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ORIGINAL ARTICLE

# An integrated approach for cutting fluid selection using multiple attribute decision making methods

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**ABSTRACT** – The choice of most appropriate cutting liquid in any machining process should be performed to attain maximum benefit. Selection of cutting fluid needs more than one dimension. For this purpose, many criteria should be deemed in the selection process. In this study decision making methods such as AHP, TOPSIS and VIKOR are employed to select the suitable cutting fluid. AHP is used to compute the objective weights for the criteria.The three alternatives considered are Ahonol- 7, Blaser and YBI. A case study of cutting fluid selection for machining LM 25 Aluminium alloy which finds application in automobile industries is presented to explain the applicability and suitability of the anticipated method. Ranking of alternatives in the above methods suggests Ahonol – 7 as the best cutting fluid for CNC turning LM 25 aluminium alloy.

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## INTRODUCTION

Over the previous decade, cutting liquids have been considered widely to describe their relative advantages and limitations as far as their utilization within the process of machining. Despite the fact that the cutting liquids are useful to the various industrial applications, its uses are being addressed now a days with respect to wellbeing and ecological issues. The principal purpose of cutting liquid is to serve as a lubricant and as a coolant. The removal of chip during machining operation is also one of the primary function of it. As a lubricant, it provides a layer of oil between the work piece and tool. Thereby reducing the friction generated during the movement of the work piece and the tool. As a coolant, it dissipates the heat generated during the machining operation thereby protects the tool and the work piece. It flushes away the chips produced during machining operation, thereby preventing the tool by becoming blunt and prevents the formation of built up edge which results in poor surface finish.

The secondary function of the cutting fluid is to provide corrosion protection, to reduce the friction, and to reduce the thermal deformation of the workpiece and tool material.

The efficiency of the machining operation can be increased with the usage of right cutting fluid. Taking this into consideration, the objectives formulated are, Identifying the criteria on the basis of which the cutting fluid to be selected, Identifying the alternatives, Obtaining scores for the criteria from the experts, Applying Analytic Hierarchy Process (AHP), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodologies and Ranking of alternatives to find the best cutting fluid.

An analysis on selection of cutting fluid using AHP, TOPSIS and VIKOR approaches is proposed. Subjective and objective views of expertize turned as quantifiable form with analytical hierarchy process (AHP). AHP is adopted to arbitrate the relative weights of assessment measures. Pair wise assessment has been done among the criteria forming decision matrix and the priority vector is calculated for each criteria and based on that overall priority vector is determined for each alternative. AHP model has been characterised in a questionnaire to expert's opinion. The relative weight of each criteria was calculated with the relative weight obtained by the AHP method, TOPSIS and VIKOR methods are implemented to find out the relative ranking of the alternatives.

This present investigation divided into five sections. The second part of this investigation details the outline of the prevailing approaches and studies. The third part illustrates the structure of the problem taken into consideration. The next part of this article details the suggested methods, explains detailed procedure and steps involved in AHP, TOPSIS and VIKOR methodologies. In part five, results, discussion and conclusion are presented.

The manufacturing domain has become one of the foremost origins of ecological contamination. Hence the manufacturers are focussing on the environmental conscious machining process [1]. It leads to the arise of the green manufacturing with its extreme aim of decreasing and lessening ecological impact [2]. Since cutting fluids is the root cause for the environmental pollution in a machining process, researchers turned their attention towards the minimization of usage of cutting fluids.

Many production practices implies the use of the optimal cutting fluid is one effective way for reducing the cost and minimize the ecological pollution caused by the cutting liquid machining with Minimum Quantity Lubrication (MQL) [3], cryogenic cooling by liquid NO2 [4] are some of the alternatives for this approach. A multi criteria decision making

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(MCDM) model of cutting liquid selection for green manufacturing was put frontward considering quality, cost and environmental impact [5].

The appropriate choice of cutting liquid depends on the material removal process, material of work piece and cutting tool. The combination of these three factors will provide the adequate information for the choice of coolant liquid [6]. Environmental conscious manufacturing (ECM) is receiving interest in the recent years. Three MCDM programs AHP, TOPSIS and modified TOPSIS were detailed to select an ECM program on the basis of evaluation of ECM program selection index [7].

As the cutting fluid selection depends on the material, it is mandatory to select appropriate material. Hence a logical procedure for material selection based on a amalgamated TOPSIS and AHP method have been selected by ranking the material selection index [8]. Cutting fluid selection based on occupation health and environmental hazards considering health hazard factors and environmental hazard factors using CAPP was performed [9].

Considering four measures such as wear on wheel, tangential force, temperature of grinding and roughness of surface have been also carried out to evaluate the right cutting fluid [10]. Diagraph and matrix approach has been adopted for the choice, identification and comparison of metal cutting fluids [11].

Selection of favourable coolant liquid for the gear hobbing process considering ecological impact (E), cost (C) and quality(Q) have done using MOOSRA (Multi Objective Optimization on the basis of Simple Ratio Analysis) and the result obtained was compared with AHP and decision making framework (DMF) [12]. Plant location facility selection was performed using combined AHP-VIKOR methodologies considering three criteria among three alternatives [13].

