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CHAFF CUTTER MACHINE STEEL SELECTION BASED ON AHP AND TOPSIS

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Abstract
Due to its direct connection to passenger safety, the automotive industry is a very appealing field for young researchers to do ongoing study in. Numerous areas, including material selection, design, manufacturing, etc., have seen recent changes in the automotive industry. The right choice of a specific material can be considered to be of the utmost importance because poor selection immediately results in product failure. Since there are other alternatives fulfilling the same purpose, the current work provides a process to choose the optimal High carbon steel for brake pads. The weighing criteria for the Analytical Hierarchical Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approaches are used to discover the optimal material, and the outcomes are described.
Keywords: Chaff Cutter Blade, TOPSIS, AHP, MCDM Method

1. Introduction

The importance of material choice in producing effective goods is well understood. It is challenging to develop a methodical method for choosing the best material because of the variety of factors that influence the selection process. In order to design an existing product for higher performance, cheaper cost, greater dependability, and lighter weight, as well as to select a material for a new product, materials selection is essential for both of these reasons. Materials selection is a crucial component of product design since it has a substantial impact on and defines a product's overall performance. Steel, aluminium, metals, and alloys used in structural applications continue to be replaced by composites in a number of industries. This is due to composite materials' capacity to perform, which is facilitated by their better strength-to-weight ratios, durability, and range of design options. Composites can be made using a variety of production techniques, depending on the type of resin, reinforcing, position of the fibres, and manufacturing process [1]. The composite industries typically employ well-liked manufacturing processes as pultrusion, resin transfer moulding, filament winding, and compression moulding. One of these methods, pultrusion, is appealing to a wide range of industries because it can create structural FRP profiles with a high fibre volume and great strength [2]. Pultrusion is recognised for producing fibre reinforced composites with consistent cross-sections, such as flat bars, beams, channels, rods, and solid and hollow sections, with the help of reinforcing fibres, resin, catalyst, fillers, pigments, and release agents. The automated method is designed to reliably manufacture linear constant cross-sections and cut them into pre-programmed lengths indefinitely [3]. The closed moulding technique has restrictions beyond the open-section geometries that can be created; pultrusion can also be used to create single- or multi-celled close-shaped profiles [4,5]. Natural fibre composites have certain clear advantages over those composed of synthetic fibres, such as being more lightweight, less expensive, recyclable, and environmentally friendly. Natural fibres have advantages in the production of composites, but their low impact strength, low thermal stability, and high moisture absorption characteristics have a detrimental impact on their long-term service behaviour and limit their use in demanding outdoor applications [6,7]. Natural fibre composites exhibit a significant moisture absorption behaviour due to their hydrophilic properties [8]. As a result, the mechanical strength and dimensional stability of the composites may be reduced. This may cause fibres to bulge. Alomayri et al. [9] claimed that moisture absorption was the root cause of the deterioration in the flexural, impact, hardness, and fracture toughness properties in cotton fabric composites. Alternately, to increase the mechanical strength and water resistance of composites, natural and synthetic fibres can be blended. Extensive research has been done on natural fibre reinforced hybrid composites, including studies on long- and short-term properties, in order to identify possible application areas for the composites. [10] Antigoni Barouni et al. Fatigue properties were evaluated by comparing hybridised flax and glass composites to flax reinforced composites. Their study revealed that alternating-layer flax/glass hybrid composites had acceptable fatigue life and outstanding fatigue properties, which are recommended for semi-structural applications. Similar results were reported in a study on the fatigue life cycle of hybrid composites reinforced with jute and glass