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Multicriteria Decision Making Approaches: A Case Study on Selection of Cutting Fluids

Raj Kamal Pandey[1], Parag Shrivastava[2]

[12]Department of Mechanical Engineering, Shri Shankaracharya Technical Campus, Bhilai-490020 Chhattisgarh, India.

ABSTRACT

Engineers working in the manufacturing industry are frequently faced with difficult multi-criteria selection problems. Over the years, a variety of multi-criteria decision-making (MCDM) methodologies have been offered to help decision-makers tackle a variety of challenging selection situations. Despite the fact that a variety of mathematical techniques are currently available to analyze, select, and rank the alternatives for a specific engineering application. This study examines the capability and usefulness of two MCDM techniques, namely Additive Ratio Assessments (ARAS) and Weighted Aggregate Sum Product Assessment, to tackle cutting fluids selection problems (WASPAS). The main justification for using these two strategies is because none of these MCDM techniques has previously been used while making decisions in such a field. Additionally, the applicability and effectiveness will be demonstrated through the selection of the optimal cutting fluid for a certain machining application. Using these two techniques, all MCDM problems are examined, and several rankings are suggested. Entropy is utilized to evaluate the relative weights of criteria in the objective weighted system

Keywords: MCDM, WASPAS, MOORA, Machining, Cutting Fluid

1. Introduction

Multicriteria decision making or MCDM has now become trend in recent few years because of its exceptional problem-solving methodologies and adaptability to any domain for the benefit of optimization. MCDM techniques were first used in the 1970s, and numerous new methods and hybrid techniques have since been created. In one of their research articles, Koksalan et al. (2013) discussed a situational analysis on the application of the MCDM technique. An incident that occurred in the province of ancient history serves as an example of the work. MCDM encompasses a wide range of techniques. The MCDM technique is further divided into two divisions, as indicated in Fig. 1.1. Discrete MADM i.e., Multiattribute decision making and Continuous MODM i.e., Multiobjective decision making.

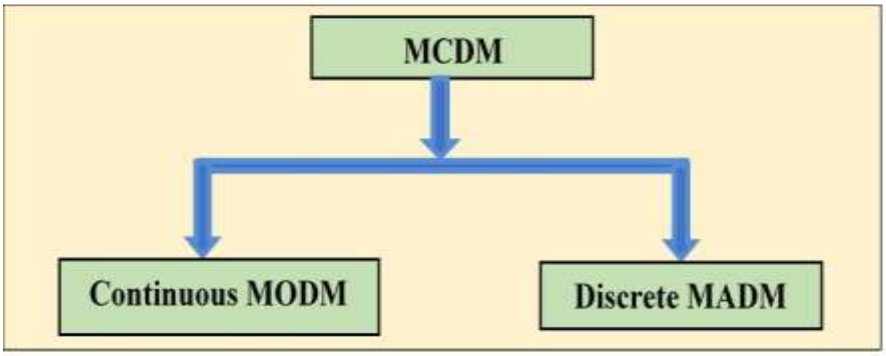

Figure 1. Classification of MCDM techniques

1.1 Multi-Objective Decision Making (MODM)

Whenever the alternatives are just not pre-specified and the purpose is to produce the best practical collection of alternatives, these methods are used using just a series of explicitly expressed design parameters and a set of quantifiable goals. MODM techniques are capable of handling difficult design courses as there are so many possibilities. It is frequently the obligation of designers to use quality materials and generate work which will satisfy when faced with difficult design difficulties.

