A Study for an Optimization of Cutting Fluids in Machining Operations by TOPSIS and Shannon Entropy Methods

PANKAJ PRASAD DWIVEDI[1*], DILIP KUMAR SHARMA[2]
[1]Department of Mathematics,
Oriental Institute of Science & Technology, Bhopal, 462022,
INDIA

[2] Department of Mathematics,
Jaypee University of Engineering and Technology, Guna, 473226,
INDIA

*Corresponding Author

Abstract: - Cutting fluids are used in machining processes to increase the quality of machined surfaces, extend the life of tools, and lessen the effect of friction and heat on contact surfaces. The least costly, least hazardous to the environment, and least poisonous lubricant would be the perfect choice. It should also be resistant to low temperatures, have high lubricating qualities, be recyclable, and have stability against oxidation, hydrolysis, and heat. Its viscosity should also fall between the ideal range and not exceed it. Taking the needed properties of the cutting fluids into consideration, for the machining process choosing the best cutting fluid is essential. Five types of cutting fluids are examined in this paper that are often used in machining operations: canola oil, mineral oil, synthetic ester, PAG (Polyalkylene Glycol), and TMPTO (trimethylolpropane trioleate). In this study, the Multicriteria decision-making (MCDM) techniques were used to identify the best choice of cutting fluids based on several parameters, such as low temperature, toxicity, lubricating ability, hydrolytic stability, thermal stability, viscosity index, oxidative stability, and cost. The most popular TOPSIS methods and Shannon's Entropy were utilized to choose these cutting fluids optimally. The TOPSIS approach is used to calculate the final ranking, and Shannon's entropy method is utilized to calculate the weight of the criterion. According to the result with the more lucid rating, PAG cutting fluid was shown to be the most effective, followed by synthetic ester in second place, as well as last place achieved by vegetable-based canola oil.

Key-Words: - Multi-criteria decision making, TOPSIS Method, Shannon's Entropy, Normalization, Material selection, lubricants, PAG (Polyalkylene Glycol).

Received: February 15, 2023. Revised: November 29, 2023. Accepted: December 28, 2023. Published: February 29, 2024.

1 Introduction

Minimizing resistance on surfaces that contact is largely dependent on the cutting fluids or lubricants used in machining operations, [1], [2]. Additionally, they lessen heat generation and enhance the quality of machined surfaces, extending tool life, [3], [4], [5], [6]. To attain these advantages while lowering expenses and the degree of toxicity connected with the fluids, choosing the right cutting fluid is crucial, [7], [8], [9]. Several studies have been conducted in the literature that use MCDM techniques to optimize the parameters of the machining process, [10], [11], [12], [13], [14]. Additionally, studies are carried out using MCDM approaches to examine the lubricants or cutting fluids utilized in machining processes across a range of parameters. Papers that add to this body of work are given in the appropriate order. The study by [15], used the AHP approach in conjunction with a system of fuzzy decision-making of two orders to identify the best-cutting fluid out of three possibilities. An MCDM approach for choosing cutting fluids that take into account factors including quality, cost, and environmental implications was covered by [16]. To provide the best cutting fluid based on the characteristics of the cutting tool in machining operations, [17] reviewed the studies and selection criteria. Applying the PROMETHEE technique, [18], chose cutting fluids based on criteria that included the lubricant's unique technical features as well as some material properties that vary. To determine the best lubricant based on factors including surface roughness, cutting force, tool wear, and temperature at which the chip-tool interface occurs, [19], employed the combined AHP-TOPSIS technique. The study by [20], looked into how well the WASPAS method worked with the cutting fluid selection problem. They also assessed how this method's parameter affected the ranking. The research conducted by [21], presents a new method for data-driven neural network-based compressible turbulent flow field prediction.

The MOOSRA approach, a novel MCDM method, was employed for cutting fluid selection by [22]. The resulting ranking has been compared with the results of the AHP and DMF methodologies. Using the PSI approach, one of the MCDM methodologies, [23], provided a methodical and easily comprehensible method for cutting fluid. They located that the effects aligned with preceding studies after they applied the strategy to 2 actual-international troubles. The study by [24], used the ROV technique to pick out the cutting fluid in four specific case situations. They as compared the rankings produced through their implemented technique with the results of the case research. They gave an instance of the way their approach produced consequences with a high degree of correlation while being realistic and smooth to use.

Using the QFD approach, by [25], created a choice-making version for choosing the first-class reducing fluid among multiple options. They used sensitivity analysis to show how this strategy works in two distinct scenarios and to illustrate how well it solves MCDM difficulties. The ELECTRE III, VIKOR, and PROMETHEE techniques were used by [26], to choose green cutting fluids that are favorable to the environment. The study by [27], used the Taguchi approach to adjust the cutting fluid's concentration, cooling pressure, and flow rate. To choose different cutting fluids, [28], presented a novel decision-making model and hybrid criterion weighting technique. To find the optimal answer, he used fifteen distinct approaches and four different normalizing techniques. To analyze the ranks and show their consistency, he did correlation tests. The COPRAS approach was employed by [29], to ascertain the perfect cutting parameters that yield the desired surface roughness during machining operations. In the study, they assessed several cooling techniques (cryogenic, flood, and MQL). In their investigation, the hybrid cooling technique produced the best outcome. To lessen environmental contamination, [30], employed the ARAS and COPRAS methodologies to determine which of the three green cutting fluids would be best. They discovered that in both approaches, the traditional cutting fluid gave the lowest results. A hybrid MCDM methodology, such as the AHP-MARCOS method, was used by [31], to identify cutting fluids. They noticed a rating that was comparable to the TOPSIS approach when they compared the rankings acquired with the rankings from the VIKOR and TOPSIS procedures.

During the procedure of machining, several cutting fluids are used to improve surface quality and cool the material. Certain requirements, including lubricating qualities, stability, viscosity, and price, must be met by these cutting fluids. For this reason, choosing the best cutting fluid is essential to guarantee the quality of the final output. Selection criteria in the literature frequently include machining parameters and output reactions such as temperature, force, wear, and surface roughness. Using the output answers as a criterion might result in mistakes if they are not acquired as a consequence of processing following the ideal process parameters. Consequently, selecting cutting fluids based on their basic characteristics produces more precise outcomes. Furthermore, critical properties of cutting fluids that are frequently disregarded in literature studies include resilience to thermal stability, hydrolytic stability, low temperatures, toxicity, oxidative stability, and affordability. This study contrasts MCDM approaches with an innovative methodology and includes original aspects, which sets it apart from previous studies. The criteria for inclusion in the literature were the cutting fluids' toxicity qualities, pricing, tolerance to low temperatures, and stability. The study also highlights the significance of using cutting fluids' fundamental characteristics as criteria during machining rather than depending exclusively on reaction parameters. Nonetheless, a lot of literature reviews employ many MCDM techniques. It is noted that different MCDM techniques provide different ranks when preference rankings are evaluated. This discrepancy results from variations in the multi-criteria decision-making method's mathematical methodology. As a result, it is essential to remove these disparities in ranking and to make the ranks produced by the methodologies clear and consistent. In response to previous issues, the following cutting fluid factors were taken into consideration as decision criteria in this study: low temperature, toxicity, lubricating ability, hydrolytic stability, oxidative stability, thermal stability, viscosity index, and cost.

These criteria's worth for information was gathered from sources in the literature, [1], [32] and [33]. The TOPSIS and Entropy techniques were used to choose the cutting fluids. The entropy approach was applied to establish the weights of the criterion. Ultimately, the TOPSIS technique provided clarification on the cutting fluid selection rankings. The study's conclusions increase the likelihood of choosing the best cutting fluid for industrial machining operations in a way that is affordable, long-lasting, sustainable, and highly beneficial. For the material selection, a comparative analysis of MCDM techniques has been provided by [34].

