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MATERIALS SELECTION FOR BRAKING SYSTEM IN GO-KARTING AUTOMOBILES

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ABSTRACT: Braking system is an integral part of automobile mechanism. For certain unique automobiles like Go-Kart systems, the braking system must be designed with accurate and material importance. This is done to keep in accordance with various parameters such as economy and weight of the automobiles etc. The braking systems have to provide enough force in order to decelerate by completely locking the wheels. The report concentrates on explaining the engineering aspects of designing a braking system and its material for Go-Kart. This report explains objectiveness, assumptions and calculations made in designing a Go-Kart braking system. A comparative study for the braking system made of grey cast iron (i.e. Conventional material), Ti-alloy, 7.5 wt% WC and 7.5wt% TiC reinforced Ti-composite and 20% SiC reinforced Al-Cu alloy (AMC1) and 30% SiC reinforced Al-Cu alloy (AMC2) was done. The purpose of this project was to analyze the test results and implement a better perspective for the installation of braking system in a Go-Kart automobile mechanism. The test parameters considered are compressive strength, coefficient of friction, wear rate, specific heat, specific gravity etc. which are believed to be the most important parameters for the operation of a braking system.

KEYWORDS: *Braking System, Digital Logic Method, Aluminum Silicon Carbide, Metal Matrix Composites(MMC).*

1. INTRODUCTION:

The brake system is the most important system in vehicles. It converts the kinetic energy of the moving vehicle into thermal energy while stopping. The basic functions of a brake system are to slow the speed of the vehicle, to maintain its speed during downhill operation, and to hold the vehicle stationary after it has come to a complete stop. The brake system is composed of master cylinder, brake lines, wheel cylinders or slave cylinders, shoes or pads, drum or disc and brake fluid the master cylinder is located under the hood and it is directly connected to the pedal. It converts the foot's mechanical pressure into hydraulic pressure.

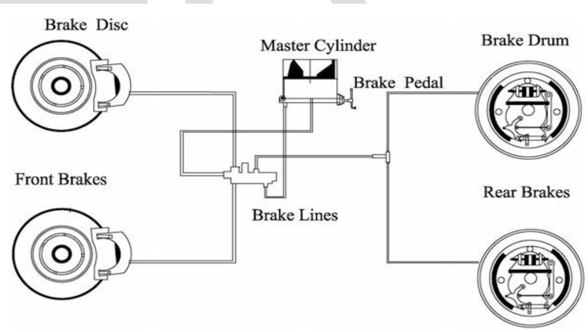

Figure 1 Automotive brake system

A master cylinder has two complete separate cylinders in one housing, each handling two wheels. Even if one cylinder fails, the other cylinder will stop the vehicle. The brake fluid travels from the master cylinder to the wheels through a series of steel tubes. It uses non-corrosive seamless steel tubing with special fittings at all attachment points. Wheel cylinders are cylinders in which the movable pistons convert the hydraulic pressure of the brake fluid into mechanical force. It consists of a cylinder that has two pistons, one on each side. Each piston has a rubber seal and a shaft that connect the piston with a brake shoe.

The wheel cylinders of the brake drum are made up of a cylindrical casting, an internal compression spring, two pistons, two rubber cups or seals, and two rubber boots to prevent the entry of dirt and water. The wheel cylinders are fitted with push rods that extent from the outer side of each piston through a rubber boots, where they bear against the brake shoes. Hydraulic pressure forces the pistons in the wheel cylinder which forces the brake shoes or pads against the machined surface of the brake drums or rotors. When the brake pedal is depressed, it moves the pistons within the master cylinder, pressurizing the brake fluid in the brake lines and slave cylinders at each wheel.

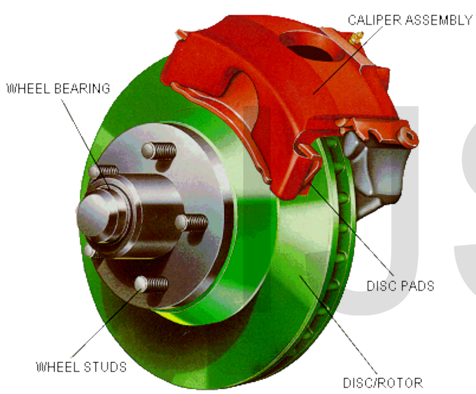

Figure2 Cross Sectional View of Brake Rotor

The fluid pressure causes the wheel cylinders pistons to move, which forces the shoes against the brake drums. Brake drums use return springs to pull the pistons back away from the drum when the pressure is released. The brake shoes consist of a steel shoe with the friction material or lining materials are riveted or bonded to it. The lining materials are either asbestos (organic), semi-metallic, or asbestos free materials. The lining material consists of fibers, fillers, binders and friction modifiers. The brake drums are made up of cast iron and have a machined surface inside the drum where the shoes make contact. The brake drums will show the signs of wear as the lining seats themselves against the machined surface of the brake drum.When new drums are installed, the brake drum should be machined smooth. The brake fluid is special oil that has specific properties. It is designed to withstand cold temperatures without thickening as well as very high temperatures without boiling.