1.1.2 Multi-Attribute Decision Making (MADM)

These techniques, which are particular to each person, are used to address issues involving a limited number of options and various characteristics. “Many well-known methods are included in MADM, including Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW), Data Envelopment Analysis (DEA), Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), VlseKriterijumska Optimizacija Kompromisno Resenje (VIKOR), Decision Making Trial and Evaluation Laboratory (DEMATEL), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), Elimination Et Choice Translating Reality (ELECTRE) but recent revision and adjustment in MCDM methods have altered its version, applying fuzzy and grey number theory it become suitable to use as hybrid form. To solve real-world problems, the latest MCDM methods such as the Cooperation Platform for Research and Standards (COPRAS), Additive Ratio Assessment (ARAS), Step Wise Weight Assessment Ratio Analysis (SWARA), multi-objective optimization by ratio analysis (MOORA), multi-objective optimization by ratio analysis plus the full multiplicative form (MULTIMOORA), Operational Competitiveness Rating (OCRA), and Weighted Aggregated Sum Product Assessment (WASPAS) were applied to solve real life problems. Analytical Network Process (ANP), Additive Ratio Assessment (ARAS) and Weighted Aggregated Sum Product Assessment (WASPAS) methods are branches of MCDM and successfully utilized in many research fields to solve the problem correlated to the real world in which people usually faces difficulties while deciding” (Zavadskas et al., 2014). In order to address both internal and external issues, numerous organisations and sectors have implemented MCDM methodologies. “The integration of ENTROPY and other techniques have been successfully utilized in evaluation of supplier, personnel selection, selection process plans and applied in many other distinct fields. In this work hybrid technique combining ENTROPY with ARAS and WASPAS were used in the field of cutting fluid selection” (Zavadskas et al., 2014).

2.1 Cutting Fluids

Cutting fluids are liquids that are often used during the machining (or cutting) process. Milling, turning, drilling, and other machining operations are examples of machining operations. A cutting fluid is sometimes referred to as a coolant, however this is inaccurate. Out of numerous functions of a cutting fluid is to keep the equipment and work piece cool. Cutting fluid is a liquid that is used to remove heat from metal cutting and other machining processes. In some situations, it's also employed as a lubricant. They're also utilized to improve tool life and cutting conditions. Friction between the tool and the chip, as well as between the tool-work piece interface, is reduced by the cutting fluids. Heat can be eliminated as soon as it is generated if the right amount of cutting fluid is used. As a result, cutting fluids are required to boost manufacturing efficiency. There was no problem selecting the cutting fluid prior to the discovery of HSS, and water was used as a coolant because machining was done at a relatively slow rate. Water, however, was no longer an option following the discovery of HSS since the heat generated during machining was excessive due to high-speed milling. As a result, several cutting fluids were found and developed for various machining processes and materials. Cutting fluids come in two forms: liquid and gaseous. It is mostly utilized in metal machining and stamping procedures.

Cutting fluids can in a variety of forms, including oil, oil-water emission, pastes, gels, and so on. Depending on the type of cutting fluid and its application, it may be referred to as cutting fluid, cutting oil, coolant, or lubricant.

2. Methodology and Result Discussion

The calculation of weights is the most crucial step in any MCDM technique. According to earlier literature, the majority of industrial personnel choose the thumb rule principles when deciding how to allocate weights as uniform weights. In this instance, all of the criteria are equally important, and the total weights add up to one. The other two weighting methods are either subjective or objective in nature.

Some of the subjective techniques employed, such as AHP, BWM, SWARA, & Simple Multi-Attribute Rating Technique (SMART), may lead to biassed decisions. As can be observed, Karande and Chatterjee (2013) used the AHP method, a subjective weighted technique that only depends on the DM's judgement, to estimate the parameter weights. Since the entropy technique is unaffected by the DM's ideas and opinions, the weights are computed and freshly created ARAS and COPRAS, that have specific advantages over earlier MCDM tools, are used to explain the existing conveyor selection problem.

In this research after setting all the criteria and based on these criteria the alternatives have been finalized in Chapter 3, i.e., problem identification. A total number of eight criteria have been selected for the research work. These selected criteria are, Wheel Wear (WW), Tangential Force (TF), Grinding Temperature (GT), Surface Roughness (SR), Recyclability (R), Toxic Harm Rate (TH), Environmental Pollution Tendency (EP), Stability (S). Based on these selected criteria next a total number of four alternatives have been identified. The comparison table has already been shown in Chapter 3. For better clarity the same table is shown below with slight modification in Table 1.

