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CRITICAL PROPERTY ASSESSMENT OF NOVEL BRAKE PAD MATERIALS BY AHP

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ABSTRACT

Asbestos, which is used as brake pad material, is harmful to human health and that is why researchers are trying to find appropriate replacement. The improvement of brake pad performance needs considerable effort including broad research in testing and evaluation of thermal, mechanical, tribological and metallurgical properties of novel materials. Selection of a novel organic brake pad material that meets all properties becomes a complex task. In this paper, attempts have been made to evaluate most criticality property of a novel brake pad material choice for a braking task by utilizing Analytic Hierarchy Process (AHP). In total nine properties of brake pad materials such as Thermal Conductivity (TC), Friction Coefficient (FC), Wear Rate (WR), Specific Gravity (SG), Compressive Strength (CS), Hardness (H), Thickness Swell in Water -TS(W), Thickness Swell in Oil -TS(O) and Flame Resistance (FR) were considered for their comparison. Ranking of the properties from most significant to less critical was analyses by AHP. It was found from the study that wear rate; thermal conductivity and friction coefficient prove to be the most crucial properties for the selection of brake pad material. However, specific gravity, compressive strength and hardness are of equal importance. This work will further contribute in development of asbestos-free eco-friendly composite friction materials for the production of automotive brake pad with an objective of high longevity.

Keywords: *AHP, Brake Pad Materials, Natural Composites.*

1. Introduction

The utilization asbestos friction material is being banned because of its cacogenic nature that may cause various health risks. The gases originated from asbestos constituent brake pad are also harmful to human being [1-2]. A lot of researches have been carried out in the development of asbestos-free organic brake pads using coconut shell [3], palm kernel shell (PKS)[4], periwinkles shell [5], maize husks [6], their property evaluation and test rigs [7]. Determination of a proper brake pad for a specific assignment relies upon various assorted criteria or characteristics. In view of item depiction, process qualities, working necessities brake pad producer can recommend brake pad that meets the clients' prerequisites. Presently a day's verity of non-metallic, composites and common composites materials have been attempted as brake pad materials. The improvement of brake pad performance needs significant effort, including broad lab testing and evaluation of thermal, mechanical, tribological, tribo-mechanical and metallurgical properties of novel materials. Despite the fact that, which property needs more weight-age for a particular braking task is required to evaluate fundamentally. In this paper, attempts have been made to evaluate most critical property of novel brake pad materials by Analytic Hierarchy Process (AHP).

The subjective importance of characteristics was patterned utilizing Analytical Hierarchy Process (AHP). It is a multi-criteria alternative approach and gave a powerful method for appropriately evaluating the applicable information, utilizing a couple insightful examinations between the parameters. The match perceptive correlations are utilized to acquire weighted of significance as a reason for choice material. AHP empowers chief to build up a various leveled structure for the characteristics which are express in the given issue and to give judgment about the relative significance of every one of these properties determine an inclination for every choice option as for each attribute, giving an organized positioning request of inclination for selection [8-12].

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2. Critical Property Assessment

Analytical Hierarchy Process (AHP) presented by Saaty [8], and subsequently used by [9-11], modified fuzzy based AHP is a multi-criteria choice approach utilizing a pair-wise correlation between the parameters.

2.1 Problem Modeling

The braking operations are performed at various conditions while driving vehicles. In these operations high temperature is generated at the brake pad-disk interface, causing shape changes and work hardening in the material; consequently affecting on its performance [12]. Under braking operation of brake pad working conditions, amount of friction and wear need to be considered for the use of appropriate brake pad material. Also in recent years, concern about the environment, health and safety have led to the enactment and enforcement of number of laws and regulations. Based on expert's opinion and with results of past works by other authors [1-7], some of the properties of brake pad materials inter-compared with each other. In total nine properties of brake pad materials such as Thermal Conductivity (TC), Friction Coefficient (FC), Wear Rate (WR), Specific Gravity (SG), Compressive Strength (CS), Hardness (H), Thickness Swell in Water -TS(W), Thickness Swell in Oil -TS(O) and Flame Resistance (FR) were considered for their comparison.

2.2 Pair-wise Comparison

Psychologists argue that, it is easier and more accurate to express one's opinion on only two alternatives than simultaneously on all the alternatives. Initial matrix is formulated by observing the scale for relative importance by Saaty [8] as shown in Table 1.

Table 1: Saaty's pair-wise comparison Scale

Strength of Importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong
8	Very, very strong
9	Extreme importance

Expecting a factor (i.e. criteria) the combine insightful examination of variables i with factor j yields a square framework [A1]NxN, where rij signifies the relative significance of factor i as for factor j. In the grid rij=1 when i=j and rji = 1/rij.

Based on the expert's opinion and with results of past works by other authors [1-7], a pair-wise comparison matrix [A_1] is prepared as shown below.

Matrix [A_1] Pair-wise Comparison

	TS(O)	WR	FR	TC	FC	SG	TS(W)	CS	H
TS(O)	1	1/9	1/5	1/5	2	2	2	2	2
WR	9	1	2	9	9	9	9	9	9
FR	5	1/2	1	2	9	9	9	9	9
TC	5	1/9	1/2	1	9	9	2	9	9
FC	1/2	1/9	1/9	1/9	1	1/2	1/2	1/2	1/2
SG	1/2	1/9	1/9	1/9	2	1	1/2	1/2	1/2
TS(W)	1/2	1/9	1/9	1/2	2	2	1	2	2
CS	1/2	1/9	1/9	1/9	2	2	1/2	1	1/2
H	1/2	1/9	1/9	1/9	2	2	1/2	2	1

2.3 Relative normalize weight

In order to find out the relative normalized weight (Wi) of each factor, the geometric mean of the ith row was calculated using equation (1) and normalization of the geometric means of rows in the comparison matrix was done.