for axial flow fan blades [11], which demonstrated that these composites had a 78% longer fatigue life than conventional composites reinforced with glass fibre. According to the researchers, the hybrid composites could be utilised in fan blades under modest normalised peak loads. Glass fibre hybridization enhances the durability of bamboo fibre reinforced polypropylene, claim Kin Liao et al. [12]. Abassi et al. [13] looked into the durability of GFRP bars in a hot, alkaline environment. According to the study, GFRP rebar's properties deteriorate over time and at higher temperatures in alkaline environments. Amaro et al. [14] investigated the flexural and impact properties of glass fibre reinforced epoxy composites in an alkaline and an acidic environment. The study found that the properties of the composites declined over time under both conditions, with an alkaline environment being more detrimental to strength depreciation than an acidic environment. The hybridization of glass fibres with natural fibres in composites has nevertheless lowered the limitations that restrict the materials' durability. To determine how environmental factors affect hybridization, Phani et al. [15] investigated the hydrothermal ageing of jute/glass reinforced hybrid composites. According to the investigations, the strength readings for long-term ageing of pure and hybrid composites are more comparable to one another. Interestingly, the experiment also revealed that glass fibres and jute can be combined. Akhila et al. [16] evaluated the mechanical performance and durability of hybrid sisal/glass fibre reinforced polymer composites for retrofitting of reinforced concrete structures by contrasting them with glass fibre, sisal fibre, and carbon fibre reinforced polymer composites, in that order. FRPs were used to construct each sample, which had concrete cylinders on the outside. In the investigations, it was found that hybrid sisal/glass fibre composites performed better in terms of axial load carrying capacity, ductility, and energy. Mayandi et al. [17] claim that adding synthetic fibres like glass fibres to the outer layers of hybrid composites will increase their mechanical performance and durability. This is due to the fact that studies have shown that glass fibres outperform natural fibres in terms of UV resistance, alkali resistance, and moisture absorption, shielding the inner layers of natural fibres from adverse environmental effects. Overall, research has shown that combining natural and synthetic materials to enhance the unique qualities of each is one way to get around the limitations of both types of materials [18, 19]. Natural/glass fibre reinforced hybrid composites can be used to make ladders, window frames, door panels, sporting equipment, biomedical equipment, and interior uses for cars and aircraft [20,21,22,23]. So können natural fibers and glass fibers be hybridized to create pultruded FRP profiles for load-bearing structural applications based on their mechanical and physical qualities. In fibre reinforced composites is this a good potential reinforcement to replace synthetic fibers. Before moving on to the subsequent research phases such as composite characterization, structural analysis, and product development, it is essential to find the best fiber for reinforcement in pultruded FRP profile applications. Consequently, the objective of this study is to first find the best natural fiber for pultrusion application by means of the analytical hierarchy process (AHP). In order to solve decision-making problems, Analytical Hierarchy Process (AHP) is a multiple-criteria decision-making (MCDM) analysis tool that is used in the systematic and quantitative selection strategy [24,25]. Researchers have used Analytical Hierarchy Process (AHP) analysis as a decision-making tool for many purposes. Dweiri et al. [26] conducted an Analytical Hierarchy Process (AHP) study to determine the best material for "keys." According to the analysis, high-carbon steel was the most preferred vector for keys. [27]. The study looked at seven criteria and fourteen natural fibre options; the cocos nucifera sheath had the highest priority vector rating in comparison to the other options. Sapuan et al. [28] used AHP analysis to decide that kenaf 60% reinforced polypropylene was the best material for use in automotive dashboard panels, using tensile strength, young's modulus, and density as the sub-criteria. In addition to being a rapid and simple technique, AHP also has other advantages, such as assisting the decision maker in making consistent judgements by identifying discrepancies and assessing the integrity of the final decision using sensitivity analysis [29,30,31,32].