The evaluation of performance of coolant liquid for green manufacturing by an amalgamated MCDM approach was conducted to select the optimal cutting fluid [14]. The temperature on Chip tool interface, cutting force, wear on tool and roughness on the machined surface are the criterion considered to evaluate the single global lubricant index to opt the appropriate lubricant and to rank it applying AHP and TOPSIS method for steel turning operation [15].A modified similarity based method is adopted for cutting fluid selection considering cutting tool material, operator safety, rancidity, reliability and compatibility with the tool material [16].

Suppliers for an effective supply chain using AHP methodologies determined that for manufacturing organizations, reliability on suppliers and their experience, the quality of product are the top three selection problem that requires to be considered up on importance for competent choice of vendor [17]. Optimum cutting fluid selection among three alternatives with cost, quality and environmental impact criteria with AHP was performed which favours green manufacturing [18].Among four alternatives considering seven criteria the most appropriate cutting fluid is selected by employing VIKOR , ELECTREE and PROMETHEE techniques [19].

Selection of coolant liquid for sustainable design for manufacturing using AHP and VIKOR method. Each coolant liquid has various ecological impact during the manufacturing process. Hence a decision making integrated theory using AHP and VIKOR method is framed to opt the coolant for sustainable design [20]. The evaluation of Environmental performance for a manufacturing process by obtaining weights for the six criteria considered using AHP methodology [21]. The selection of location of plant for a manufacturing industry using analytical hierarchy process is carried out incorporating both financial and non financial factors among five alternatives [22]. Identifying the most noticeable sustainable manufacturing practices in Indian electrical panel manufacturing organizations considering six criteria among three alternatives was presented using AHP [23]. TOPSIS – PSI approach is applied for material selection in marine applications [24].

The aspiration of this present exploration is to suggest a MCDM method to assess the cutting fluid. A set of questionnaires are developed based on the criteria identified and with the responses collected from the experts working in the relative field, are used to illustrate the cutting fluid selection procedure. Subjective and objective suggestions of experts turned in to quantitative form with AHP. Ten different criterias are identified. They are Environmental Pollution (EP), Hazards to Workers (HW), Ease of Disposal (ED), Lubrication Ability (LA), Cooling Ability (CA), Stability (S), Corrosion Resistance (CR), Recycling Cost (RC), Storage Cost (SC) and Cost for Washing and Drying of the Work piece (CWD).

Apparently cutting fluid choice is a multi-aspects problem which contains both quantitative and qualitative aspects. It is essential to make trade off amongst these tangible and intangible factors while considering cutting fluid selection. There are alternate cutting fluids available. In analyzing the data, AHP, TOPSIS and VIKOR methods are adopted for the outranking of cutting fluid substitutions.

## STRUCTURE OF THE CUTTING FLUID SELECTION PROBLEM

An exploration is accomplished in a manufacturing company, which manufactures and supplies parts of automobiles.LM 25 aluminium alloy has been adopted as work piece material which finds application in all automobile vehicles where it is utilized for cylinder blocks, heads and other engine and body castings. The Aluminium Alloy is machined with poly crystalline diamond tool material by Computerised Numerical Control (CNC) turning operation.

**Table 1.** Criteria considered for evaluating the alternatives

| Sl. No | Criteria | Aspect considered |
|---|---|---|
| 1 | Environmental Pollution | The toxic content of cutting fluid to land and air are considered |
| 2 | Hazards to Workers | Health problems created to workers due to the usage of cutting fluid |
| 3 | Ease of Disposal | Treatment required for the cutting fluid after usage |
| 4 | Lubrication Ability | Ability to produce a friction free surface between tool and work piece |
| 5 | Cooling Ability | Acts as an agent for dissipation of heat generated during machining process. |
| 6 | Stability | The change in chemical property of the liquid during usage |
| 7 | Corrosion Resistance | Cutting fluid act as a protective layer against corrosion on the machined surface |
| 8 | Recycling Cost | Cost involved in re-processing the cutting fluid |
| 9 | Storage Cost | Cost for storing the cutting fluid |
| 10 | Cost for Washing and Drying of the Work piece | Composition of cutting fluid, the residue deposited on the machined surface to be washed and dried for further usage |

As several environmental and health issues are arising when working with the cutting fluids, the company wish to select a suitable cutting fluid in order to meet an environmental conscious machining. At the end of interview with the experts from the company, the information related to cutting fluids are obtained. The three alternatives for cutting fluid are identified. They are Ahonol-7, Blaser 2000 and YBI. Ahonol-7 is mineral oil based cutting fluid which is stable at normal temperature and pressure. Blaser 2000 is a mineral based metal working fluid used for lubrication. YBI is a water soluble type metal cutting fluid for cooling the heated zone of machining. Criteria taken into account for cutting fluid selection is shown in Table 1.

## PROPOSED METHODOLOGY

The responses for the questionnaires [25] are collected from three experts. Data were collected from the experts and a pair wise comparison is made at a given level on the criteria to recognize the relative precedence. AHP, being a simple but influential tool for decision making, it is appropriate to resolve the problems where the decision criteria can be grouped hierarchically into sub criteria. The Criteria for the choice of the cutting fluid were identified by literature review and by opinion from the experts. Questionnaires have been developed based on the criteria selected for evaluation of cutting fluid. Experts have been examined to rank the criteria in terms of importance or weights. Each expert is asked to encircle the relevant weight in a 9 point scale evaluation table. The procedural steps involved in this work are illustrated in Figure 1.