The rest of the article is structured as follows: Section 2 provides the material and method. Section 3 provides the results and discussion. Finally, section 4 describes the conclusion of the study.

2 Materials and Methods

2.1 Selection Criteria and Materials

Inadequate use of cutting fluids during machining operations might result in challenges as well as surface and dimensional issues, [35], [36]. In machining operations, cutting fluids is crucial to counteract these unwanted consequences. Five distinct alternative cutting fluids were considered for the selection procedure in this material selection research. Furthermore, the selection of cutting fluids was based on eight criteria: low temperature, toxicity, lubricating ability, viscosity index, thermal stability, hydrolytic stability, oxidative stability, and cost. References in the literature were used to get data on the cutting fluid statistics and substitute cutting fluids [1], [32], [33].

First up is canola oil, which is derived from vegetables. Vegetable-based oils consist of triglyceride molecules with long-chain fatty acids connected to hydroxyl groups through ester bonds. The structure of the lubricating coating's long chain fatty acids interacts with the surface to reduce wear and friction effects, [37], [38]. The second is TMPTO (trimethylolpropane trioleate), a substitute cutting fluid made of oleic acid that is produced using vegetable oil and polyol ester. Because of its biodegradability, it is referred to as "green cutting fluid", [39]. The third type of cutting substance is a synthesized ester, which is made up of fatty acid and alcohol and is created as a cutting fluid with two or more carboxylate groups, [40]. Polyalkylene Glycol (PAG), a copolymer of propylene and ethylene oxide, is the fourth cutting fluid, [41]. Which is Mineral oil, a petroleum-based product made from crude oils by vacuum distillation, is the best sort of replacement cutting fluid. Cutting fluids are selected using the hierarchical model (Figure 1) under the specified parameters. The relationships between the several factors considered while choosing a cutting fluid are displayed in this hierarchical model. The relative weighting factors of the criteria employed in the decision-making process are gradually established when the hierarchical model is built. A list of substitute fluids and their definitions may be found below:

- Vegetable oil (Canola A1): Cutting fluids are increasingly using canola oil as a sustainable substitute. Canola oil has inherent lubricating qualities and is renewable and biodegradable. It offers green cooling and lubrication at some point of metalworking operations while combined with slicing fluids. Because it is biobased, it has much less of a destructive impact on the surroundings and poses fewer fitness dangers than standard reducing fluids. The intrinsic traits of canola oil, such as its excessive flash factor and coffee volatility, make the place of work more secure. Canola oil is a feasible choice for efficient and sustainable metal-cutting packages due to its renewability and availability, which coincide with the increasing consciousness of environmentally responsible sports.
- TMPTO (Trimethyl propane trioleate A2): Trimethylolpropane and oleic acid are blended to produce trimethyl propane trioleate (TMPTO), a synthetic ester. This substance is prized for its many uses of, mainly as an additive for lubricants. TMPTO minimizes friction, boosts oxidative balance, and promotes lubricity in a number of formulations, making it best to be used in metalworking fluids and business lubricants. Its low volatility and high viscosity index contribute to its effectiveness at very low temperatures. Because of its molecular makeup, TMPTO may also paintings as a plasticizer and a surface-lively agent in precise programs. This versatility makes it useful for enhancing lubricating oil's overall performance and prolonging its lifespan in quite a few sectors, along with commercial, automobile, and chemical processing.
- Synthetic ester (A3): Combining natural acids with alcohols results in the chemical compounds referred to as artificial esters, which might be used to make several purposeful materials and artificial lubricants. These esters are more lubricating, thermally solid, and immune to oxidation than conventional mineral oils. Synthetic esters are regularly utilized in hydraulic fluids, metalworking programs, and business lubricants due to their excellent overall performance in tough situations and excessive temperatures. Because of their exactly customizable chemical and bodily qualities due

to their specific molecular architectures, they're best for precise packages in the automobile, aviation, and other sectors. Extended service intervals, much less wear, and advanced equipment efficiency are all facilitated through artificial esters.

- PAG (Polyalkylene Glycol A4): Polyalkylene Glycols (PAGs) are synthetic lubricants from the polyglycol own family this is extensively employed in many industrial packages. Alkylene oxides go through polymerization to create those polymers. PAGs can face up to harsh environments such as high temperatures and massive masses due to their super lubricity, thermal, and oxidative balance. In the car, production, and aerospace industries, they're frequently used as compressor lubricants, hydraulic fluids, and tool oils. PAGs are useful as lubricants in vital machinery because of their low volatility and compatibility with a variety of materials, which are crucial for improved performance and longer equipment life.
- Mineral oil (A5): Mineral oil is a clear, colorless liquid with a petroleum base that has no smell. It is a kind of oil consisting of complex hydrocarbon mixtures with a hydrocarbon foundation. Mineral oil has several applications in the industrial, cosmetic, and medical fields as an insulator, coolant, and lubricant. It may be found in skincare products like lotions and baby oil in the cosmetics industry because of its moisturizing properties. Medical professionals use mineral oil as a laxative. Its versatility is derived from its ability to provide a smooth, firm, and inert foundation for several products, even in the face of a growing demand for more ecologically friendly and natural alternatives.

The MCDM involves making decisions in the presence of multiple and often conflicting criteria. The term "criteria" in mixed-criteria decision-making refers to the range of variables or aspects that are taken into account while assessing and contrasting distinct options. These standards, which are selected following the particular circumstances of the choice issue, are crucial for evaluating the effectiveness or attractiveness of options. The goals, principles, and inclinations of the decision-makers and other stakeholders are taken into consideration while choosing the criteria. Both qualitative and quantitative criteria may be used, and they may cover topics including social concerns, risk, quality, cost, and time. The decision-making process cannot succeed unless specific, pertinent criteria are identified and defined. For better organizing and structuring the choice issue, criteria are frequently divided into various groups or dimensions. To represent each criterion's relative significance throughout the decision-making process, weighting may also be used.

We have determined the following criteria for cutting fluids in machining operations based on a survey of the literature.

- Low temperature (C1): Cutting fluids with low-temperature performance for machining operations has several advantages. First of all, it aids in preventing workpieces and cutting tools from overheating during machining processes. Lower temperatures are maintained to minimize tool wear and increase tool life, which saves money. Lower temperatures can improve the dimensional accuracy of machined products by lowering thermal expansion. Cooling also encourages chip evacuation and lessens the possibility of formed built-up edges. It also improves surface polish and overall machining efficiency. To ensure precision, maximize machining efficiency, and make bigger the life of reducing gear, choose slicing fluids with incredible low-temperature houses.
- Toxicity (C2): The phrase "toxicity" refers back to the doubtlessly disastrous consequences that cutting fluids may additionally have on both human health and the environment. Cutting fluids can incorporate a wide variety of chemical substances, in addition to biocides, corrosion inhibitors, and lubricants. Cutting fluids are utilized in metalworking activities further to grinding and machining. Skin touch, inhalation, or ingestion of these materials can also result in pores and skin infections, respiration problems, and other critical side effects. When spent reducing fluids are disposed of, the surroundings are likewise put in danger. Manufacturers are stimulated to deliver fewer, less harmful fluids which will defend employee fitness, lessen environmental effects, and market greater constant and ecologically pleasant metalworking operations.
- Lubricating potential (C3): This refers to the capacity of reducing fluids to reduce put on and friction on the bulk of the workpiece and the decreasing tool on the quit of machining processes. Appropriate lubrication is crucial for metalworking to ensure reducing accuracy, remove defects from the ground, and develop device lifespans. Cutting fluids with brilliant lubricating homes creates a defensive layer between the tool and the workpiece, reducing frictional forces and warmth technology. By reducing put on, this complements widespread

machining performance, allows chip evacuation, and will increase device life. Proper cutting fluid lubrication will increase workpiece notable, reduce electricity intake, and increase productivity in many machining procedures.