The analysis of the existing literature reveals that none of the aforementioned scholars have addressed the use of AHP to select the ideal material for the composite Chaff Cutter Machine. The goal of this study is to assist designers in evaluating various materials and selecting the optimal one using AHP.

2. A Chaff Cutter with a Variety of Bases

Composite materials are now being used more widely by Chaff Cutter Machine. Chaff Cutter Machine is facing increasing market demand to manufacture goods of high quality more quickly and inexpensively. The right material must be chosen carefully for the Chaff Cutter Machine. Chaff Cutter Recently, the use of composites has drawn a lot of attention to machines like the chaff cutter. According to common understanding, the chaff cutter machine is made up of the four basic chaff cut components seen in Fig. 2. One of the most important components of the chaff cutter machine is the cutter. So it's important to pick the right material for the Chaff Cutter Machine.

Figure 1 Straight Rectangular Chaff Cutter Blade and Chaff Cutter Blades

3. Considerations for selecting a composite chaff cutter machine's materials

The following factors need to be taken into account while selecting the best material for the composite chaff cutter blades.

1. Angle:

Two rays that have a common endpoint and are referred to as the angle's sides and vertices, respectively, form an angle.

2. Deformation:

a body's size or shape changing as a result of stress; strain.

3. Von mises stresses:

The von Mises stress is used to predict the yielding of materials under complex loads using the results of uniaxial tensile tests. The von Mises stress satisfies the requirement that two stress states with identical distortion energy have equal von Mises stresses.

4. Thickness:

the smallest of an object's three dimensions (length, breadth, and thickness); a measurement of the distance between two surfaces of an object.

4. Methodology

4.1 AHP procedures for concept selection

AHP was developed by to help people define priorities and get the optimal decisions. It is a powerful and flexible weighted scoring decision-making approach. When both qualitative and quantitative variables must be considered before making a decision. AHP is based on three fundamental principles: decomposition, comparative evaluation, and priority synthesis. These concepts can be clarified further by arranging them into a more extensive nine-step process, as shown in Fig. 3.

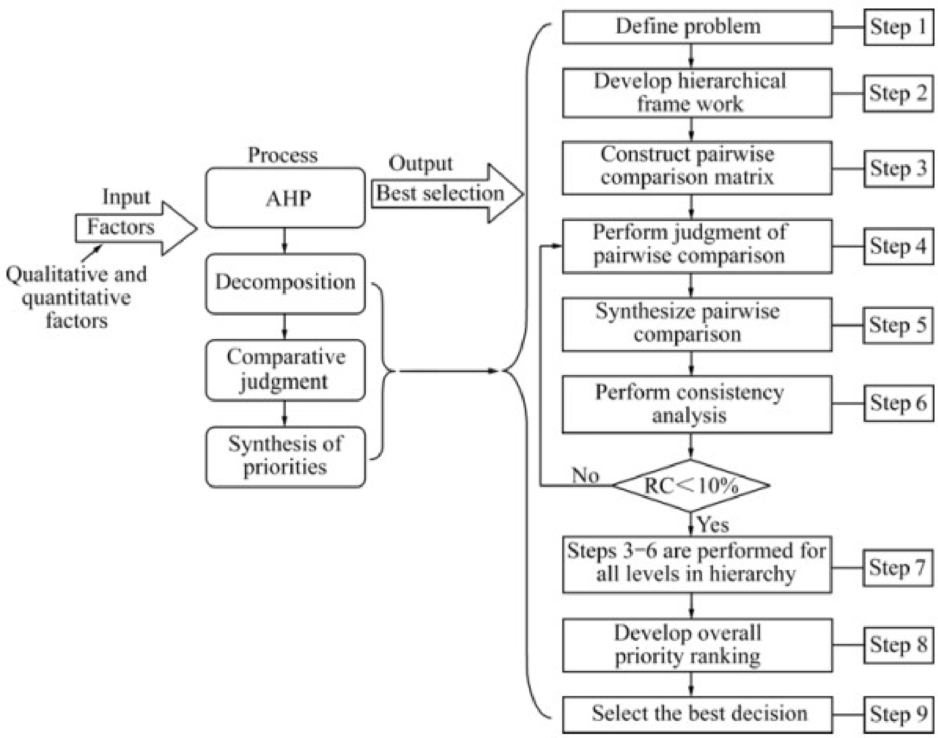

Figure 2 illustrates how the AHP principle works.

Step 1 is to determine the problem. The initial step in using AHP is identifying the issue and determining its function. In order to make informed decisions, decision-makers must clearly state the problem and any variables or criteria that will affect the selection process. According to them, the method's most original and crucial part is the identification of the factors that have an impact on the selecting process.

Next, create a hierarchical framework. Creating a hierarchy of options is the most important step in the decision-making process. Therefore, after determining the issue, purpose, criteria, sub-criteria, and available options, decision-makers must organise a complicated problem in a hierarchical framework or model, as shown in Fig. 4. They must also consider the connections between the overarching objective, the criteria, the sub-criteria, and the options.