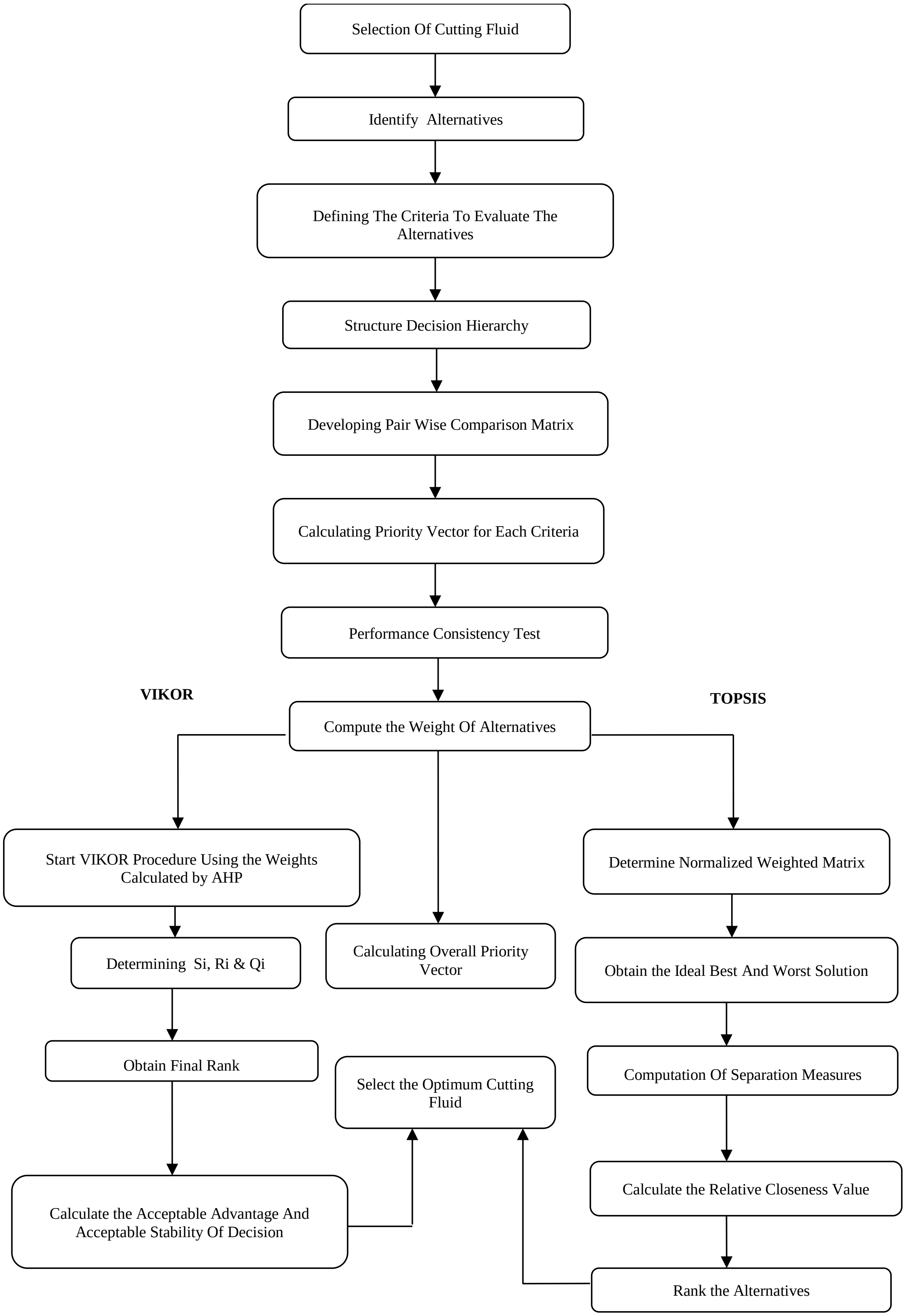


**Figure 1.** Procedural steps of the proposed method

## Using AHP to Analyse Priorities

AHP is one among the MCDM approach that was initially evolved by Saaty, Thomas L [26]. It offers the measures of judgement uniformity and originates priorities amongst various aspects and alternatives.

This method assists the researchers makers to prioritize the alternates and determining the alternatives using pair wise comparison.

