MULTIPLE ATTRIBUTE DECISION-MAKING METHODS HELPS IN LOGICALLY SELECTION OF CHAFF CUTTING MACHINE BLADES

Hemant Rajendra Nehete[1*], Dr.Nilesh Diwakar[2], Dr.M.K Chopra[3], Dr.Nikhil J Rathod[4]

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Abstract

In order to choose the best material for a given design and manufacturing process, decision-making is crucial. The researchers employed tools to aid in their decision-making because proposing a novel material is usually difficult. The selection of the piston material is handled in the current paper using Multi-Attribute Decision Making (MADM) techniques to ensure the best design process. A comparison of the weights of subjective and objective criteria for a few MADM approaches is conducted. Sensitivity analysis is done to show that the ranking order for performance scores is consistent despite the fact that the weights of the criteria for each alternative differ.

Keywords: Chaff Cutter Blade, Saw,Wpm,Ahp,Mcdm Method

[1*] PhD scholar, Department of Mechanical engineering, RKDF IST,Bhopal, Sarvepalli Radhakrishnan University, Bhopal,Madhya Pradesh, India

[2] Professor, Department of Mechanical engineering, RKDF IST,Bhopal, Sarvepalli Radhakrishnan University, Bhopal,Madhya Pradesh, India

[3] Professor & Head, Department of Mechanical engineering, RKDF IST,Bhopal, Sarvepalli Radhakrishnan University, Bhopal,Madhya Pradesh, India

[4] Assistant Professor,Department of Mechanical engineering, IES University, Bhopal, Madhya Pradesh, India

