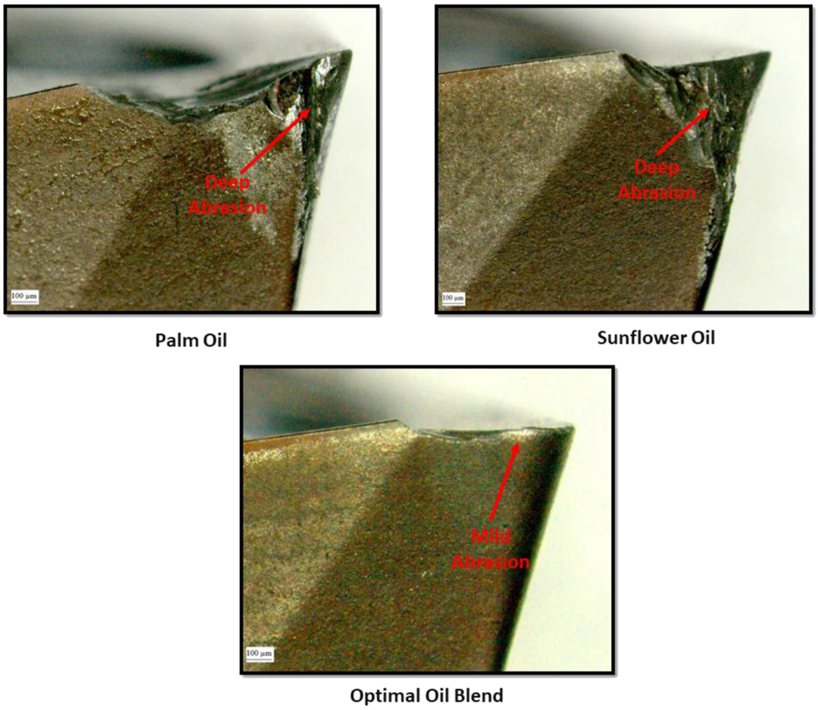

FIG. 8. Tool wear pattern using different lubricating oil.

synchronization underscores the credibility and rationality of the suggested MCDM technique for pinpointing the best palm–sunflower oil volume ratio.

C. Comparing palm oil, sunflower oil, and optimal oil blend

The machining performances achieved using the optimal palm–sunflower oil volume fraction (1:2) were juxtaposed with those of pure palm and sunflower oil. A comparison revealed that MQL milling with the palm–sunflower volume fraction (1:2) showcased significantly superior machining responses compared to other media (refer to Fig. 6). Indeed, the utilization of the optimal palm–sunflower volume fraction led to a 16.79% and 14.92% reduction in surface roughness, an 11.82% and 10.98% decrease in specific cutting energy, and a 10.19% and 8.45% decline in tool wear when juxtaposed with the performances attained using pure palm and sunflower oil media, respectively. The microscopic images of the milled areas subjected to various lubrication media are depicted in Fig. 7. Feed marks are evident on the milled surfaces across all media; however, they are notably less pronounced in the blended medium. In addition, several chip weldments are observed in the first two media, indicating a robust bonding between the chips and the workpiece surface, likely due to increased friction. Figure 8 illustrates the flank faces of the tool when using palm oil, sunflower oil, and a palm–sunflower blended medium, all showing similar types of wear on the tool. However, the blended medium exhibits a reduced tendency for tool damage compared to the other two media. Several years ago, Sen *et al.*[43] determined that the primary cause of flank wear in superalloy machining is abrasion. The abrasive wear detected on the tool emerges from the heightened friction between the chips and the workpiece surface. Predominantly, diverse carbide particles within the workpiece material serve as abrasive agents, generating discernible cracks resembling elongated strips. Possessing formidable elements and compounds, carbide particles exhibit notable stability, marked by their elevated melting points and considerable strength. Throughout milling endeavors, these resilient particles intersect with the tool substrate material, initiating surface abrasions and thereby advancing the wear process.

The reduction in machining responses when using blended bio-lubricants can be explained by contact angle theory. The contact angle delineates the angle formed at the juncture of gas, fluid, and solid phases by the tangent line to the gas–fluid interface. Also termed the degree of wettability, this angle plays a pivotal role in discerning the fluid's wetting behavior. Greater contact angles signify diminished wettability, whereas lesser contact angles denote heightened wettability.[45,46] Figure 9 compares the contact angles for pure palm oil, pure sunflower oil, and palm–sunflower blended mixture. It has been observed that the blended mixture has a lower contact angle value as compared to pure palm and sunflower oil. With drops of similar size, a smaller contact angle enhances wettability, thereby expanding the wetting area. This increase in the wetting area improves lubrication, resulting in reduced milling force and surface roughness of the machined zone, ultimately reducing the wear of the tool. Previous literature showed that the reduction in contact angle can be attributed to the synergistic interaction between the two oil components, which alters their physicochemical properties. In the mixture, the presence of different fatty acid compositions from both oils leads to a more heterogeneous molecular structure at the oil–air interface. This heterogeneity can enhance the spreading behavior of the oil mixture on surfaces, resulting in a lower contact angle. In addition, the mixture may exhibit a reduced surface tension compared to the pure oils, further promoting increased wettability. Therefore, the combined effects of molecular interactions and modified surface tension in the mixed oil system contribute to the observed decrease in contact angle.