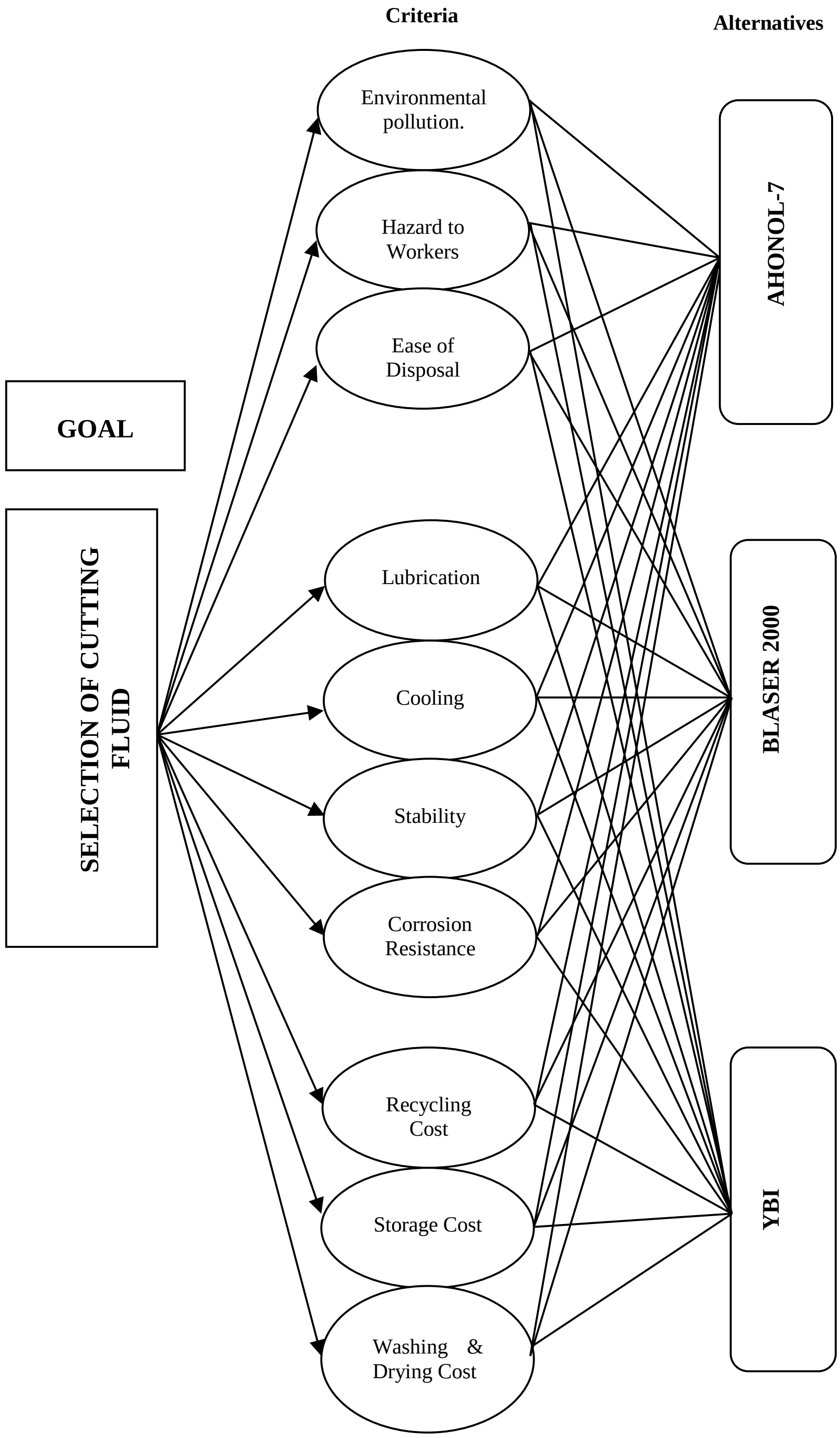


**Figure 2.** Hierarchical structure for cutting fluid selection

Step by Step Procedure in AHP

***Step 1:*** The Problem is disintegrated into a hierarchy of goal, criteria, sub criteria and alternates. Structuring the decision making problem as a hierarchy is essential to the process of the AHP.

The Figure 2 depicts the hierarchical structure of the problem taken into consideration. The goal is to find the optimum cutting fluid considering ten criteria among three alternates.

***Step 2:*** Data are composed from the experts with respect to the to the hierarchic structure, in the pair wise comparison of alternates on a quantitative measure as described below.

Experts may give rating the comparison as equal, marginally strong, strong, very strong and extremely strong. Questionnaire is developed to get responses for the relative importance of alternatives with respect to criteria, preference of alternatives with respect to criteria and to find the relative importance between criteria.

Graduation scale for quantitative comparison of alternatives is shown in Table 2.

**Table 2.** Graduation scale for quantitative comparison of alternatives

| Opinion | Numerical Values | Explanation |
|---|---|---|
| Equal | 1 | The alternatives equally contribute to the objective |
| Marginally Strong | 3 | The experience and judgement slightly favour one alternative over another |
| Strong | 5 | The experience and judgement strongly favour one alternative over another |
| Very Strong | 7 | An alternative is favoured very strongly over another |
| Extremely Strong | 9 | The evidence favouring one alternative over another is of the highest possible order of affirmation |
| Intermediate values | 2,4,6,8 | Sometimes one needs to interpolate a compromise judgement numerically |

***Step 3:*** The pair wise comparison of various criteria made at step 2 are structured into a square matrix. Based on the response collected from one of the experts a square matrix is formed as revealed in table 3.