Figure 2. Process of cylindrical grinding using cutting fluids

Table 1. Comparison Table

Type	**Max.**	**Max.**	**Min.**	**Min.**	**Min.**	**Min.**	**Min.**	**Min.**
Criteria →	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Alternatives ↓	**R**	**S**	**WW**	**TF**	**GT**	**SR**	**TH**	**EP**
Units	**(Value)**	**(Value)**	**(mm)**	**(N)**	**(0C)**	**(µm)**	**(Value)**	**(Value)**
Water soluble	0.335	0.59	0.035	34.5	847	1.76	0.5	0.59
Straight mineral oil	0.335	0.665	0.027	36.8	834	1.68	0.665	0.665
Chlorinated oil	0.59	0.5	0.037	38.6	808	2.4	0.59	0.41
Sulfochlorinated oil	0.5	0.41	0.028	32.6	821	1.59	0.59	0.59

WW, Wheel Wear; TF, Tangential Force; GT, Grinding Temperature; SR, Surface Roughness; R, Recyclability; TH, Toxic Harm Rate; EP, Environmental Pollution Tendency; S, Stability

The above table is the finally identified comparison table. From this table it is very clear that a total number of six criteria are of minimization or non-beneficial type whereas two of are of maximization or beneficial type. Now the prime task is to select the best alternatives and rank the others.

Table 2. Normalization of Comparison Table

Type	**Max.**	**Max.**	**Min.**	**Min.**	**Min.**	**Min.**	**Min.**	**Min.**
Criteria →	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Alternatives ↓	**R**	**S**	**WW**	**TF**	**GT**	**SR**	**TH**	**EP**
Units	**(Value)**	**(Value)**	**(mm)**	**(N)**	**(0C)**	**(µm)**	**(Value)**	**(Value)**
Water soluble	0.190	0.273	0.276	0.242	0.256	0.237	0.213	0.262
Straight mineral oil	0.190	0.307	0.213	0.258	0.252	0.226	0.284	0.295
Chlorinated oil	0.335	0.231	0.291	0.271	0.244	0.323	0.252	0.182
Sulfochlorinated oil	0.284	0.189	0.220	0.229	0.248	0.214	0.252	0.262