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1. Introduction

It is generally known how crucial material selection is to the creation of successful products. The best material is decided by a number of elements that affect the selection process, making it difficult to design a systematic technique for picking it. Materials selection is necessary for two primary reasons: first, to design an existing product for improved performance, lower cost, greater dependability, and lighter weight; and second, to choose a material for a new product. Because the process of selecting materials has a significant impact on and determines a product's overall performance, materials selection is a key factor in product design. Composites continue to displace conventional materials including steel, aluminium, metals, and alloys used in structural applications across a variety of sectors. This is because composite materials, which have higher strength-to-weight ratios, durability, and a variety of design options, can deliver. Depending on the type of resin, reinforcing, location of the fibres, and manufacturing process, composites can be produced utilising a variety of production procedures [1]. Popular production techniques like pultrusion, resin transfer moulding, filament winding, and compression moulding are frequently used in the composite industries. A lot of different sectors are interested in pultrusion, one of these techniques, because it can produce structural FRP profiles with a high fibre volume and exceptional strength [2]. With the aid of reinforcing fibres, resin, catalyst, fillers, pigments, and release agents, pultrusion is renowned for manufacturing fibre reinforced composites with consistent cross-sections, such as flat bars, beams, channels, rods, and solid and hollow sections. The automated technique is made to consistently and endlessly produce linear constant cross-sections and then reliably cut them into pre-programmed lengths [3]. The open-section geometries that can be produced by the closed moulding technique are not its only limitations; single- or multi-celled close-shaped profiles can also be produced using pultrusion [4,5]. Composites made of natural fibres have certain distinct advantages over those made of synthetic fibres, including being more lightweight, cheaper, recyclable, and environmentally benign. The low impact strength, low thermal stability, and high moisture absorption qualities of natural fibres, despite their advantages in the manufacturing of composites, have a negative impact on their long-term service behaviour and restrict their usage in harsh outdoor applications [6,7]. The hydrophilic characteristic of natural fibres is what causes the high moisture absorption behaviour in natural fibre composites [8]. This could cause fibres to swell, ultimately weakening the composites' mechanical strength and dimensional stability. According to Alomayri et al. [9], the decline of flexural, impact, hardness, and fracture toughness qualities in cotton fabric composites was caused by moisture absorption. Alternately, natural and synthetic fibres can be mixed to improve the mechanical strength and water resistance of composites. In order to find potential application areas for the composites, extensive studies have been conducted on natural fibre reinforced hybrid composites, including investigations on long- and short-term properties. Antigoni Barouni et al. [10]. By contrasting hybridised flax and glass composites with flax reinforced composites, fatigue characteristics were assessed. Their research showed that flax/glass hybrid composites with alternating layers exhibit excellent fatigue properties and good fatigue life, which are suggested for semi-structural applications. Similar findings were found in a study on the fatigue life cycle of jute/glass reinforced hybrid composites for axial flow fan blades [11], which showed that these composites had a 78% longer fatigue life than standard glass fibre reinforced composites. The hybrid composites may be used in fan blades at low normalised peak loads, according to the researchers. The endurance of bamboo fibre reinforced polypropylene is improved by glass fibre hybridization, according to Kin Liao et al. [12]. According to research on environmental ageing, the strength degradation of hybrid samples was almost two times less than that of composites reinforced with bamboo fibre. Abassi et al. [13] investigated how long GFRP bars would last in a hot, alkaline atmosphere. The study found that the characteristics of GFRP rebar decrease over time and at higher temperatures in alkaline conditions. Glass fibre reinforced epoxy composites' flexural and impact characteristics in an alkaline and an acidic environment were studied by Amaro et al. [14]. According to the study, the composites' characteristics deteriorated over time in both circumstances, with an alkaline environment contributing to greater strength deterioration than an acidic environment. The constraints that affect the materials' endurance have been lessened, nevertheless, as a result of the hybridization of glass fibres with natural fibres in composites. Phani et al. [15] studied the hydrothermal ageing of jute/glass reinforced hybrid composites to assess the influence of environmental variables on hybridization. According to the investigations, pure and hybrid composites' strength readings for long-term ageing are more similar to one another. Interestingly, the investigation also showed that combining glass fibres with jute. By contrasting them with glass fibre, sisal fibre, and carbon fibre reinforced polymer composites, respectively, Akhila et al. [16] investigated the mechanical performance and durability of hybrid sisal/glass fibre reinforced polymer composites for retrofitting of reinforced concrete structures. All of the samples were created using FRPs to contain concrete cylinders on the outside. According to the investigations, hybrid sisal/glass fibre composites perform better in terms of axial load carrying capacity, ductility, and energy absorption rate than individual sisal and glass fibre composites. The hybrid composites may eventually take the place of carbon fibres in applications for retrofitting concrete, according to the researchers. According to Mayandi et al. [17], the durability and mechanical performance of hybrid composites can be improved by using synthetic fibres like glass fibres in the outer layers. This is because glass fibres' superiority over natural fibres in terms of UV resistance, alkali resistance, and moisture absorption has been demonstrated, protecting the inner layers of natural fibres from harmful environmental effects. Overall, research has demonstrated that the hybridization of composites is one method for overcoming the constraints of both natural and synthetic materials by fusing the two to enhance the distinctive properties of each material [18, 19]. Ladders, window frames, door panels, sporting equipment, biomedical equipment, and interior uses for automobiles and aircraft can all be made using natural/glass fibre reinforced hybrid composites [20,21,22,23]. Therefore, with regard to their mechanical and physical performances, natural fibres can be hybridised with glass fibres via pultrusion to develop pultruded FRP profiles for load-bearing structural applications. This is a good potential reinforcement replacing synthetic fibres in fibre reinforced composites. Finding the optimum fibre for reinforcement in pultruded FRP profile applications is crucial before moving on to subsequent research phases such composites characterization, structural analysis, and product development. As a result, the objective of this study is to first identify the best natural fibre for pultrusion application using the analytical hierarchy process (AHP) as a method.