- Hydrolytic stability (C4): Fluids with slicing houses that are hydrolytically resistant are those that don't break down as quickly as they come into touch with water. In metalworking operations, water-based absolute coolants and unintentional water touch are frequent occurrences. By use of hydrolytic stability, the cutting fluid's ability to preserve its standard performance traits and withstand degradation in the presence of water is guaranteed. High hydrolytic stability fluids inhibit the manufacturing of undesirable byproducts, such as acids, that can corrode steel surfaces and reduce the efficacy of the decreasing fluid. Advanced hydrolytic balance in reducing fluids allows to make sure the sturdiness of metalworking systems and gadgets. It additionally offers a longer fluid existence, appreciably less safety, and maintains overall overall performance.
- Oxidative balance (C5): Oxidative stability is the ability of cutting fluids to withstand degradation brought on using exposure to oxygen inside the air. Throughout metalworking operations, reducing fluids are subjected to excessive temperatures, and oxidation can be due to oxygen. Oxidative stability ensures that the fluid continues its chemical balance by preventing the manufacturing of dangerous byproducts that might compromise the decreasing fluid's capability. Reducer fluids with high oxidative stability have longer company lifetimes even as still capable of lubricating and unfasten. This choice is critical for reducing working charges, minimizing the need for routine fluid refills, and galvanizing dependable and green machining tactics in industries where metalworking is popular.
- Thermal balancing (C6): Thermal balance is the capability of lowering fluids to go through and keep function effectively at excessive temperatures inside the route of metalworking techniques. Because cutting sports generates a number of heat, the fluid desires with a purpose to withstand thermal breakdown for you to preserve ordinary average performance. High warmness stability decreasing fluids withstand degradation and show off small viscosity variations, which prevent the formation of deposits and breakdown products. This function preserves the fluid's cooling and lubricating properties, which finally lengthens the tool's lifespan and complements the workpiece's fantastic high quality. Thermal stability plays a widespread position in extending the life of the reducing system and the lowering fluid itself in slight-name for machining applications, which enables to increase productivity and decrease downtime.
- Viscosity index (C7): The viscosity index of a reducing fluid is used to measure how resistant it is to modifications in viscosity because of temperature versions. Temperature variations have some distance much less of an impact on the fluid's viscosity thanks to an extra viscosity index. Because of the warm temperature generated during cutting operations, reducing fluids enjoy temperature versions in metalworking tactics. With the help of retaining an extra steady viscosity across a w ide temperature variety, high-viscosity slicing fluids provide dependable lubricating and cooling tendencies. This is essential for maintaining proper fluid flow and lubrication under a variety of working circumstances, which enhances tool performance and workpiece quality and helps maximize machining efficiency.
- Cost (C8). Cutting fluid costs encompass acquisition, upkeep, and disposal costs. High-performance fluids may be more expensive up front, but by prolonging tool life and decreasing downtime, they may save money over time. Costs are also affected by proper fluid management techniques, which take waste disposal, recycling, and filtering into account. Even while they may cost very little initially, high-quality fluids for cutting can save money over time by reducing the need for more frequent tool changes and enhancing machining productivity. Finding the sweet spot between initial costs and continuing advantages is necessary to maximize the benefits of cutting fluid selections in machining operations.

To maximize the potential output and optimize processes for both useful and non-beneficial factors, trade-offs need to be balanced. MCDM uses methods such as the AHP and PROMETHEE. The objective is to maximize usable criteria, i.e., to look for solutions with high ratings for good aspects. Minimization, which attempts to lessen adverse effects, is one of the non-beneficial criteria. Decision-makers can select options that perform well in positive features while reducing negative consequences by weighting and ranking these characteristics.

Table 1. Alternatives for cutting fluids in machining operations

Alternative ↓ Criteria→	C1 +	C2 –	C3 +	C4 +	C5 +	C6 +	C7 +	C8 –
A1	1	2	5	1	1	2	4	2
A2	3	2	4	2	2	3	4	4
A3	3	2	4	3	4	4	4	7
A4	3	2	4	3	3	3	4	2
A5	3	5	3	4	3	3	2	1

A thorough assessment of the optimization process is necessary, taking into account the proportional weight of each criterion as well as the particular objectives and limitations of the choice issue. The optimization for beneficial criteria is represented as ‘+’ and non-beneficial criteria represented as ‘–’. Table 1 presents the selection criteria, relevant data, and alternatives utilized in this work for the MCDM techniques of cutting fluid selection. The data are derived from [1], [32], [33]. Based on eight selection criteria, the best cutting fluid is selected among five different cutting fluids in this study.

2.2 Methods

The MCDM methods are employed in situations where a single best choice or alternative must be selected from a set of available options, and these options need to be evaluated against various criteria that may have different importance levels or preferences. MCDM approaches are employed in this work to select and compare different cutting fluids utilized in the machining operations. In this study, offering a tool for those involved in industrial manufacturing industries is the goal. For assessment, the widely-used and computationally effective MCDM methods, TOPSIS and Entropy, are used. To avoid taking into account the decision maker's viewpoint, the entropy approach is used to compute the weighting factors for the criterion in the chosen method. Next, the TOPSIS MCDM approach steps are applied to establish the cutting fluid selection rankings. Lastly, the flowchart of the procedures used in this study to choose other cutting fluids is displayed in Figure 2. Cutting fluids are chosen using the MCDM methodologies' processing stages.