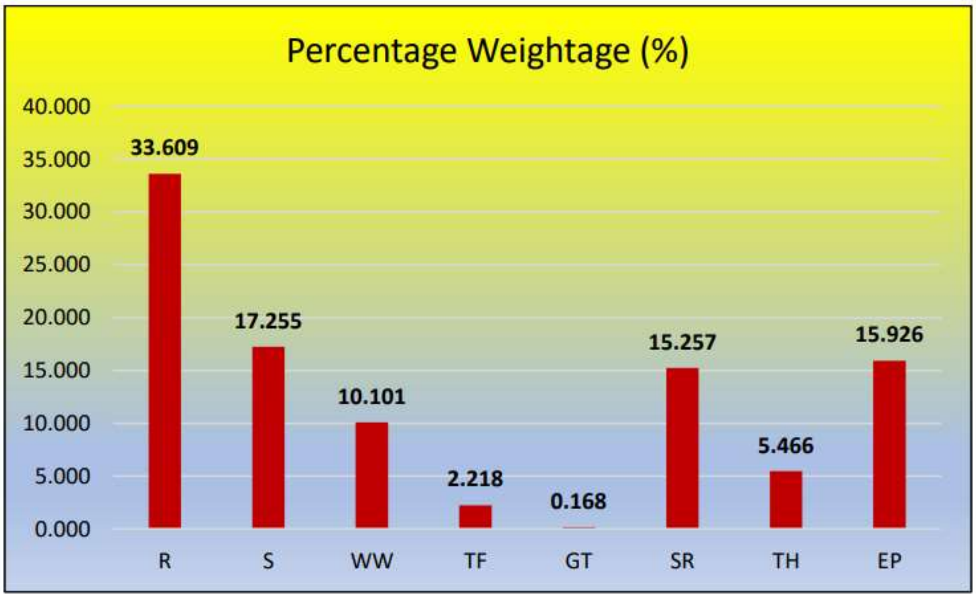

Figure 3. Percentage Weights of Eight Criteria

From the Figure 3, it is observed that the highest percentage weightage of 33.609% is assigned to recyclability (R). The stability (S) has been assigned 17.255% weightage, Environmental Pollution Tendency (EP) and Surface Roughness (SR) with 15.926% and 15.257% weightage holds the position of third and fourth correspondingly. This completely suggests that, more weightage has been provided to recyclability and stability. Then the next weightage of 10.101% has been given to wheel wear (WW). The weight of the grinding temperature (GT)was found to be the least percentage weightage.

3. Summary

The chapter reveals the ranking of all the four alternates and find out the best alternate among these four alternatives. Table 5.28 shows rankings with AHP and WASPAS with ENTROPY and AHP weights. Both of the MCDM techniques are providing similar results in terms of ranking with ENTROPY and AHP weights correspondingly.

Table 3. Rankings with AHP and WASPAS with ENTROPY and AHP weights

S. No.	Alternatives	ENTROPY-ARAS	ENTROPY-WASPAS	AHP-ARAS	AHP-WASPAS
1	Water soluble	4	4	4	4
2	Straight mineral oil	3	3	2	2
3	Chlorinated oil	1	1	3	3
4	Sulfochlorinated oil	2	2	1	1

Chlorinated oil has achieved the first rank and found to be the most suitable alternative among the four alternatives using ARAS and WASPAS with ENTROPY weights. Whereas, Sulfochlorinated oil received first rank and found to be the most suitable alternative among the four alternatives using ARAS and WASPAS with AHP weights. Water soluble cutting fluid has ranked last with all the optimization techniques in this work. Further, to test the consistency of MCDM methods Spearman rank coefficients are being calculated and the results obtain are found satisfactory and competent. Hence both of the MCDM methods namely, ARAS and WASPAS are found suitable for ranking and use.

4. Conclusion

In this work, cutting fluid selection issue for an industry situated in Industrial area Bhilai has been considered and analyzed profoundly. The basic requirement for the industry is to choose best cutting fluid for cylindrical grinding operation. The industry management meant to choose the most suitable cutting fluid for their work environment. Under this circumstance, four cutting fluids are under consideration and feasibility of MCDM techniques are needed to be checked. These techniques are namely, Entropy method, Additive Ratio Assessment (ARAS) and Weighted Aggregated Sum Product Assessment (WASPAS) methods are branches of MCDM and successfully utilized. The weights will be determined using Entropy technique, and then by using those calculated weights ARAS and WASPAS strategy will be tested and the choices will be ranked. In order to select a right lubricant from amongst a number of lubricants during cylindrical grinding operations. "Four cutting fluids i.e., alternatives were evaluated based on eight criteria such as wheel wear (WW), tangential force (TF), grinding temperature (GT), surface roughness (SR), recyclability (R), toxic harm rate (TH), environment pollution tendency (EP) and stability (S). Among the eight selection criteria, R and S are the only beneficial criteria. The four alternatives which are under consideration are i) Water soluble based, ii) Straight mineral oil based, iii) Chlorinated oil based and iv) Sulfochlorinated oil based" (Rao, 2007).

In case of any decision-making issue, decision can be made immediately when there exists just a single criterion. But it is very difficult to settle on decisions when there are numerous criteria is accessible. For these sorts of multi-criteria decision-making issues MCDM methods can be applied. The present research work is mainly focused on selection of cutting fluids. There is a huge number of alternatives available in the market and it is very difficult to finalize the best. The present work is acquainted with multi-criteria decision-making problem with several criteria involved. The multi-criteria decision-making tool is very useful for selection of one alternative over a given set of alternatives with numerous criteria. In this research, to identify a superior cutting fluid as per various criteria three MCDM techniques namely, ARAS and WASPAS.

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