**Table 3.** Relative importance of alternatives with respect to criteria

**Table 3(a).** Relative importance of alternatives with respect to environmental pollution

| Environmental pollution | Ahonol – 7 | Blaser 2000 | YBI | Priority vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 6 | 4 | 0.694 |
| Blaser 2000 | 1/6 | 1 | 4 | 0.210 |
| YBI | 1/4 | 1/4 | 1 | 0.096 |

$\lambda_{max}$ = 3.016, CI = 0.008, CR = 0.014

**Table 3(b).** Relative importance of alternatives with respect to hazard to workers

| Hazards to Workers | Ahonol – 7 | Blaser 2000 | YBI | Priority vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 7 | 4 | 0.705 |
| Blaser 2000 | 1/7 | 1 | 1/3 | 0.084 |
| YBI | 1/4 | 3 | 1 | 0.212 |

$\lambda_{max}$ = 3.001, CI = 0.00, CR = 0.001

**Table 3(c).** Relative importance of alternatives with respect to ease of disposal

| Ease of Disposal | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 1/8 | 1/4 | 0.088 |
| Blaser 2000 | 8 | 1 | 1 | 0.559 |
| YBI | 4 | 1/2 | 1 | 0.352 |

$\lambda_{max}$ = 3.009, CI = 0.005, CR = 0.008

**Table 3(d).** Relative importance of alternatives with respect to lubrication ability

| Lubrication Ability | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 8 | 9 | 0.778 |
| Blaser 2000 | 1/8 | 1 | 1/7 | 0.049 |
| YBI | 1/9 | 7 | 1 | 0.173 |

$\lambda_{max}$ = 3.006, CI = 0.003, CR = 0.005

**Table 3(e).** Relative importance of alternatives with respect to cooling ability

| Cooling Ability | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 1/4 | 1/5 | 0.100 |
| Blaser 2000 | 4 | 1 | 1 | 0.433 |
| YBI | 5 | 1 | 1 | 0.466 |

$\lambda_{max}$ = 3.001, CI = 0.001, CR = 0.001

**Table 3(f).** Relative importance of alternatives with respect to stability

| Stability | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 4 | 2 | 0.571 |
| Blaser 2000 | 1/4 | 1 | 1/2 | 0.143 |
| YBI | 1/2 | 2 | 1 | 0.286 |

$\lambda_{max}$ = 3.440, CI = 0.220, CR = 0.038

**Table 3(g).** Relative importance of alternatives with respect to corrosion resistance

| Corrosion Resistance | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 8 | 5 | 0.733 |
| Blaser 2000 | 1/8 | 1 | 1/4 | 0.068 |
| YBI | 1/5 | 4 | 1 | 0.199 |

$\lambda_{max}$ = 3.000, CI = 0.000, CR = 0.000

**Table 3(h).** Relative importance of alternatives with respect to recycling cost

| Recycling Cost | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 5 | 6 | 0.714 |
| Blaser 2000 | 1/5 | 1 | 1/4 | 0.085 |
| YBI | 1/6 | 4 | 1 | 0.201 |

$\lambda_{max}$ = 3.008, CI = 0.004, CR = 0.007

**Table 3(i).** Relative importance of alternatives with respect to storage cost

| Storage Cost | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 1/6 | 1/7 | 0.071 |
| Blaser 2000 | 6 | 1 | 1 | 0.451 |
| YBI | 7 | 1 | 1 | 0.478 |

$\lambda_{max}$ = 3.001, CI = 0.000, CR = 0.001

**Table 3(j).** Relative importance of alternatives with respect to cost for washing and drying the workpiece

| Cost for Washing and Drying the Workpiece | Ahonol – 7 | Blaser 2000 | YBI | Priority Vector |
|---|---|---|---|---|
| Ahonol – 7 | 1 | 1/6 | 1/5 | 0.075 |
| Blaser 2000 | 6 | 1 | 4 | 0.674 |
| YBI | 5 | 1/4 | 1 | 0.251 |

$\lambda_{max}$ = 3.015, CI = 0.008, CR = 0.013

Table 3(a) to 3(j) represents the response of the relative importance of the alternatives with respect to the criteria.

***Step 4:*** Performing consistency analysis

The aspiration of exploration is to assure that the original preference rating have been reliable. The calculation for priority vector and consistency is performed with Microsoft excel.

There are 3 steps to arrive at the consistency ratio.

Calculate the consistency measure.

Calculate the consistency index (CI)

$$C.I = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Calculate the consistency ratio (CR)

$$CR = \frac{CI}{RI} \quad (2)$$

In practice, a CR of 0.1 or below is deemed as satisfactory. Any higher values at any level indicate that the judgement needs reexamination. Based on the steps mentioned above consistency analysis is carried out and found that the consistency ratio is below 0.1 for all the criteria considered and hence the judgement arrived is acceptable.

The CI of a randomly produced pair wise comparison matrix is shown in Table 4.

**Table 4.** Random index values

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.00 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.46 | 1.49 |

n – Order of the matrix : Random consistency indices for n=10

The overall priority for each criteria with respect to alternatives is calculated which is depicted in Table 5.