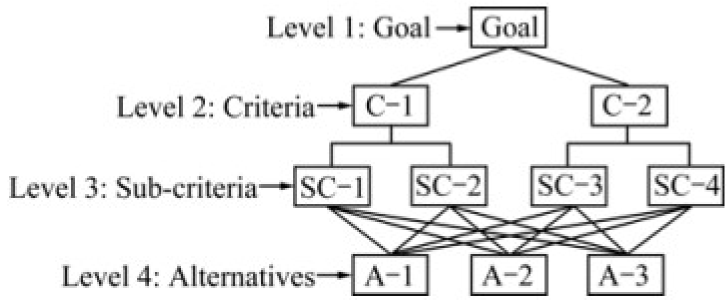

Figure 3 A hierarchy with four levels

The four tiers described below make up the hierarchy's overall structure.

Aim at Level 1. The decision's purpose or main goal is stated at level 1, which is the top of the hierarchy. For example, selecting the best material for a composite vehicle bumper beam, the objective represents the problem that needs to be solved.

(2) Level 2 criteria. At level 2 (level 2), the main criteria or crucial components that significantly influence the selection process are represented. The criteria used by the decision-makers are based on the kinds of challenges that contribute to the goal's achievement.

(3) Level 3 level sub-criteria. Because the sub-criteria are at level 3 of the hierarchy, the AHP model can be more accurate. By including sub-criteria or more specific issue criteria, the selection process can be carried out more accurately to determine the best option.

Level 4: Choices for decision-making. The choice alternatives or possibilities are shown at level 4, the bottom of the hierarchy.

Step 3: Establish a matrix for pairwise comparisons. One of AHP's primary advantages for finding precise ratio scale priority is pairwise comparison.

The pairwise comparisons form a significant part of the AHP technique. The next step is to use one matrix from the level above to create a pairwise comparison matrix (size nn) for the lower levels. The pairwise comparisons produce a matrix of relative ranks for each level of the hierarchy. The total number of elements at each level determines the overall number of matrices. The rank of the matrix at each level is determined by how many items at the lower level each element is related to.

Step 4: Analyse the pairwise comparison's findings. The initial stage in a pairwise comparison is to compare the relative importance of two things. The collection of matrices in step 3 must be created using n(n1) judgements. As shown in Table 1, the decision-makers must assess each component using a pairwise comparison relative scale. The decision makers' or users' experience and expertise are used to form their conclusions. Because of the AHP comparison scale, the decision-maker is able to innately incorporate experience and information. For example, if C1 is significantly more significant than C3 (Table 2), then an a=5 is required to do a pairwise comparison.Reciprocals are automatically provided for each pairwise comparison.

Step 5: Write an overview of pairwise comparisons.In hierarchical synthesis, the eigenvector entries are weighted using the criterion weights, and the total is used to determine the overall weighted eigenvector entries, which correspond to the eigenvector entries at the next lower level of the hierarchy. To determine eigenvectors or vectors of priority, one method that can be utilised is the average of normalised column (ANC) method. The components or scale points of each column in ANC 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 calculates the average of the normalised columns. The mathematical construction of the eigenvector or vector of priority is

$$W = \frac{1}{q}\sum_{h=1}^{i}\frac{H_{ij}}{\sum H_{ij}} \quad (1)$$

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

Step 6: Conduct a consistency analysis. Since the comparisons are based on individual or subjective judgements, some degree of inconsistency may appear. In order to ensure that the judgements are accurate, the consistency ratio is computed, which is regarded as one of the key advantages of the AHP. The consistency is assessed using the consistency ratio (CR), which compares the consistency index (CI) to the random index (RI) for matrices of the same order. To calculate CR, three steps must be completed.

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

CI=(λmax-m)/(m-1) (3)

CR=CI/RI (4)

Step 7: Repetition of steps 3 through 6. Each level of the hierarchy goes through steps three through six.

Step 8: Create a rating to arrange the priority. To choose the best alternate layout, a broad priority is established. The best design concept must be chosen when all tiers' consistency calculations are finished. In order to take this into account, the overall priority vector needs to be further computed.

In Step 9, pick the best choice. Choose the finest choice while keeping in mind the results of step 8.

4.2 TOPSIS Method

Among the MADM approaches, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is another technique. Ching-Lai Hwang and Yoon created this technique in 1981. This strategy is a way to choose a different course of action in a multi-objective setting that comes the closest to the ideal solution and the furthest from the unfavourable ideal option. Calculate the separation measures of each alternative after the data have been normalised and the weights have been calculated. Rank and relative closeness are then evaluated. There are numerous examples and thorough formulas for calculating performance online. This strategy has the benefit of being simple to use regardless of the magnitude of the challenge. Engineering, management, business, and marketing domains have all used TOPSIS successfully.