AHP is a multiple-criteria decision-making (MCDM) analysis tool utilised in the systematic and quantitative selection strategy to solve decision-making problems [24,25]. AHP analysis has been used by researchers as a tool for decision-making in a variety of applications. Using Expert Choice software, Dweiri et al. [26] did an AHP study to determine the best material for "keys." High carbon steel, which had the greatest priority vector according to the analysis, is the best material for keys. When Kevlar 29 and the chosen Cocos nucifera sheath from the AHP process were combined to create an armour, it was created by Naveen et al. [27]. Seven criteria and fourteen natural fibre options were examined in the study; the cocos nucifera sheath had the highest priority vector rating relative to the other alternatives. With tensile strength, young's modulus, and density serving as the sub-criteria, Sapuan et al. [28] employed AHP analysis to determine that kenaf 60% reinforced polypropylene was the optimum material for usage in car dashboard panels. AHP has other benefits in addition to being a quick and easy technique, such as helping the decision maker make consistent judgements by detecting inconsistencies and examining the integrity of the final decision using sensitivity analysis [29,30,31,32]. The literature evaluations show that the researchers mentioned above have not addressed the use of AHP to choose the best material for the composite Chaff Cutter Machine. The purpose of this study is to help designers analyze different materials and choose the best one by using AHP.

2. Material selection throughout the conceptual design phase

At the conceptual design stage, the selection procedure aids the designers in choosing the ideal material for a concept. A primary concern is a fundamental problem with polymeric composite chaff cutter machine, particularly one connected to the choice of materials. As a result, this paper only addresses how to choose the best material in a concurrent engineering environment. The best material for the chaff cutter machine is then selected by linking AHP, a decision support tool, to the framework. In order to strengthen trust in the selection of material and evaluate the stability of the priority ranking, many scenarios of the sensitivity analysis are carried out after the best material is decided or called the material picked.

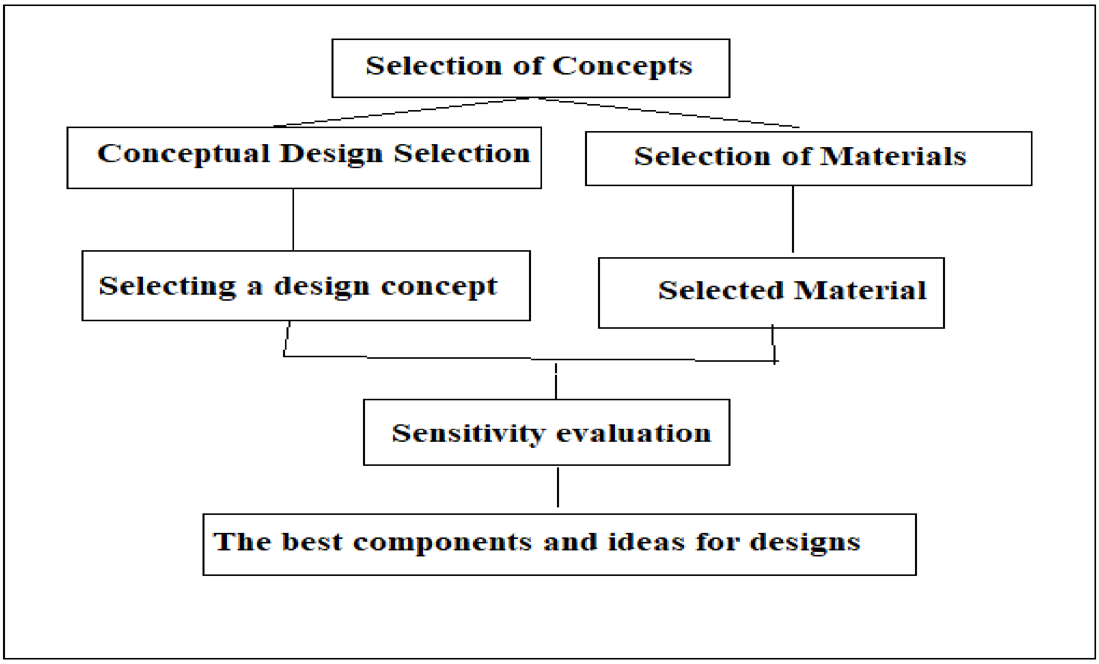

Figure 1. Framework for the selection process at the conceptual level in a concurrent engineering environment

Chaff Cutter Machine with Various Bases: Chaff Cutter Machine has quickly extended its use of composite materials. Chaff Cutter Machine is under growing market pressure to produce high-quality goods faster and cheaper. A critical choice for the Chaff Cutter Machine is selecting the appropriate material. Chaff Cutter Machines like the chaff cutter have received a lot of attention recently when it comes to the use of composites. The Chaff Cutter Machine is typically understood to consist of four fundamental Chaff Cut parts, as shown in Fig. 2. The Chaff Cutter is one of the most crucial parts of the Chaff Cutter Machine. Therefore, choosing the appropriate material for the Chaff Cutter Machine is crucial.