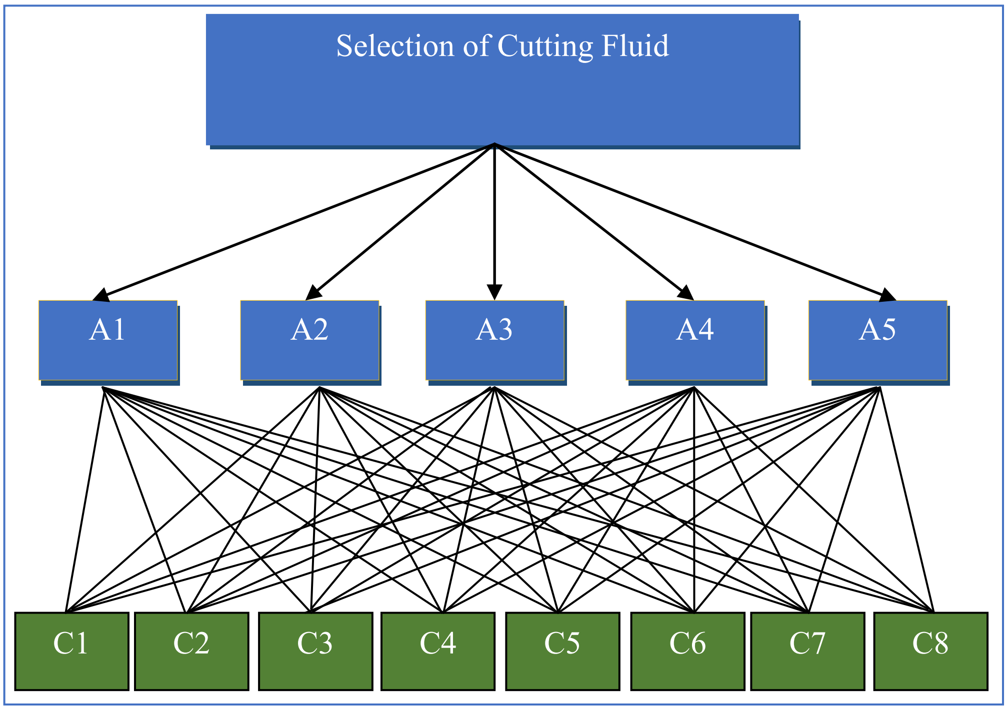

Fig. 1: The hierarchical model for selection of cutting fluid

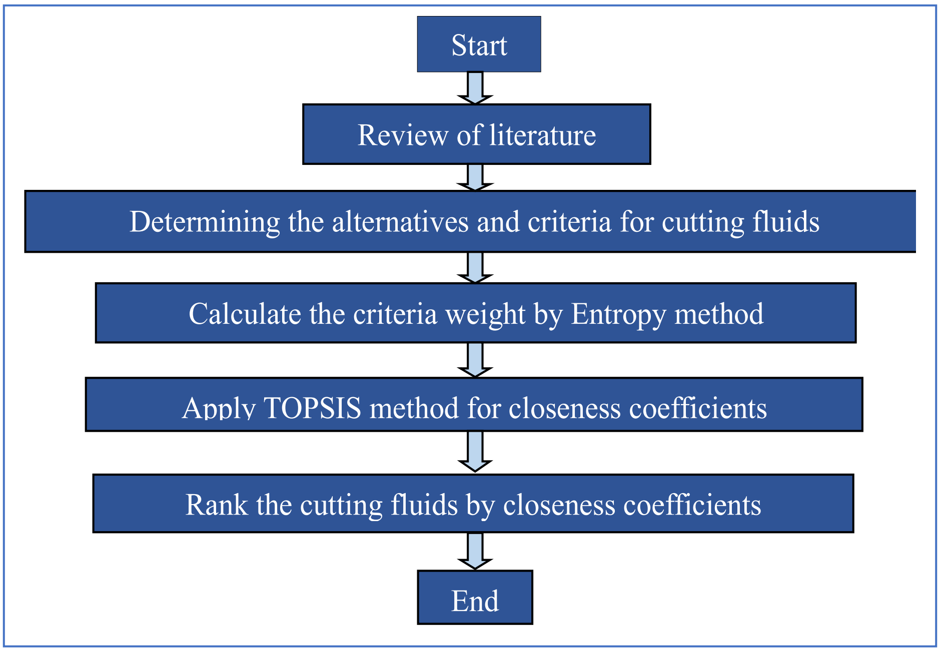

Fig. 2: The flowchart of the selection of cutting fluid

2.2.1 TOPSIS Method

The TOPSIS method is particularly useful when making decisions involving conflicting criteria and trade-offs. It allows decision-makers to quantify and balance the impact of different criteria in the selection process. However, it's important to carefully define criteria, normalize data, and assign appropriate weights to ensure the reliability of the results. Hwang and Yoon developed it, [42], [43]. In this process, various choice criteria are evaluated using both positive and negative ideal solutions. The optimal decision is determined by the maximization of the distance from the negative ideal solution and the minimization of the distance from the positive ideal solution.

The decision-makers preferences and the particulars of the decision issue will determine which of the several MCDM methods—of which TOPSIS is just one—are used. It is a tool for decision assistance that is often used in many different sectors, such as economics, business, engineering, and environmental management. The TOPSIS approach takes into account several different criteria or qualities to assist decision-makers in choosing the best choice from a range of possibilities. TOPSIS may be used to evaluate and rank some cutting fluid options based on several criteria when selecting cutting fluids for machining processes.

This is a comprehensive guide to selecting, cutting fluids for machining processes utilizing TOPSIS: First, determine the key parameters that will be used in the cutting fluid selection procedure. This step is necessary to compare different parameters equitably. Two formulas that may be used to normalize the decision matrix are min-max normalization and z-score normalization. Every criterion is given a weight based on how important they are concerning one another. The weight given to each criterion is reflected in the decision-making process. All weight must add up to one. First, construct the decision matrix with a criterion in each column and a cutting fluid option in each row. Each criterion's normalized values are included in the matrix. For every parameter, the ideal and anti-ideal solutions are computed. For every criterion, the anti-ideal solution represents the lowest value, and the ideal solution, the largest value. Each alternative's Euclidean distances to the ideal and anti-ideal solutions are computed. A metric for similarity or dissimilarity is the Euclidean distance. The relative closeness of each option to the optimal solution is computed using the computed distances. The ranking of alternatives is determined by how close they are to the best possible answer. The best option is the one with the highest TOPSIS score.

Applying the TOPSIS method in machining processes to the selection of cutting fluids requires careful consideration of the criteria, their normalization, weight assignment, and the actual calculation steps. Keep in mind that the success of the TOPSIS method depends on the accuracy of the parameters, weights, and normalization process. The popularity, ease of use, and mathematical computations of this TOPSIS approach make it the recommended one. The method's application phases are listed below, [44].

Step 1: A decision matrix (DM) is produced during this stage. The following criteria, which were established at the outset, yield this matrix.

$$DM = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{31} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

In the following equation, the performance of alternative $i = 1,2,3, \dots m$ in $j = 1,2,3, \dots n$ criterion is indicated by a_{ij}. The original decision matrix has n criteria and m alternatives.

Step 2: Each value of the Decision matrix is normalized as the following equation:

$$a_{ij}^{*} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \quad (2)$$

Step 3: A weighted decision matrix (WDM) is developed. The weight values of the assessment criteria's relevance are used to determine this matrix.

The normalized decision matrix's elements are multiplied by the weight (w_j) values, which are determined as follows to generate the WDM.

$$WDM_{ij} = a_{ij}^{*} * w_j \quad (3)$$

Step 4: The values of the optimum solution, both positive and negative, are found. The biggest value in each column of the matrix WDM represents the positive ideal solution, while the smallest value in each column represents the negative ideal solution. $WDM^{+} = \{WDM_1^{+}, WDM_2^{+}, \dots \dots, WDM_n^{+}\}$ is the definition of the positive ideal solution set, while $WDM^{-} = \{WDM_1^{-}, WDM_2^{-}, \dots \dots, WDM_n^{-}\}$ is the definition of the negative ideal solution set.

Step 5: In this step the equations (4) and (5), which relate the distance values (S_i^{+}, S_i^{-}) to the positive and negative ideal solution, are used to compute the distance value as well as the number of possible decisions.

$$S_i^{+} = \sqrt{\sum_{j=1}^{n} \left(WDM_{ij} - WDM_j^{+}\right)^2} \quad (4)$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{n} \left(WDM_{ij} - WDM_j^{-}\right)^2} \quad (5)$$

Step 6: In this step, the equation (6) is used to determine the relative closeness coefficients (C_i) of each decision alternative to the ideal solution. There are observed to be distances from both positive and negative ideal solution values.

$$C_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \quad (6)$$

Step 7: Finally, the calculation of the closeness coefficients that were obtained which fall within the range of $0 \leq C_i < 1$. Sorting based on values bigger than the established closeness coefficients is how the selection procedure is carried out.

2.2.2 Shannon's Entropy Method

Weighing the factors is one of the most crucial procedures in selecting a different cutting fluid. The Shannon entropy, [45], method is used to generate the criterion's weighting elements. As stated in [46], this method measures the amount of uncertainty in the data that is given in probability theory.

Claude Shannon proposed the idea of information entropy, commonly known as Shannon entropy, in his 1948 work "A Mathematical Theory of Communication". Three components make up a data communication system, according to Shannon's theory: a data source, a communication channel, and a receiver. According to Shannon, the "fundamental problem of communication" is the receiver's ability to determine, from the signal it gets over the channel, what data originated from the source. In his renowned source coding theory, Shannon demonstrated that the entropy reflects an absolute mathematical limit on how effectively data from the source can be losslessly compressed onto a totally noiseless channel. Shannon took into account various methods of encoding, compressing, and transmitting messages from a data source. Shannon's noisy-channel coding theorem significantly reinforced this outcome for noisy channels.