5. Results and Discussion

The actions listed in Section 1 are used to deploy MADM methodologies. The next step is to create a normalized table based on beneficiary and non-beneficiary factors after creating the decision table 1. The weights were summarized in Table after being calculated using the AHP method. . Table 1 shows that all of the materials have significantly different angle values, which result in greater weights, but Von Mises stresses, Deformation, and Thickness have extremely low

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weightage factors. These results are consistent with the decision table materials' nearly identical performance behavior. It is also clear that these characteristics have little impact on the choice of the best material.

Table 1 lists the qualities' AHP weights.

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

Table 2 Matrix comparisons for each material on a pair-wise basis.

	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

5.1 TOPSIS Method

The normalised matrix and weight matrix are used to generate the normal decision matrix Rij and the weighted normalised matrix Vij. The ideal best and worst solutions, as well as the separation measures for each alternate, are calculated from the weighted normalised matrix and are displayed in Table 3 below. Each material's performance scores were calculated and are displayed in Fig. 4. According to TOPSIS, the order of preference for the selection of materials in panel application is 1-3-2, as can be seen from Fig. 4 where A1 has the highest performance score compared to the other materials.

CRITERIA	V +	V -	V	Rank
A 1	0.054452	0.089205	0.620961	1
A 2	0.091359	0.08185	0.472551	3
A 3	0.08185	0.091359	0.527449	2

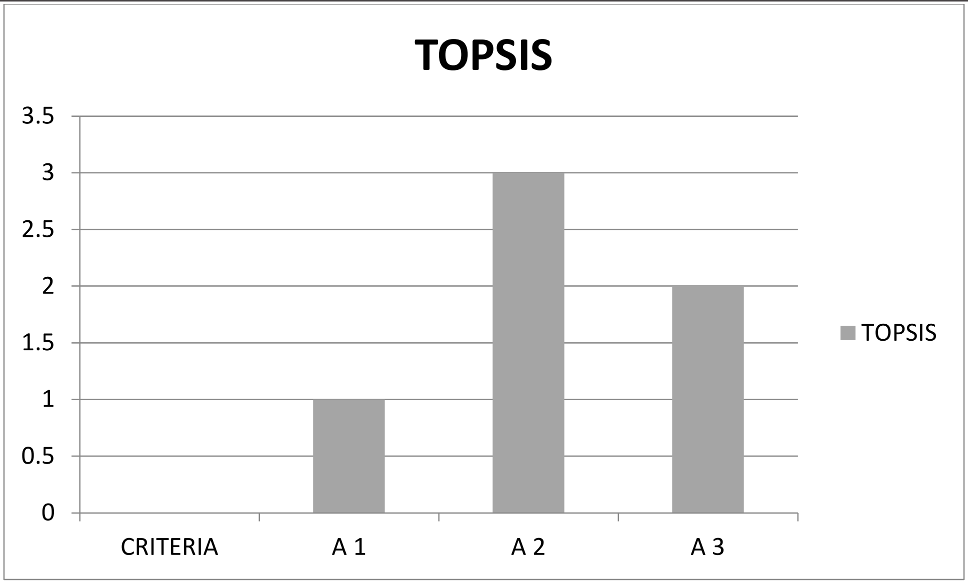

Figure 4 shows the performance ratings for each material using TOPSIS.

6. Conclusion

High carbon steel is thought to be the finest alternative to steel in terms of weight reduction measures for the automobile sector. Since there are numerous High carbon steel used for the same purpose, replacing them with an alloy that meets all functional requirements is a difficult undertaking. In the current study, three distinct types of steel with seven properties are taken into account. The selection brake pad application process for the class of MADM methods like AHP and TOPSIS is described in detail and effectively carried out. The material A1 condition is the best alternative, according to the findings. The same material was recommended by both systems as the best option for this specific situation, even though AHP and TOPSIS differ in their respective methods. The current method attempts to locate the best material in a logical way, however more research must be done before the suggested material may really be used in the relevant field.

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