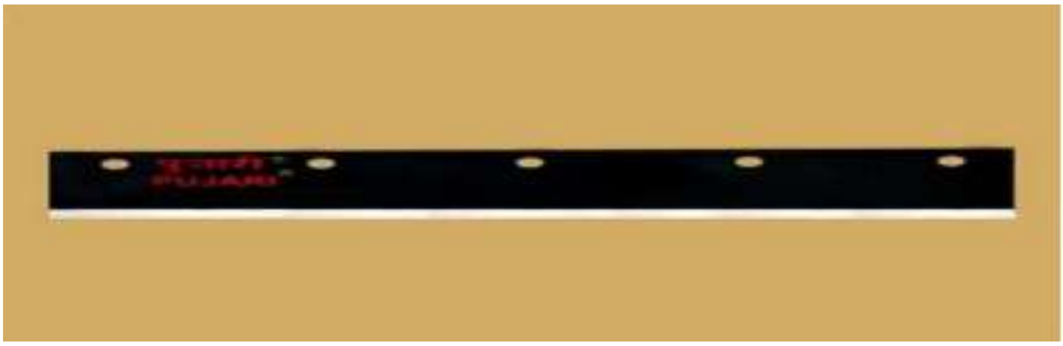

Fig No.2 Straight Rectangular Chaff Cutter Blade and Chaff Cutter Blades

Factors to take into account while choosing materials for a composite chaff cutter machine

Following are the considerations that must be made while choosing the optimum material for the composite chaff cutter blades.

Angle:

An angle is a shape created by two rays that share a terminus and are referred to as the angle's sides and vertices, respectively. Due to their location in the plane that the rays are contained in, angles formed by two rays are also referred to as plane angles.

Deformation:

a stress-related change in the size or shape of a body; strain.

Von mises stresses:

From the results of uniaxial tensile tests, the von Mises stress is used to forecast the yielding of materials under complicated loads. The property that two stress states with equal distortion energy have an equal von Mises stress is satisfied by the von Mises stress.

Thickness:

a measurement of how far apart two surfaces of an object are from one another; typically the smallest of an object's three dimensions (length, breadth, and thickness).

3. Methodology

AHP steps at concept selection stage: AHP, created by, is a strong and adaptable weighted scoring decision-making technique that aids individuals in setting priorities and making the best decisions. when a judgement must take into account both qualitative and quantitative factors. Decomposition, comparison evaluation, and priority synthesis are the three foundational tenets of AHP. By organising these ideas into a more comprehensive nine-step procedure, as seen in Fig.3, they can be further explained.