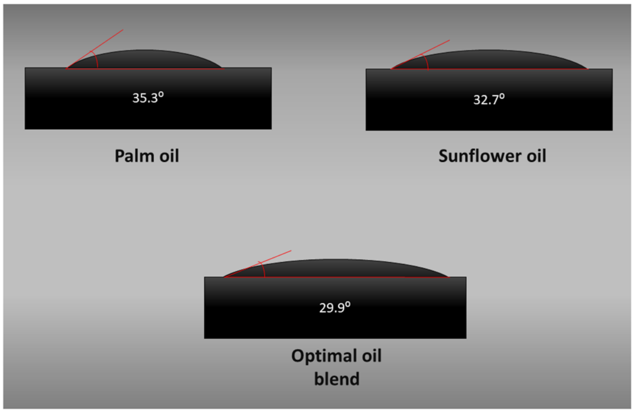

FIG. 9. Contact angle values of different oils and oil blend.

D. Sustainability assessment

Within the framework of cleaner production, sustainability assessment holds paramount importance across every manufacturing sector. Sustainability, in essence, denotes development that fulfills present requirements without jeopardizing the capacity of future generations to meet their own needs. "Sustainable or Cleaner Manufacturing" encompasses not only the product itself but also a spectrum of considerations including worker well-being, environmental integrity, expenses, waste management, post-machining procedures, and product excellence. In this endeavor, a Pugh matrix approach is employed to assess the sustainability implications of milling Inconel 718 under diverse cutting conditions. The Pugh matrix is an effective decision-making tool that compares the performance among various options using a pairwise matrix.[47,48] It assigns numerical weights to quality factors for optimal results, following these steps:

(a) Selection of Criteria: Define and identify weightage criteria.
(b) Base Criteria: Use the best-known criteria as the baseline.
(c) Comparison: Allocate weights based on importance, with "+1" for better results and "−1" for worse, "+2" for much better, and "−2" for much worse.
(d) Final Results: Sum allocated values to select the best criterion.

In the current investigation, the sustainability appraisal of the milling process is diligently examined, incorporating an array of environmental and ecological considerations, operator well-being, coolant costs linked to recycling and disposal, post-machining cleaning of parts, surface roughness, specific cutting energy, and tool wear. The paramount consideration is the environment, assigned a priority weightage of "2" for its environmental and ecological aspects, while all other criteria are uniformly assigned a weightage

TABLE III. Paugh matrix-based comparison.

Factors	Weightage	Dry	Compressed air	Flooded	MQL
Environmental effect	2	Baseline	1	−2	1
Health of operators	2	Baseline	1	−2	1
Cost of coolants	2	Baseline	1	−2	1
Recycling and disposal of coolants	2	Baseline	2	−2	1
Part cleaning	2	Baseline	2	−2	1
Surface roughness	1	Baseline	1	2	2
Specific cutting energy	1	Baseline	1	2	2
Tool wear	1	Baseline	1	2	2
Total (+)		0	10	6	11
Total(−)		0	0	−10	0
Score		0	10	−4	11

of "1." Dry milling serves as the reference baseline method. Various techniques have been allocated points or weightage for diverse criteria as detailed in Table III. Primarily, machining under dry and compressed air-based conditions was conducted without cutting fluid, whereas in MQL conditions, a minimal amount of blended vegetable oils along with compressed air was utilized. Consequently, operator health and environmental safety are maintained, as the process does not emit any pollutants or harmful substances. Therefore, a score of "1" is accorded to both compressed air and MQL, in contrast to a score of "−2" for the flood cooling system, which extensively employs coolants containing environmentally harmful chemicals that are difficult to dispose of and expensive to recycle. In addition, these fluids pose health risks to operators, such as skin and lung diseases, and contribute to air pollution. In terms of coolant cost, a score of "1" is attributed to both compressed air and MQL, whereas a score of "−2" is assigned to the flood cooling system, which consumes nearly 40 l of cooling fluid. This encompasses costs for storage, circulation (via motor and pump), and accessories (including pipes, nozzles, and filters). Furthermore, the cost of recycling, disposal, and part cleaning yields a score of "2" for compressed air, "1" for MQL, and "−2" for flood cooling. The flood cooling technique incurs additional costs due to the expensive coolant requiring repeated cleaning and filtering, and disposal necessitates special procedures to mitigate environmental harm. Conversely, compressed air and MQL involve minimal coolant usage, with no wetting of the workpiece, although MQL does necessitate manual cleaning, incurring some labor costs. Regarding machining responses, MSQL and flood cooling are each assigned a score of "2," while compressed air receives a score of "1." Following these calculations, MQL achieves the highest score, followed by compressed air, with flood cooling ranking last. As previously stated, dry milling is used as the standard reference. The environmental impact of each process is depicted in a Kiviat diagram in Fig. 10, underscoring that flood cooling is decidedly unsustainable. Dry and compressed air-based cutting conditions are feasible provided that high temperatures do not adversely affect other machinability aspects. Ultimately, the MQL condition yields the lowest surface roughness, specific cutting energy, and tool wear among all assessed methods.