**Table 5.** Overall priority obtained from the responses of expert 1

| | EP 0.264 | HW 0.223 | ED 0.142 | LA 0.114 | CA 0.088 | S 0.063 | CR 0.042 | RC 0.028 | SC 0.020 | CWD 0.016; | Priority Vector |
|---|---|---|---|---|---|---|---|---|---|---|---|
| AHONOL-7 | 0.694 | 0.705 | 0.088 | 0.778 | 0.100 | 0.571 | 0.733 | 0.714 | 0.071 | 0.075 | 0.540 |
| BLASER 2000 | 0.210 | 0.084 | 0.59 | 0.049 | 0.433 | 0.143 | 0.068 | 0.085 | 0.451 | 0.674 | 0.231 |
| YBI | 0.096 | 0.212 | 0.352 | 0.173 | 0.466 | 0.286 | 0.199 | 0.201 | 0.478 | 0.251 | 0.229 |

Similar calculations were carried out to find the overall priority of the alternatives based on the data collected from expert 2 and expert 3. Table 6 exhibits the geometric mean of the priority of the alternatives with respect to criteria.

**Table 6.** Geometric mean of priorities obtained by responses from 3 experts

| Alternatives | Overall priority from Expert 1 | Overall priority from Expert 2 | Overall priority from Expert 3 | Geometric mean of Overall priority | Rank |
|---|---|---|---|---|---|
| AHONOL- 7 | 0.588 | 0.540 | 0.557 | 0.561 | 1 |
| BLASER 2000 | 0.225 | 0.231 | 0.261 | 0.239 | 2 |
| YBI | 0.203 | 0.229 | 0.182 | 0.204 | 3 |

The three alternatives are ranked based on the priority vector obtained from the three experts. It is clear from the table 6 that the opinion of the three experts reveals that Ahonol – 7 is the most preferred cutting fluid.

## TOPSIS Method

The word TOPSIS is (expanded as Technique for Order Preference by Similarity to Ideal Solution) a method has been evolved by Hwang and Yoon in 1981.

The fundamental tactic of this technique is selecting an alternate that should have the minimum distance from the positive ideal solution and farthest distance from the negative ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes the conflicting criteria. The negative ideal solution minimizes the benefit criteria.
The basic steps in TOPSIS Method are as follows:

***Step 1:*** Determination of the objective and identification of the criteria is the first step. The goal represents the optimum solution of the decision problem. It can be a selection of the best alternative among many feasible alternatives.

The data collected from the questionnaire containing relative importance of alternative with respect to criteria and relative importance between the criteria is employed here to find the optimum cutting fluid.

***Step 2***:

**Table 7.** Normalized matrix

| | EP | HW | ED | LA | CA | S | CR | RC | SC | CWD |
|---|---|---|---|---|---|---|---|---|---|---|
| AHONOL-7 | 0.472 | 0.369 | 0.260 | 0.424 | 0.379 | 0.326 | 0.308 | 0.262 | 0.363 | 0.348 |
| BLASER 2000 | 0.304 | 0.392 | 0.345 | 0.169 | 0.423 | 0.264 | 0.412 | 0.459 | 0.349 | 0.367 |
| YBI | 0.224 | 0.240 | 0.394 | 0.407 | 0.198 | 0.410 | 0.280 | 0.278 | 0.288 | 0.285 |

Table 7 gives the normalized value of the geometric mean of the responses of three experts represented by $X_i$.

***Step 3***: The normalized weight for each criteria is determined .

**Table 8.** Normalized geometric mean of weights obtained for different criteria ($W_j$)

| Criteria | Weight from Expert 1 | Weight from Expert 2 | Weight from Expert 3 | Geometric Mean |
|---|---|---|---|---|
| Environmental Pollution | 0.264 | 0.075 | 0.098 | 0.125 |
| Hazards to Workers | 0.223 | 0.178 | 0.121 | 0.169 |
| Ease of Disposal | 0.142 | 0.034 | 0.067 | 0.069 |
| Lubrication Ability | 0.114 | 0.230 | 0.185 | 0.170 |
| Cooling Ability | 0.088 | 0.122 | 0.132 | 0.113 |
| Stability | 0.063 | 0.053 | 0.032 | 0.048 |
| Corrosion Resistance | 0.042 | 0.104 | 0.166 | 0.090 |
| Recycling Cost | 0.028 | 0.110 | 0.097 | 0.067 |
| Storage Cost | 0.020 | 0.039 | 0.049 | 0.034 |
| Cost for Washing & Drying the Work Piece | 0.016 | 0.056 | 0.055 | 0.037 |

Based on the data collected from the experts the geometric means of the weights of the criteria is assessed and shown in table 8.