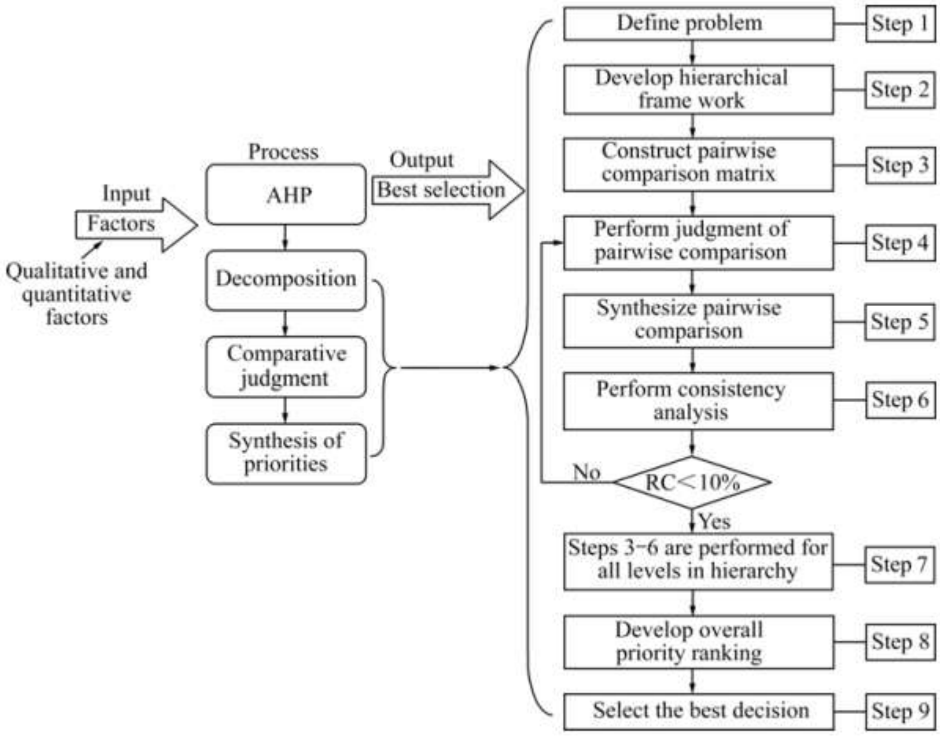

Figure 3. The steps of the AHP principle

Step 1: Identify the issue. Finding the issue and figuring out its purpose is the first step in using AHP. Decision-makers must define the variables or criteria influencing the selection process and express the problem properly. The identification of the variables impacting the selection process, in their opinion, is both the method's most inventive and vital component.

Step 2: create a hierarchical structure. Making a decision as a hierarchy is the most important aspect of decision-making. As a result, after identifying the problem, goal, criteria, sub-criteria, and decision options, decision-makers must organise a complex problem in a hierarchical structure or model while considering the connections between the overall goal, criteria, sub-criteria, and alternatives, as shown in Fig. 4.

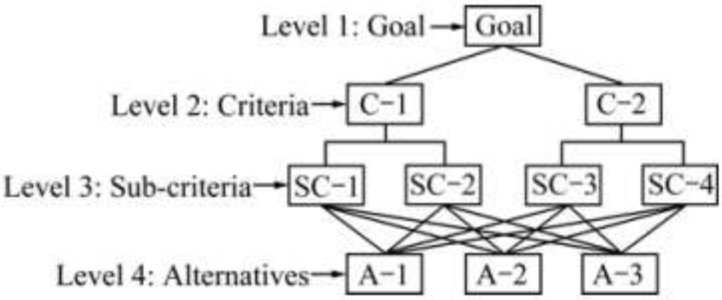

Figure 4: Four-level hierarchy

The hierarchy's general structure consists of the four tiers listed below.

Goal at Level 1. At the top of the hierarchy (level 1), the decision's objective or overarching goal is given. The objective stands in for the issue that needs to be resolved, such as choosing the optimal material for a composite vehicle bumper beam. (2) Criteria at Level 2. The primary criteria or important elements that have a significant impact on the selection process are represented at level 2 (level 2). The decision-makers' criteria are based on the kinds of issues that help achieve the goal.

(3) Sub-criteria for Level 3 levels. The sub-criteria are positioned at level 3 of the hierarchy, allowing the AHP model to be more precise. The selection procedure can be carried out more precisely to identify the best choice by adding sub-criteria or more detailed criteria of the issue.

Level 4: Alternatives for making decisions. At the bottom level (level 4) of the hierarchy, the choice alternatives or options are provided.

Step 3: Create a pairwise comparison matrix. Pairwise comparison is one of AHP's key strengths in determining precise ratio scale priorities.

The AHP methodology relies heavily on pairwise comparisons. The next step is to build a pairwise comparison matrix (size nn) for the lower levels using one matrix from the level above. For each level of the hierarchy, the pairwise comparisons provide a matrix of relative rankings. The total number of matrices is determined by the total number of elements at each level. The number of items at the lower level that each element relates to determines the order of the matrix at that level.

Step 4: Evaluate the results of the pairwise comparison. Comparing two things' relative importance is the first step in a pairwise comparison. To create the set of matrices in step 3, n(n1) judgements are necessary. The decision-makers must evaluate each component using a pairwise comparative relative scale, as illustrated in Table 1. The judgements are made based on the experience and knowledge of the decision makers or users. The decision-maker is able to instinctively assimilate experience and knowledge because to the scale utilised for comparisons in AHP. If C1 is much more important than C3, for example (Table 2), then a=5 is needed to perform a pairwise comparison.Each pairwise comparison is automatically given reciprocals.