Information theory entropy and statistical thermodynamics entropy are exactly comparable. Gibbs' formula for entropy is technically equal to Shannon's formula when the values of the random variable denote the energies of microstates, as is the case in this comparison. Other branches of mathematics, like combinatorics and machine learning, are related to entropy. A series of axioms showing that entropy should be a measure of the average result of a variable's informativeness may be used to construct the definition. Differential entropy is equivalent to entropy for a continuous random variable. Shannon's entropy, a fundamental concept in information theory, has several applications in fields where determining uncertainty and information content is essential. It provides a scientific and rigorous way to measure the information or randomness included in a dataset or system. [47], provide information measures with data illustration.

The entropy approach's phases, [48], [49], [50], are listed below and were utilized to establish the weights of the criterion.

Step 1: The decision matrix (DM) is generated using the values of the criteria and alternatives in Table 1. It is obtained, as equation (1) shows.

$$DM = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{31} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mn} \end{bmatrix} \tag{7}$$

Step 2: The following equation (8) is used to convert the values of the choice matrix presented in expression (7) to their normalized values. Where N_{ij} represents the normalized value of the i alternative for the j criteria:

$$N_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \tag{8}$$

Step 3: The following equation (9) is used to determine each criterion's entropy value (E_j):

$$E_j = -\frac{\sum_{i=1}^{m} N_{ij} \log_2 N_{ij}}{\log m} \tag{9}$$

Step 4: Finally, the entropy weight values (w_j) for each criteria are computed using equation (10). The weighting of each criterion must equal one, i.e., $\sum_{j=1}^{n} w_j = 1$:

$$w_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \tag{10}$$

2.3 Direction of Future Study

With further investigation on stabbing fluids in MCDM-based machining transactions, metal-cutting processes may become more aesthetically pleasing, more businesslike, and more sustainable. Efficient fluids may be selected and evaluated by applying MCDM techniques such as entropy to calculate the TOPSIS, ELECTRE (Expelling and Prize Expressing Realism), and unit criteria.

More aspects, such as environmental change, agency account, aboveground smoothness, cost-effectiveness, and methods vivification, may be taken into consideration at the outset of an investigation into knifelike liquid pick improvement. This ecumenical meeting ensures a far more complete presentation of the trade-offs involved in making compliant judgments. Furthermore, by enabling real-time machining process modifications, the combination of cutting-edge analytics and tool acquisition may alter the predictive state of MCDM.

A closer look at innovative sustainable knife-like changing possibilities, such as bio-based or environmentally friendly fluids, inside the MCDM potential may also lead to improved, more environmentally friendly production techniques. Further research should be done to improve iron mind models that predict projectile machining conditions and changing environmental restrictions.

This will assist in striking a balance between the performance, cost, and environmental effects of metal-cutting processes.

3 Results and Discussion

The corresponding weighting variables associated with eight parameters in the selection of cutting fluids used in machining processes have been established in this study using the entropy technique. Following that, the weighting factors for the criterion are computed using the study's equations (8) – (10). The entropy weight of the decision matrix and criterion utilized in the MCDM approach are shown in Table 2, equation (2) is used to calculate the normalized value of the decision matrix. The graphical representation of criterion weight is presented in Figure 3.

Table 2. Normalize the decision matrix for cutting fluids

Alternative ↓ Criteria→	C1 +	C2 –	C3 +	C4 +	C5 +	C6 +	C7 +	C8 –
A1	0.164	0.312	0.552	0.160	0.160	0.292	0.485	0.232
A2	0.493	0.312	0.442	0.320	0.320	0.438	0.485	0.465
A3	0.493	0.312	0.442	0.480	0.641	0.583	0.485	0.814
A4	0.493	0.312	0.442	0.480	0.480	0.438	0.485	0.232
A5	0.493	0.781	0.331	0.641	0.480	0.438	0.243	0.116
Entropy	0.964	0.944	0.992	0.947	0.947	0.986	0.982	0.871
Weight w_j	**0.036**	**0.056**	**0.008**	**0.053**	**0.053**	**0.014**	**0.018**	**0.129**

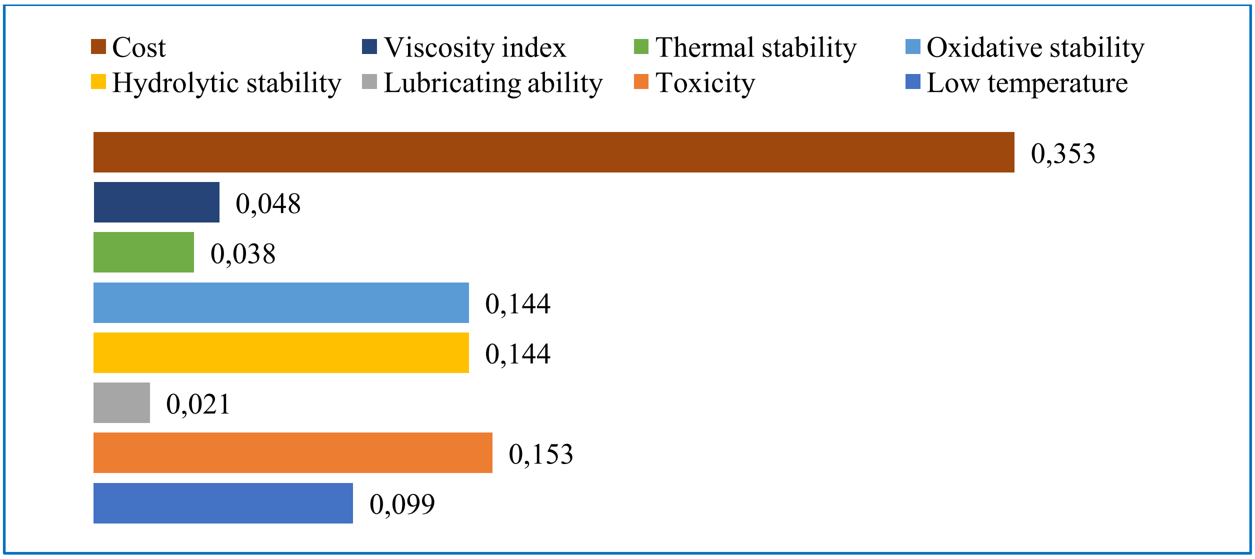

Fig. 3: Graphical representation of criterion weight for selection of cutting fluid

Table 3. Weighted normalized decision matrix for cutting fluids

Alternative ↓	C1	C2	C3	C4	C5	C6	C7	C8
Criteria→	+	–	+	+	+	+	+	–
A1	0.016	0.048	0.012	0.023	0.023	0.011	0.023	0.082
A2	0.049	0.048	0.009	0.046	0.046	0.017	0.023	0.164
A3	0.049	0.048	0.009	0.069	0.092	0.022	0.023	0.287
A4	0.049	0.048	0.009	0.069	0.069	0.017	0.023	0.082
A5	0.049	0.119	0.007	0.092	0.069	0.017	0.012	0.041

Table 2 displays the weighting factors that were determined using the entropy approach. With a weight of 0.353, the cost criteria are the most weighted, followed by the toxicity criterion (0.153). Conversely, the capacity to lubricate has the lowest weight value (0.021). It is significant to remember that the use of water in cutting fluids can have detrimental outcomes in machining operations, including wear and corrosion [51]. As a result, it is customary to rank the cost criteria as the most significant one. Furthermore, toxicity is frequently a key factor that many customers take into account. It makes sense that the lubrication criteria have the lowest weighting coefficient because the chosen cutting fluids have comparable characteristics.

The TOPSIS approach is used to pick cutting fluids once the entropy method has determined the criterion weights. For this, the decision matrix from Table 1 is used. The ranking system for cutting fluid selection is derived by utilizing the procedures specified in equations (3) – (5). Table 3 contains the weighted normalized decision matrix values as well as the ideal solution sets (WDM_j^+, WDM_j^-) that were produced using the TOPSIS approach. These numbers stand for each criterion's maximum and minimum values.