***Step 4***: Attain the weighted normalized matrix $V_{ij}$. This is attained by the multiplication of each element of the column of the matrix $X_i$ with its associated weight.

$$V_{ij} = W_j X_i \tag{3}$$

**Table 9.** Weighted normalized matrix

| | EP | HW | ED | LA | CA | S | CR | RC | SC | CWD |
|---|---|---|---|---|---|---|---|---|---|---|
| AHONOL-7 | 0.059 | 0.062 | 0.018 | 0.072 | 0.043 | 0.016 | 0.028 | 0.018 | 0.012 | 0.013 |
| BLASER 2000 | 0.038 | 0.066 | 0.024 | 0.029 | 0.048 | 0.013 | 0.037 | 0.031 | 0.012 | 0.014 |
| YBI | 0.028 | 0.040 | 0.024 | 0.069 | 0.022 | 0.020 | 0.025 | 0.019 | 0.010 | 0.014 |

***Step 5:*** This step ascertains the positive ideal ( best ) and negative ideal ( worst ) solutions. The positive ideal and negative ideal solution is given as

The positive ideal solution

$$C^+ = \left\{V_1^+, \ldots\ldots\ldots V_m^+\right\} \tag{4}$$

$$C^+ = \left\{(\max V_{ij} / j\varepsilon I'), (\min V_{ij} / j\varepsilon I'')\right\} \tag{5}$$

The negative ideal solution

$$C^- = \left\{V_1^-, \ldots\ldots\ldots V_m^-\right\} \tag{6}$$

$$C^- = \left\{(\min V_{ij} / j\varepsilon I'), (\max V_{ij} / j\varepsilon I'')\right\} \tag{7}$$

Here

$I' = \{ j = 1, 2, \ldots\ldots\ldots n / j\}$

related with the beneficial attributes

$I'' = \{ j = 1, 2, \ldots\ldots. n / j\}$

associated with non-beneficial adverse attributes.

***Step 6:*** Attain separation measures of each alternative from the positive ideal solution and negative ideal solution that is specified by the Euclidean distance given by the equations.

$$D_i^+ = \sqrt{\sum_{i=0}^{m}\left(V_{ij} - V_j^+\right)^2}, i = 1, 2, \ldots. n \tag{8}$$

$$D_i^- = \sqrt{\sum_{i=0}^{m}\left(V_{ij} - V_j^-\right)^2}, i = 1, 2, \ldots. n \tag{9}$$

**Table 10.** Separation of each alternative from the positive ideal solution and negative ideal solution

| Cutting Fluid | AHONOL -7 | BLASER 2000 | YBI |
|---|---|---|---|
| Di+ | 0.020 | 0.049 | 0.051 |
| Dj- | 0.061 | 0.042 | 0.042 |

***Step 7***: Evaluate the relative closeness to the ideal solution of each alternative which is given by the formula

$$C_i^* = \frac{D^-}{\left(D_i^+ + D_i^-\right)}, i = 1, 2, \ldots. n \tag{10}$$

Select the superlative alternate that is having maximum closeness to the ideal solution. Arrange the alternative as an increasing order of $C_i^*$.

**Table 11.** Relative closeness to the ideal solution

| Cutting Fluid | $C_i$* | Rank |
|---|---|---|
| AHONOL-7 | 0.752 | 1 |
| BLASER 2000 | 0.464 | 2 |
| YBI | 0.453 | 3 |

The relative closeness of the alternatives to the ideal solution is calculated and is shown in table 11. The alternatives are ranked with an increasing order of Ci*

Ahonol – 7 is chosen as the best cutting fluid and ranked first having largest relative closeness value to the ideal solution.

## VIKOR Method

The VIKOR approach is a MCDM technique. VIKOR the name, appeared from Serbian word "visekriterijumsha optimizacija I Kompromisno Resenje" that means Multi criteria optimisation and compromise solution. It helps to determine the list of compromise ranking and the compromise solution attained with the given weights. This approach mainly focussing on ranking and choosing from a set of alternates in the presence of conflicting criteria. The steps involved in VIKOR Method.

***Step 1:*** attain the weight normalized matrix Vij. This is attained by the multiplication of each element of the column of the matrix Xij with its associated weight.

$$V_{ij} = W_j X_i \tag{11}$$

**Table 12.** Weighted normalized matrix

| | EP | HW | ED | LA | CA | S | CR | RC | SC | CWD |
|---|---|---|---|---|---|---|---|---|---|---|
| AHONOL-7 | 0.059 | 0.062 | 0.018 | 0.072 | 0.043 | 0.016 | 0.028 | 0.018 | 0.012 | 0.013 |
| BLASER 2000 | 0.038 | 0.066 | 0.024 | 0.029 | 0.048 | 0.013 | 0.037 | 0.031 | 0.012 | 0.014 |
| YBI | 0.028 | 0.040 | 0.024 | 0.069 | 0.022 | 0.020 | 0.025 | 0.019 | 0.010 | 0.014 |

The weighted normalized matrix obtained for TOPSIS method is used in VIKOR method.

***Step 2:*** Attain the values of the criterion function for all the alternative fij, fij is the jth criterion function of Xi alternative.