Step 5: Create a pairwise comparison synopsis.The weights of the criterion are employed in hierarchical synthesis to weight the eigenvector entries, and the sum is taken as the overall weighted eigenvector entries, which correspond to those at the next lower level of the hierarchy. The average of normalised column (ANC) method is one of several approaches that may be used to calculate eigenvectors or vectors of priority. In ANC, each column's components or scale points are divided by the sum of the columns, added to each resulting row, and the resulting sum is divided by the number of elements in the row (n). This averages the columns that have been normalised. The eigenvector or vector of priority can be constructed mathematically as

$$W = \frac{1}{m}\sum_{k=1}^{m}\frac{K_{ij}}{\sum K_{ij}} \tag{1}$$

the number of criteria is n, W is the eigenvector (priority vector), K_{ij} is the relative scale, which is 1, 3, 5,...

Step 6: Carry out a consistency analysis. Some degree of inconsistency may arise since the comparisons are made using individual or subjective judgements. The degree of consistency among the pairwise comparisons is measured by computing the consistency ratio, which is regarded as one of the main benefits of the AHP, in order to ensure that the judgements are accurate. The consistency is determined by the consistency ratio (CR), which compares the consistency index (CI) to the random index (RI) for matrices of the same order. Three stages must be carried out in order to compute CR.

Calculate eigenvalue λmax

$$\lambda\text{max} = \frac{1}{m}\sum_{k=1}^{m}\frac{K_{ij}\ X\ W}{W} \tag{2}$$

$$CI=(\lambda\text{max}-m)/(m-1) \tag{3}$$

$$CR=CI/RI \tag{4}$$

Step 7: Repeat steps three through six. Steps 3 through 6 are done out for each level of the hierarchy.

Step 8: In order to rank the priority, create a rating. A general priority is defined in order to select the best alternative layout. When the consistency calculations for all levels are complete, the optimal design concept must be picked. The overall priority vector must be further computed in order to account for this.

In Step 9, select the best choice. Choose the best selection option in accordance with the results of step 8.

SAW method

Among all MADM Techniques, the SAW technique is a fundamental strategy. Using this method,

$$Q = \sum_{k=1}^{m} \text{wj ni} \tag{5}$$

performance is measured by Q is the individual variable's performance score, and wj is the attribute's weighting factor. nij is the fundamental table's normalised matrix.

Weighted Product Method

Both single attribute MADM methods and multi attribute MADM approaches use the weighted product method. The WPM has an advantage over the SAW approach since it employs relative values rather than real values. The model in this case includes multiplication notwithstanding addition. The relative value's power increases each separate criterion.

$$Q = \sum_{k=1}^{m} wj \qquad (6)$$

where m is the number of choice criteria, Wi is the weight matrix, and wj is a normalised matrix, and wj is the WPM performance score of the ideal alternative.

4. Results and Discussion

AHP: The steps 1 and 2 in this procedure are the same as those in the SAW method explained above. As stated in the methodology section of this method, the relative importance of attributes (rij) is assigned before creating a pair-wise comparison matrix. When choosing a CMM, the attributes Angle, Deformation (mm), Von Mises Stresses (Mpa), and Thickness are seen to be more significant than the attribute; Now Matrix A2, A3, and A4 are found from pairwise matrix as below The average of matrix A4's eigenvalues is found to be 4.11. By multiplying these weights by the corresponding normalised attributes of all alternatives, the relative normalised weights in matrix A2 are operated. The calculation for the Performance index for each choice.