$$GM_{\mathrm{i}} = \left\{ \prod_{j=1}^{N} r_{ij} \right\}^{1/N} \text{------------------------} \quad (1)$$

	TS(O)	WR	FR	TC	FC	SG	TS(W)	CS	H
TS(O)	1	0.11	0.20	0.20	2	2	2	2	2
WR	9	1	2	9	9	9	9	9	9
FR	5	0.50	1	2	9	9	9	9	9
TC	5	0.11	0.50	1	9	9	2	9	9
FC	0.50	0.11	0.11	0.11	1	0.50	0.50	0.50	0.50
SG	0.50	0.11	0.11	0.11	2	1	0.50	0.50	0.50
TS(W)	0.50	0.11	0.11	0.50	2	2	1	2	2
CS	0.50	0.11	0.11	0.11	2	2	0.50	1	0.50
H	0.50	0.11	0.11	0.11	2	2	0.50	2	1

$$GMi = \begin{bmatrix} GM_i \\ 0.80 \\ 5.95 \\ 4.04 \\ 2.48 \\ 0.32 \\ 0.38 \\ 0.71 \\ 0.44 \\ 0.51 \end{bmatrix}$$

and, matrix $[A_2]$ is,

$$W_i = \frac{GM_i}{\sum_{i=1}^{N} GM_i} \text{ ---------------------(2)}$$

$$[A_2] = [0.05 \quad 0.38 \quad 0.25 \quad 0.15 \quad 0.02 \quad 0.02 \quad 0.04 \quad 0.02 \quad 0.03]^T$$

2.4 Calculate Matrix A_3 and A_4

such that $A_3 = A_1 \times A_2$ & $A_4 = A_3 / A_2$ Hence, matrix A_3 and matrix A_4 are as follows,

$$[A_3] = \begin{bmatrix} 0.48 \\ 4.15 \\ 2.39 \\ 1.63 \\ 0.19 \\ 0.23 \\ 0.43 \\ 0.27 \\ 0.31 \end{bmatrix} \qquad [A_4] = \begin{bmatrix} 9.36 \\ 10.92 \\ 9.25 \\ 10.32 \\ 9.59 \\ 9.58 \\ 9.51 \\ 9.57 \\ 9.56 \end{bmatrix}$$

2.5 Find Out the Max Eigen Value

Which is the average of matrix A_4. Hence, λavg= 10.92

2.6 Consistency Index (CI)

CI= [(λmax - N)/(N-1)] ---------------------- (2)

CI= 0.0929

2.7 Random Index (RI)

For the number of factors used in decision-making. Random Index (RI) or correction for random error is denoted by RI and their values for different values of attributes (N) are given by Saaty [8] as follows:

Table 2: Random Index Values for Different Values of N

N	3	4	5	6	7	8	9	10
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Hence the value of Random Index (RI) for nine attributes is 1.45 i.e. RI=1.45.

2.8 Consistency Ratio (CR)

Consistency Ratio (CR), which is the ratio of the Consistency Index to the Random Index, is calculated.

CR = CI/RI ---------------------------------- (3)

CR = 0.0929/1.45 = 0.064

This ratio is CR = 0.064 which is less than allowed CR of 0.1 and hence the results are very much acceptable. Thus, there is a good consistency in choices of weight-ages made while preparing the initial matrix. Table 3 shows the ranking of the critical property in brake pad material selection on the basis of critical assessment are represented graphically in Fig. 2

Table 3: Ranking of Critical Property in Brake Pad Material

	Critical Parameter	Relative Worth
WR	Wear Rate	10.92
TC	Thermal conductivity	10.32
FC	Friction Coefficient	9.59
SG	Specific Gravity	9.58
CS	Compressive Strength	9.57
H	Hardness	9.56
TS(W)	Thickness Swell in Water	9.51
TS(O)	Thickness Swell in Oil	9.36
FR	Flame Resistance	9.25

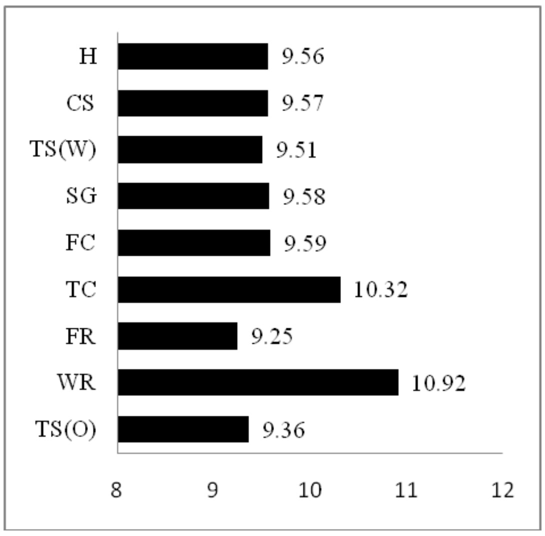

Fig. 2 : Rankings of Brake Pad Material Properties

3. Conclusions

The broad utilization of AHP is significant because of its simplicity and structure. In total nine properties of brake pad materials were considered for their comparison. Ranking of the properties for performance point of view was analyzed by AHP. It was found that Wear Rate (WR) and Thermal Conductivity (TC) are the most vital properties followed by Friction Coefficient (FC). However, specific gravity, compressive strength, and hardness are of equal importance. The thickness swell in oil and water are of less importance while developing a material for the brake pad. This work may contribute to the development of asbestos-free eco-friendly composite friction materials for the production of automotive brake pads with an objective of high longevity. The relative worth of the cost factor is less as compare to the above properties because the use of proper brake pad materials can increase its durability.

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