Here i=1,2,......n, the number of alternatives

j=1,2...........m, the number of criteria

***Step 3:*** Attain the maximum criterion function fj* and the minimum criterion function fj- where j=1,2,........m.

$$f_j^* = {}^{\max}_{i} f_{ij} = \max\left[\left(f_{ij}\right)\right] i = 1, 2, \ldots n \tag{12}$$

**Table 13.** Maximum criterion function

| 1 | EP | HW | ED | LA | CA | S | CR | RC | SC | CWD |
|---|---|---|---|---|---|---|---|---|---|---|
| fi* | 0.059 | 0.066 | 0.027 | 0.072 | 0.048 | 0.020 | 0.037 | 0.031 | 0.012 | 0.014 |

$$f_j^- = {}^{\min}_{i} f_{ij} = \min\left[\left(f_{ij}\right)\right] i = 1, 2, \ldots n \tag{13}$$

**Table 14.** Minimum criterion function

| | EP | HW | ED | LA | CA | S | CR | RC | SC | CWD |
|---|---|---|---|---|---|---|---|---|---|---|
| fi- | 0.028 | 0.040 | 0.018 | 0.029 | 0.022 | 0.013 | 0.025 | 0.018 | 0.010 | 0.011 |

***Step 4***: Evaluate the utility measure and regret measure for all the alternatives.

$$S_i = \sum_{j=1}^{m} W_j \left( f_j^* - f_{ij} \right) / \left( f_j^* - f_j^- \right) \tag{14}$$

**Table 15.** Utility measure

| Cutting Fluid | AHONOL-7 | BLASER 2000 | YBI |
|---|---|---|---|
| Si | 0.291 | 0.334 | 0.640 |

$$R_i = \max_j \left[ W_j \left( f_j^* - f_{ij} \right) / \left( f_j^* - f_j^- \right) \right] \tag{15}$$

**Table 16.** Regret measure

| Cutting Fluid | AHONOL-7 | BLASER 2000 | YBI |
|---|---|---|---|
| Ri | 0.071 | 0.170 | 0.169 |

***Step 5***: Calculate VIKOR index value

$$Q_i = v \frac{\left( S_j - S^* \right)}{\left( S^- - S^* \right)} + (1-v) \frac{\left( R_j - R^* \right)}{\left( R^- - R^* \right)} \tag{16}$$

Where $v$ is presented as weight for the strategy of the maximum group utility, whereas (1-v) is the weight of the individual regret. Generally the value of the v is considered as 0.5 (Liu,H.C., Mao,L.X., Zhang,Z.Y.,Li,P.,(2013).

***Step 6:*** Rank the alternatives, sorting by the values S, R and Q in decreasing order.

**Table 17.** VIKOR Index value Qi

| Qi | Cutting Fluid | Rank |
|---|---|---|
| 0.000 | AHONOL-7 | 1 |
| 0.561 | BLASER 2000 | 2 |
| 0.995 | YBI | 3 |

***Step 7***: Suggest as a compromise solution of the alternative (a') which is ranked the best by the measure (Q) minimum of the following two conditions are satisfied.

C1. Checking for Acceptable Advantage

$$Q(a'') - Q(a') \geq DQ \tag{17}$$

Therefore the alternatives Ahonol – 7 and Blaser 2000 are in closeness. Where a" is the alternative with second position in the ranking list by Q:

$$DQ = \frac{1}{j-1} \tag{18}$$

DQ = 1/2= 0.5

$Q(a'') - Q(a') = 0.561$

0.561-0 $\geq$ DQ

0.561 > 0.5

C2: Acceptable stability in decision making.
Alternative a' must also be the best ranked by S or/and R.
If one of the conditions is not satisfied, then a compromise solution is proposed, that contains of Alternatives a' and a'' if only condition C2 is not satisfied or

Alternatives $a', a''..........a^{(M)}$, if condition C1 is not satisfied by the relation $Q\left(a^M\right) - Q\left(a^-\right) < DQ$ for maximum m (the position of these alternatives are in closeness)

Alternative Ahonol – 7 is in the best ranked by Q, S, and R. This compromise solution is stable within a decision making process.

## RESULTS AND DISCUSSION

In AHP the higher value of the priority vector is used to rank the alternatives. In TOPSIS method the relative closeness to the ideal solution is used to rank the cutting fluids. The cutting fluid which has maximum closeness value is ranked first whereas in VIKOR method a compromise solution is attained by the minimum value of the vikor index. Hence the alternative which has minimum vikor index value is ranked as the best compromise solution.

**Table 18.** Comparative Analysis

| Cutting Fluid | AHP | | TOPSIS | | VIKOR | |
|---|---|---|---|---|---|---|
| | Score | Rank | Score | Rank | Score | Rank |
| AHONOL-7 | 0.561 | 1 | 0.752 | 1 | 0.000 | 1 |
| BLASER 2000 | 0.239 | 2 | 0.464 | 2 | 0.561 | 2 |
| YBI | 0.204 | 3 | 0.453 | 3 | 0.995 | 3 |

Table 18 shows the comparison of the results obtained by AHP, TOPSIS and VIKOR methods. Ahonol – 7 cutting fluid is selected as an optimum cutting fluid with high priority vector value, maximum relative closeness value to the ideal solution and minimum vikor index value.

## CONCLUSIONS

A detailed method based on a combined MCDM method (AHP, TOPSIS and VIKOR methods) is recommended that supports in the selection of cutting fluid from different alternatives .The measures of the criteria and their relative importance have been adopted to rank the alternatives, which assists in the better evaluation of cutting fluid from the alternatives. The suggested technique is appropriate to any type of machining processes and any number of criteria can be considered. This proposed methodology can be used for any selection problems that involves multiple and conflicting criteria. The selection of cutting fluid can also be performed using other MCDM methods for comparing the results.

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