Table1. Numerical Attributes Data

	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
High carbon steel	27.5	0.3532	636.69	4
Tungsten carbide	27.5	0.1303	639.58	4
FRP-Steel composite plate	27.5	0.682	269.81	4

Table 2. Normalized Data

	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
Angle	1	4	2	6
Deformation (mm)	0.15	1	0.5	2
Von mises stresses(Mpa)	0.5	2	1	1
Thickness	0.17	0.5	1	1

W 1	0.549001
W 2	0.129803
W 3	0.208575
W 4	0.112621

A 3= A 1 X A 2

	2.1576			0.549
A3	0.5408		A2	0.129
	0.8536			0.2085
	0.47893			0.1126

	3.930054645

	4.192248062
A4	4.094004796
	4.253374778
λmax=	16.46968228
λmax=	4.11742057

WPM: The same concepts are given in this technique as in the SAW method. As mentioned in the methodology section of this technique, the weights wa, wd, wv, and wt are now applied to normalised attribute data for various options to produce the CMM's overall performance index, which is displayed in Table 8.

Table 3. Cmm Performance Index Determination (Wpm Method)

CRITERIA	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
ALTERNATIVES	C 1	C 2	C 3	C 4
WEIGHT	0.549	0.129	0.2085	0.1126
A 1	27.5	0.3532	636.69	4
A 2	27.5	0.1303	639.58	4
A 3	27.5	0.682	269.81	4

Table 4. Cmm Performance Index Determination

CRITERIA	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
ALTERNATIVES	C 1	C 2	C 3	C 4
WEIGHT	0.549	0.129	0.2085	0.1126
A 1	15.0975	0.0455628	132.749865	0.4504
A 2	15.0975	0.0168087	133.35243	0.4504
A 3	15.0975	0.087978	56.255385	0.4504

Table 5 Rank Tables

CRITERIA	D	RANK
A 1	8.79	1
A 2	8.72	2
A 3	8.40	3

The above composite performance index values for all options are listed in decreasing order. The final order of ranks is determined as 1-2-3-. The highest value of is ranked first, the lowest value of is ranked last, and other values between highest and lowest are ranked according to their position in the order. The CMM marked as 1 is the last or third choice, according to these rankings, while the CMM identified as 5 is the top. As a result, the SAW technique's alternative order is provided by the WPM approach.

SAW: Angle, Deformation (mm), Von Mises Stresses (Mpa), and Thickness—the least significant attributes—are used to calculate weight for each attribute. As explained in the methodology section of this method above, these points are now divided individually by the total of these points to get the relative weight of each feature. To produce the performance index of the SAW technique, the weights wa, wd, wv, and wt are now operated on normalised data of characteristics in Table for various CCM choices. As indicated in Table 7, the performance index (Pi) values are ranked I through V and presented in descending order.

Table 6. Cmm Performance Index Determination (Saw Method)

CRITERIA	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
ALTERNATIVES	C 1	C 2	C 3	C 4
WEIGHT	0.549	0.129	0.2085	0.1126
A 1	27.5	0.3532	636.69	4
A 2	27.5	0.1303	639.58	4
A 3	27.5	0.682	269.81	4

Table 7. Cmm Performance Index Determination

CRITERIA	Angle	Deformation (mm)	Von mises stresses(Mpa)	Thickness
ALTERNATIVES	C 1	C 2	C 3	C 4
WEIGHT	0.549	0.129	0.2085	0.1126
A 1	1	2.71066769	3053.669065	35.52398
A 2	1	1	3067.529976	35.52398
A 3	1	5.234075211	1294.052758	35.52398

Table 8 Rank Tables

CRITERIA	D	RANK
A 1	641.59	2
A 2	644.26	1
A 3	275.03	3

The ranking of all options reveals that they are ordered as 2-1-3. According to this ranking, CCM identified as two is the last option and CCM designated as is the finest.

5. Conclusion

Science and technology are a major part of today's world. As a result of quick technological advancements brought about by new scientific discoveries, better, more resilient, aesthetically pleasing, and more affordable mechanical items are now being produced. In order to choose the best option from the given options, consumers need some logical and simple approaches. In this study, SAW, WPM, and AHP techniques are illustrated while a selection of the optimal CMM from a set of four possibilities is made, along with three characteristics that are shared by all four options. Results revealed that whereas SAW and WPM ranked alternative selections differently, AHP and gave the same order of ranks. The option identified as distinct is the conclusion reached using all the techniques. Any kind of mechanical engineering selection can be made using these techniques.

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