After the creation of the weighted decision matrix, step 4 is the process of allocating the best ideal values and worst ideal values for each criterion based on whether or not they are advantageous. It is also noteworthy that criteria $C2$ and $C8$ are non-beneficial criteria while the remaining criteria are beneficial. The ideal values that are best and worst, respectively, are shown in Figure 4 as WDM_j^+= {0.049, 0.048, 0.012, 0.092, 0.022, 0.023, 0.041} and WDM_j^-= {0.016, 0.119, 0.007, 0.023, 0.023, 0.011, 0.012, 0.287}.

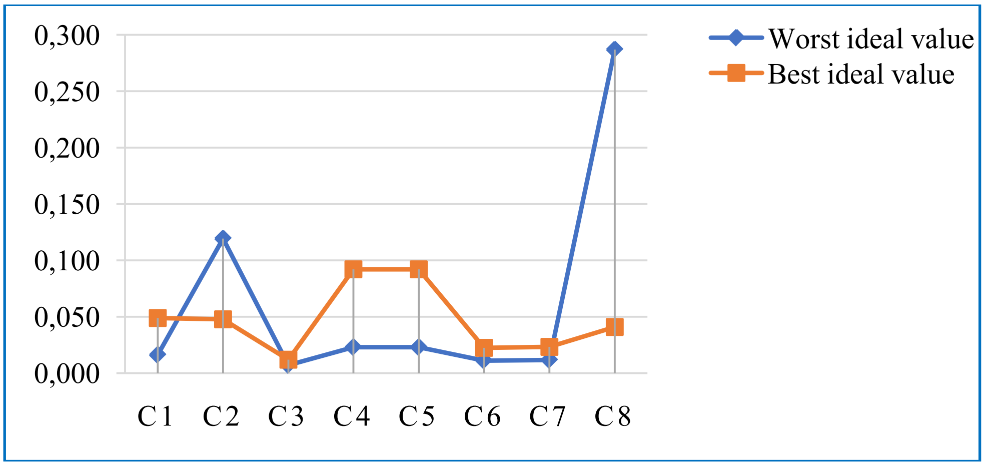

Fig. 4: Illustration of variation between best ideal and worst ideal values

The best ideal value represents the most favorable values for each criterion. For maximization criteria, the best ideal value would have the highest possible values for all criteria, while for minimization criteria, it would have the lowest possible values.

Conversely, the worst ideal value represents the least favorable value for each criterion. For maximization criteria, the worst ideal value would have the lowest possible values, and for minimization criteria, it would have the highest possible values. The difference between these two sets of optimal solutions indicates how well the alternatives perform across the board. It aids in evaluating how well each option stacks up against the decision space's performance extremes. Practically speaking, the more variations there are, the more varied the range of options is about how well they meet the specified requirements. To choose solutions that fit their objectives and preferences, decision-makers must analyze this variance to comprehend the compromises and trade-offs involved with each option. This variation's computation is frequently used to assess how close or comparable each alternative is to the best options.

Additionally, Table 4 displays the rankings for the cutting fluid as well as the relative closeness coefficients (C_i) and distance values (S_i^+, S_i^-) to the positive and negative solution sets. The PAG (Polyalkylene Glycol) cutting fluid is ranked first and has the highest closeness coefficient (C_i) according to the rankings produced by the TOPSIS approach. Mineral oil is shown to be the second-best cutting fluid.

Table 4. Final ranking for cutting fluids based on S^-, S^+ ,and closeness score

Alternative ↓	S_i^+	S_i^-	C_i	Ranking
A1	0.111	0.218	0.661	3
A2	0.139	0.150	0.519	4
A3	0.247	0.115	0.318	5
A4	0.053	0.229	0.813	1
A5	0.076	0.262	0.774	2

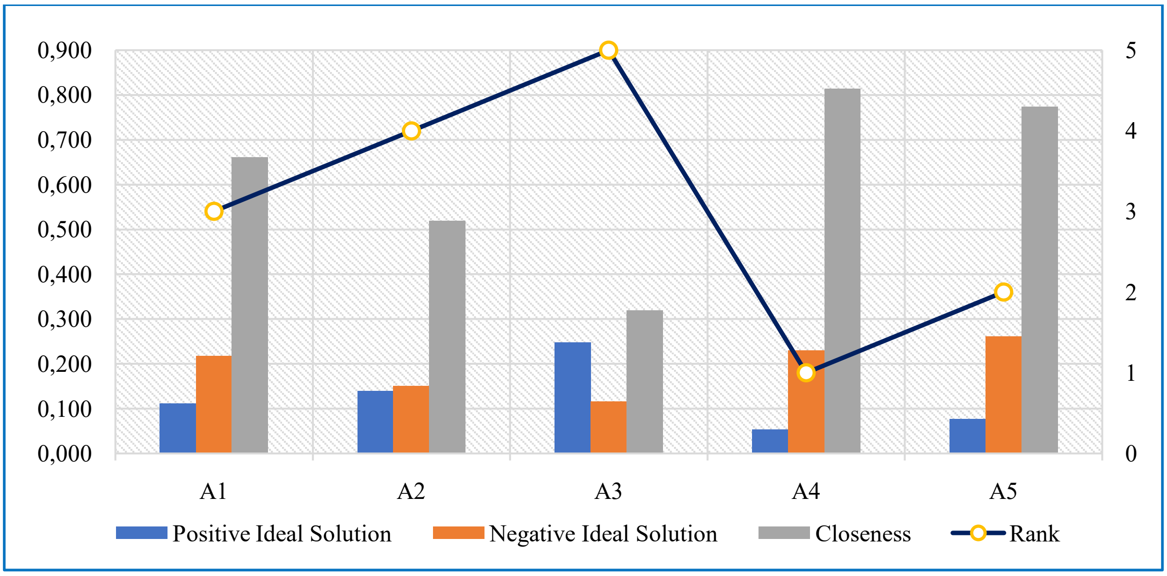

Fig. 5: Graphical representation of closeness scores with positive and negative ideal solutions

Through the evaluation of eight criteria, five distinct cutting fluids utilized in machining operations are to be chosen for this study. The TOPSIS and Entropy approaches are used in the selection process. Figure 5 displays the rankings derived from the TOPSIS technique. Out of all the cutting fluids that were assessed, the TOPSIS approach ranks the PAG cutting fluid as the best. By [52] favored the PAG cutting fluid exclusively in their study due to its superiority over other cutting fluids due to its high-quality surfaces.

According to [53], PAG cutting fluids' recyclability allows them to display better qualities. Based on the outcomes of the TOPSIS and entropy techniques, it can be stated that the PAG cutting fluid could be the best option. In both the TOPSIS and entropy approaches, mineral oil ranks second. However, when it comes to cutting fluids, synthetic ester comes in last when using the TOPSIS and Entropy methodologies. Some of the drawbacks of vegetable-based oils are their susceptibility to fire, less stability, and diminished performance at high temperatures and fast processing speeds [54],[55]. Therefore, out of the five cutting fluids examined in this study, it shouldn't be chosen.

The clarifying technique is a useful strategy to use in selecting applications and multi-criteria decision-making processes. The suggested method has many benefits. First off, it may be a very useful tool for solving selection issues. Secondly, it remains effective regardless of the number of methods employed to evaluate possibilities. Thirdly, it provides a reliable method of eliminating rank discrepancies resulting from different approaches. Despite these advantages, it's crucial to keep in mind that the specific multi-criteria decision-making methods employed can result in negligible variations in the rankings in the end. By performing more investigation and analysis within the corpus of existing literature, the limitations of this approach might be made even more apparent.