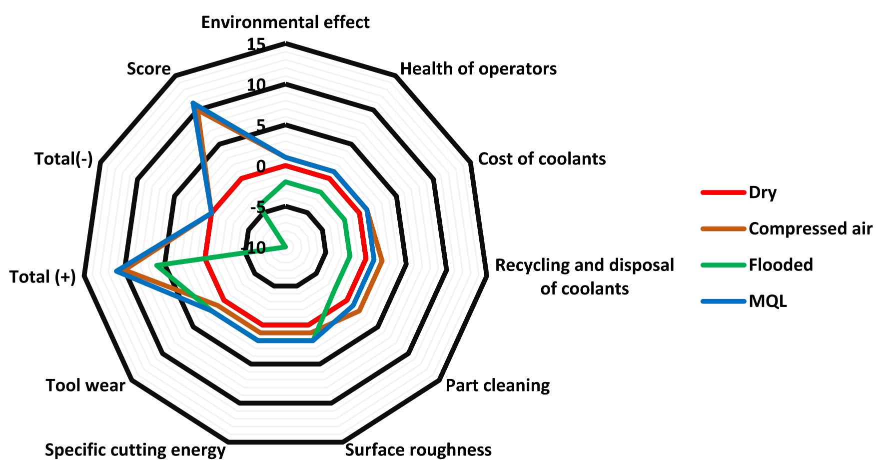

FIG. 10. A Kiviat diagram of sustainability assessment.

IV. CONCLUSION

The quest for sustainable machining practices has led researchers to explore the potential of bio-lubricants derived from vegetable oils. This study focuses on investigating the efficacy of blended bio-lubricants, specifically palm and sunflower oils, in MQL environment for machining Inconel 718, a superalloy known for its challenging machinability characteristics. The following conclusions can be drawn from the study:

(a) Blended bio-lubricants, particularly a 1:2 ratio of palm to sunflower oil, exhibit superior performance in terms of surface roughness, specific cutting energy, and cutting temperature.
(b) The reduction in machining responses, such as specific cutting energy and surface roughness, can be attributed to the enhanced wettability facilitated by a lower contact angle in the blended oil mixture.
(c) Microscopic images showed that the blended medium of palm and sunflower oils reduced tool damage compared to pure palm or sunflower oils. The blended medium results in less pronounced feed marks on the milled surfaces and fewer chip weldments, indicating reduced friction and improved lubrication.
(d) The application of the Entropy-TOPSIS method, in conjunction with Shannon's entropy technique, proves effective in determining the optimal palm–sunflower oil volume ratio for MQL-assisted machining operations.
(e) Sustainability assessment using a Pugh matrix approach highlights the environmental and economic advantages of Minimum Quantity Lubrication over dry, compressed air, and flood cooling methods.

The findings demonstrate that using a 1:2 palm–sunflower oil blend in machining significantly improves surface quality while reducing energy consumption and tool wear. This enhanced performance is attributed to better wettability and lubrication. When combined with the Entropy-TOPSIS optimization method and a sustainability assessment, this approach provides manufacturers with a viable path toward more sustainable and cost-effective machining practices. Future research could explore the impact of various bio-lubricant blends on the machinability of different materials, investigate the long-term effects of blended bio-lubricants on tool longevity and surface quality, and extend the study to a broader range of machining processes and materials for a more comprehensive understanding of sustainable machining techniques.

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AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

Ethics Approval

All authors have given their consent for the publication of this manuscript.

Author Contributions

All authors listed have significantly contributed to the development and the writing of this article.

Binayak Sen: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Investigation (equal); Methodology (equal); Software (equal); Validation (equal); Writing – original draft (equal); Writing – review & editing (equal). **Sunil Kumar Kothapalli**: Methodology (supporting); Validation (supporting); Writing – original draft (supporting); Writing – review & editing (supporting). **Raman Kumar**: Methodology (supporting); Validation (supporting); Writing – original draft (supporting); Writing – review & editing (supporting). **Manjunath C**: Formal analysis (supporting); Methodology (supporting); Writing – review & editing (supporting). **Irsyad Abdullah**: Software (supporting); Writing – original draft (supporting); Writing – review & editing (supporting). **Gurpartap Singh**: Software (supporting); Writing – original draft (supporting); Writing – review & editing (supporting). **A. Johnson Santhosh**: Formal analysis (supporting); Software (supporting); Writing – original draft (supporting); Writing – review & editing (supporting).

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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