Using the TOPSIS skyway, selecting and stemming fluids for machining activities may be done with precision. TOPSIS gives less weight to additional variables in this masking to activity decision-makers analysis and bodily possibilities for fluid laxation. Knifelike fluids are highly valued for many reasons, such as their durability, lubricating qualities, cooling effectiveness, environmental friendliness, and amazing and assured features. To provide a rigorous make-in care, TOPSIS analyses every contrastive dilution available with the best and worst ideal solutions for these parameters. For instance, the apotheosis piercing discard may also blackball the depression toll, the smallest possession of an environmental mate, and the initial combining criteria. In addition to providing decision-makers with an unparalleled option for the small, elegant method of figuring out liquid, TOPSIS's comprehensive evaluation may also help them surpass the fine-reducing discard. A humorous e-book tracheophyte's decision-making processes are fundamentally compacted using the TOPSIS move. By bridging the gap between the prejudiced non-solvent and the compensated set, TOPSIS provides a clear framework for sorting. Examine and finance prospects in a comic that overlaps with strategy series. In complicated decision scenarios, the approach improves objectivity, efficiency, and transparency in decision-making, empowering stakeholders to make informed decisions and perform better overall.

4 Conclusion

This study explores cutting liquid determination for machining processes utilizing the TOPSIS and Entropy MCDM methods. Various details were acquired from distributed hotspots for cutting liquids that contained mineral oil, manufactured ester, PAG, canola, and TMPTO. While making decisions, the accompanying highlights of the cutting liquid were considered: low temperature, low poisonousness, greasing up capacity, hydrolytic security, consistency record, oxidative steadiness, and warm dependability. The determination rankings were obtained by following the procedural periods of the strategies. The areas beneath show the review's outcomes:

- The PAG cutting fluid approach that produced the greatest rating was TOPSIS and Entropy. Mineral oil secured the second position. On the other hand, synthetic ester performed the worst out of all the MCDM approaches used.
- Cutting fluid options are carefully evaluated by TOPSIS based on how close they are to the best ideal solution and how different from the worst ideal solution they are from.
- Cost, safety, cooling effectiveness, lubricating characteristics, and environmental effects are only a few of the variables taken into consideration.
- Using this method permits decision-makers to check a few matters and choose the slicing fluid that satisfactorily fits their wishes. The effects, which offer a wonderful and properly-organized ranking, provide a knowledgeable choice based totally on precise targets and choices.

Furthermore, TOPSIS assists in figuring out criterion change-offs by using emphasizing the concessions made using every answer. Through a system that ensures the selected slicing fluid satisfies performance standards and is in keeping with more preferred goals like economics and environmental obligation.

With the use of TOPSIS, choice-makers may also carefully weigh and recall several reducing fluid-associated standards, together with fee, and protection, which have an effect on the environment, lubricating features, and cooling effectiveness. Its capacity to address both quantitative and qualitative facts is a further gain. Quantitative components like cost or cooling prices can be efficaciously controlled by way of TOPSIS similar to qualitative ones like safety rules and environmental consequences. In precis, the consequences of the TOPSIS and entropy technique offer a stable basis for choosing a cutting fluid, making it simpler to decide which fluid quality fits the tricky and sundry requirements of machining tactics.

References:

[1] Abdelrazek A H, Choudhury I A, Nukman Y and Kazi S N, Metal cutting lubricants and cutting tools: a review on the performance improvement and sustainability assessment. *J. Adv. Manuf. Technol.* 106, 2020, pp. 4221–4245

[2] Said Z, Gupta M, Hegab H, Arora N, Khan A M, Jamil M, and Bellos E, A comprehensive review on minimum quantity lubrication (MQL) in machining processes using nano-cutting fluids. J. *Adv. Manuf. Technol*. 105, 2019, pp. 2057–2086.

[3] Liew P J, Shaaroni A, Sidik N A C and Yan J, An overview of current status of cutting fluids and cooling techniques of turning hard steel. *Int. J. Heat. Mass Transf.* 114, 2017, pp. 380–394.

[4] Shokoohi Y, Khosrojerdi E and Shiadhi B R, Machining and ecological effects of a new developed cutting fluid in combination with different cooling techniques on turning operation. *J. Clean Prod.* 94, 2015, pp. 330–339.

[5] Wickramasinghe K C, Sasahara H, Abd Rahim E and Perera G I P. Green metalworking fluids for sustainable machining applications: a review. *J. Clean Prod.* 257, 2020, 120552.

[6] Yan P, Rong Y and Wang G, The effect of cutting fluids applied in metal cutting process. *Proc. Inst. Mech. Eng. B J. Eng. Manuf.* 230, 2016, pp. 19–37.

[7] Lee C W and Kwak N K, Information resource planning for a health-care system using an AHP-based goal programming method. *J. Oper. Res. Soc.* 50, 1999, pp. 1191–1198.

[8] Meciarova J and Stanovsky M, Cutting fluids evaluation based on occupational health and environmental hazards. *Eng. Rural Dev.* 10, 2011, pp. 418–422.

[9] Sofuoglu M A, A new hybrid decision-making strategy of cutting fluid selection for manufacturing environment. *Sadhana*, 46, 2021, pp. 1–9.

[10] Yan P, Rong Y and Wang G, The effect of cutting fluids applied in metal cutting

process. *Proc. Inst. Mech. Eng. B J. Eng. Manuf.* 230, 2016, pp. 19–37.

[11] Khan A and Maity K, Application of MCDM-based TOPSIS method for the selection of optimal process parameter in turning of pure titanium. *Benchmarking Int. J.* 24, 2017, pp. 2009–2021.

[12] Lukic D, Cep R, Vukman J, Antic A, Djurdjev M and Milosevic M, Multi-criteria selection of the optimal parameters for high-speed machining of aluminum alloy Al7075 thin-walled parts. *Metals*, 10, 2020, 1570.

[13] Niu J, Huang C, Li C, Zou B, Xu L, Wang J, and Liu Z, A comprehensive method for selecting cutting tool materials. *J. Adv. Manuf. Technol.* 110, 2020, pp. 229–240.

[14] Pathapalli V R, Basam V R, Gudimetta S K, and Koppula M R, Optimization of machining parameters using WASPAS and MOORA. *World J. Eng.* 17, 2020, pp. 237–246.

[15] Sun J, Ge P and Liu Z, Two-grade fuzzy synthetic decision-making system with the use of an analytic hierarchy process for performance evaluation of grinding fluids. *Tribol. Int.* 34, 2001, pp. 683–688.

[16] Tan X C, Liu F, Cao H J and Zhang H, A decisionmaking framework model of cutting fluid selection for green manufacturing and a case study. *J. Mater. Process. Technol.* 129, 2002, pp. 467–470.

[17] Cakir O, Yardimeden A, Ozben T, and Kilickap E, Selection of cutting fluids in machining processes. *J. Achiev. Mater. Manuf. Eng.* 25, 2007, pp. 99–102.

[18] Venkata Rao R and Patel B K, Decision making in the manufacturing environment using an improved PROMETHEE method. *Int. J. Prod. Res.* 48, 2010, pp. 4665–4682.

[19] Abhang L B and Hameedullah M, Selection of lubricant using combined multiple attribute decision-making method. *Adv. Prod. Eng. Manag.* 7, 2012, pp. 39–50

[20] Chakraborty S and Zavadskas E K, Applications of WASPAS method in manufacturing decision making. *Informatica* 25, 2014, pp. 1–20.

[21] Nemati, M., & Jahangirian, A. A Da ta-Driven Machine Learning Approach for Turbulent Flow Field Prediction Based on Direct Computational Fluid Dynamics Database. *Journal of Applied Fluid Mechanics*, 17(1), 2023, pp. 60 -74. doi: 10.47176/jafm.17.1.2109.

[22] Jagadish R A and Ray A, Green cutting fluid selection using MOOSRA method. *Int. J. Res. Eng. Technol.* 3, 2014, 559–563.

[23] Attri R, Dev N, Kumar K and Rana A, Selection of cutting fluids using a novel, decision-making method: preference selection index method. *Int. J. Inf. Decis. Sci.* 6, 2014, pp. 393–410.

[24] Madic M, Radovanovic M, and Manic M, Application of the ROV method for the selection of cutting fluids. *Decis. Sci. Lett.* 5, 2016, pp. 245–254.

[25] Prasad K and Chakraborty S, A quality function deployment-based model for cutting fluid selection. *Adv. Tribol.* 2016, 3978102.

[26] Jayant A, Chaudry N, and Singh P, A decision-making framework model of cutting fluid selection for green manufacturing: a synthesis of 3 MCDM approaches. *Int. Conf. Adv. Eng. Technol.* 2018, pp. 1–7.

[27] Tu H X, Jun G, Hien B T, Hung L X, Tung L A, and Pi V N, Determining optimum parameters of cutting fluid in external grinding of 9CrSi steel using Taguchi technique. *SSRG Int. J. Mech. Eng.* 5, 2018, pp. 1–5.

[28] Sofuoglu M A, A new hybrid decision-making strategy of cutting fluid selection for manufacturing environment. *Sadhana*, 46, 2021, pp. 1–9.

[29] Ross N S, Mia M, Anwar S, Manimaran G, Saleh M, and Ahmad S, A hybrid approach of cooling lubrication for sustainable and optimized machining of Ni-based industrial alloy. *J. Clean. Prod.* 321, 2021, 128987.

[30] Goswami S S and Behera D K, Implementation of COPRAS and ARAS MCDM Approach for the Proper Selection of Green Cutting Fluid. In: *Current Advances in Mechanical Engineering*, 2021, pp. 975–987.

[31] Varghese B and Karande P, AHP-MARCOS, a hybrid model for selecting gears and cutting fluids. *Mater. Today: Proc.* 52, 2022, pp. 1397–1405.

[32] Benedicto E, Carou D and Rubio E M, Technical, economic and environmental review of the lubrication/cooling systems used in machining processes. *Procedia Eng.* 184, 2017, pp. 99–116.

[33] Madic M, Radovanovic M, and Manic M, Application of the ROV method for the selection of cutting fluids. *Decis. Sci. Lett.* 5, 2016, pp. 245–254.

[34] Moradian M, Modanloo V, and Aghaiee S, Comparative analysis of multi criteria decision making techniques for material selection of brake booster valve body. *J. Traffic Transp. Eng*. 6, 2019, pp. 526–534.

[35] Pearson K VII. Note on regression and inheritance in the case of two parents. *Proc. R. Soc. Lond*. 58, 1895, pp. 240–242

[36] Petkovic D, Madic M an d Radenkovic G, Selection of the most suitable non-conventional machining processes for ceramics machining by using MCDMs. *Sci. Sinter*. 47, 2015, pp. 229–235.

[37] Fernando Martinez, Marina Cauhape, Luis Zorzutti, Silvia Angelone, Validation of a Mathematical-Based Model for the Rheological Characterization of Asphalt Mixtures, WSEAS Transactions on Fluid Mechanics, vol. 18, 2023, pp. 135 -145, DOI:10.37394/232013.2023.18.14.

[38] Ozcelik B, Kuram E, Demirbas E, and S¸ ik E, Effects of vegetable-based cutting fluids on the wear in drilling. *Sadhana*, 38, 2013, pp. 687–706.

[39] Qiao S, Shi Y, Wang X, Lin Z, and Jiang Y, Synthesis of biolubricant trimethylolpropane trioleate and its lubricant base oil properties. *Energy Fuels*, 31, 2017, pp. 7185–7190.

[40] Pettersso A, High-performance base fluids for environmentally adapted lubricants. *Tribol. Int*. 40, 2007, pp. 638–645.

[41] Tsai T H and Shih Y P, Recovering low-turbidity cutting liquid from silicon slurry waste. *J. Hazard. Mater*. 271, 2014, pp. 252–257.

[42] Madanhire I and Mbohwa C, Environment and the economics of long drain interval. In: *Mitigating environmental impact of petroleum lubricants,* 2016, Springer, Berlin, pp. 149–164.

[43] Hwang C L and Yoon K, Methods for multiple attribute decision making. In: *Multiple Attribute Decision Making,* 1981, Springer, Berlin, pp. 58–191.

[44] Dwivedi, P.P. & Sharma, D.K, Evaluation and ranking of battery electric vehicles by Shannon's entropy and TOPSIS methods. *Mathematics and Computers in Simulation*. 212, 2023, https://doi.org/10.1016/j.matcom.2023.05.013.

[45] Shannon C E, A mathematical theory of communication. *Bell Syst. Tech. J*. 27, 1948, pp. 379–423.

[46] Kumar R and Ray A, Selection of material for optimal design using multi-criteria decision making. *Procedia Mater. Sci*. 6, 2014, pp. 590–596.

[47] Dwivedi, P.P. & Sharma, D.K, Generalized 'Useful' Converse Jensen's Inequality with Data Illustration. WSEAS Transactions on Systems. 2022;21:62-67. https://doi.org/10.37394/23202.2022.21.7

[48] Dwivedi, P.P. & Sharma, D.K., Selection of Combat Aircraft by Using Shannon Entropy and VIKOR Method. *Defence Science Journal,* 73, 2023, pp. 411 -419. https://doi.org/10.14429/dsj.73.17996.

[49] Dwivedi, P.P. & Sharma, D.K., Application of Shannon Entropy and CoCoSo Methods in Selection of the Most Appropriate Engineering Sustainability Components. *Cleaner Materials*. 5, 2022, 100118. https://doi.org/10.1016/j.clema.2022.100118.

[50] Dwivedi, P.P. & Sharma, D.K., Assessment of Appropriate Renewable Energy Resources for India using Entropy and WASPAS Techniques. *Renewable Energy Research and Applications*, 5, 2 023, pp. 51-61. https://doi.org/10.22044/rera.2023.12960.1215.

[51] Gautam S, Guria C and Rajak V K, A state of the art review on the performance of high-pressure and high temperature drilling fluids: Towards understanding the structure-property relationship of drilling fluid additives. *J. Pet. Sci. Eng*. 213, 2022, pp . 110318

[52] Born D K and Goodman W A, An empirical survey on t he influence of machining parameters on tool wear in diamond turning of large single-crystal silicon optics. *Precis. Eng*. 25, 2001, pp. 247–257.

[53] Tsai T H and Shih Y P, Recovering low-turbidity cutting liquid from silicon slurry waste. *J. Hazard. Mater*. 271, 2014, pp. 252–257.

[54] Kuram E, Ozcelik B, Bayramoglu M, Demirbas E, and Simsek B T, Optimization of cutting fluids and cutting parameters during end milling by using D-optimal design of experiments. *J. Clean Prod*. 42, 2013, pp. 159–166.

[55] Shokrani A, Dhokia V, and Newman S T, Environmentally conscious machining of difficult-to-machine materials with regard to cutting fluids. *Int. J. Mach. Tools Manuf*. 57, 2012, pp. 83–101.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Pankaj Prasad Dwivedi: Performed the measurements, Wrote the original paper also planning and supervising the work. He was involved in all stages from the formulation of the problem to the final findings and solution.
- Dilip Kumar Sharma: Processed the experimental data, performed the analysis, and supervised the work. Developed the theoretical formalism, performed the analytic calculations, and performed the numerical simulations.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

The authors did not receive support from any organization for the submitted work.

Conflict of Interest

The authors have no conflict of interest to declare.