2. PROBLEM DEFINITION:

The brake system is the most important system in vehicles. It converts the kinetic energy of the moving vehicle into thermal energy while stopping. The basic functions of a brake system are to slow the speed of the vehicle, to maintain its speed during downhill operation, and to hold the vehicle stationary after it has come to a complete stop. The brake system is composed of master cylinder, brake lines, wheel cylinders or slave cylinders, shoes or pads, drum or disc and brake fluid the master cylinder is located under the hood and it is directly connected to the pedal. It converts the foot's mechanical pressure into hydraulic pressure. A master cylinder has two complete separate cylinders in one housing, each handling two wheels. Even if one cylinder fails, the other cylinder will stop the vehicle. The brake fluid travels from the master cylinder to the wheels through a series of steel tubes. It uses non-corrosive seamless steel tubing with special fittings at all attachment points. Wheel cylinders are cylinders in which the movable pistons convert the hydraulic pressure of the brake fluid into mechanical force.It consists of a cylinder that has two pistons, one on each side. Each piston has a rubber seal and a shaft that connect the piston with a brake shoe. The wheel cylinders of the brake disc are made up of a cylindrical casting, an internal compression spring, two pistons, two rubber cups or seals, and two rubber boots to prevent the entry of dirt and water. The wheel cylinders are fitted with push rods that extent from the outer side of each piston through a rubber boots, where they bear against the brake shoes. Hydraulic pressure forces the pistons in the wheel cylinder which forces the brake shoes or pads against the machined surface of the brake discs or rotors. When the brake pedal is depressed, it moves the pistons within the master cylinder, pressurizing the brake fluid in the brake lines and slave cylinders at each wheel. The fluid pressure causes the wheel cylinders pistons to move, which forces the shoes against the brake discs. Brake discs use return springs to pull the pistons back away from the drum when the pressure is released. The brake shoes consist of a steel shoe with the friction material or lining materials are riveted or bonded to it. The lining materials are either asbestos (organic), semi-metallic, or asbestos free materials. The lining material consists of fibers, fillers, binders and friction modifiers. The brake discs are made up of cast iron and have a machined surface inside the drum where the shoes make contact. The brake discs will show the signs of wear as the lining seats themselves against the machined surface of the brake disc.

DISADVANTAGES OF THE EXISTING SYSTEM:

Three major problems exist with this aluminum-composite rotor. First, because of the density difference between aluminum and SiC, segregation or inhomogeneous distribution of SiC particles during solidification cannot be avoided. Also, adding SiC particles in an aluminum matrix dramatically reduces the ductility of the material, resulting in low product liability. The third problem is a lack of a solid lubricant, such as graphite. The lack of graphite in the system results in low braking efficiency, adhesive wear, and galling. In a cast iron rotor, graphite is always present in the iron. As the break wears, the graphite is freed from the iron matrix to be used as a solid lubricant on the wear surface.

3. PROPOSED METHODOLOGY:

PART 1: DIGITAL LOGIC METHOD

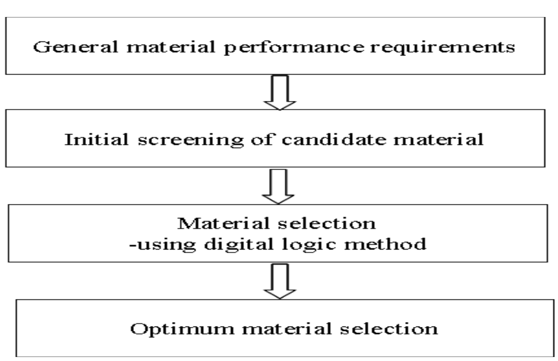

Figure3.Algorithm of This Method

4. MATERIAL SELECTION USING DIGITAL LOGIC (DL) METHOD:

The digital logic method can be employed for the optimum material selection using with ranking. As a first step, the property requirements for a brake rotor were determined based on previous discussion. The properties and the total number of decisions, i.e. $N (N - 1)/2 = 10$ are given in Table 4.1. The weighting factor for each property, which is indicative of the importance of one property as compared to others, was obtained by dividing the numbers of positive decisions given to each property by the total number of decisions. The total positive decisions for each property and corresponding weighting factor were calculated and are presented in Table 4.2. From Table 4.2, it can be seen that friction coefficient and wear resistance have the highest weighting factors followed by thermal capacity, whereas the least important properties are compressive strength and specific gravity hence, obtained lower weighting factor.

	Decision numbers									
	1	2	3	4	5	6	7	8	9	10
Compressive strength	0	0	0	1						
Friction coefficient	1				1	0	1			
Wear rate		1			0			1	1	
Thermal capacity			1			1		0		0
Specific gravity				0			0		0	1

Table 4.1 Application of digital logic method to material selection for brake

Property	Positive decisions	Weighting factor (α)
Compressive strength	1	0.1
Friction coefficient	3	0.3

Wear rate	3	0.3
Thermal capacity	2	0.2
Specific gravity	1	0.1
Total	10	1.0

Table 4.2 Weighting factors for brake

In order to complete the DL method, the next step is to scale the properties of the materials based on their respective weighting factor and the scale value is shown in Table 4.2. For the present application, materials with higher compressive strength, friction coefficient and thermal capacity are more desirable and highest value is rated as 100. Their scaled values are calculated using the following equation (1).

$$\text{Scaled property} = \frac{\text{Numerical value of property} \times 100}{\text{Maximum value in the list}} \dots (1)$$

Since lower wear rate and specific gravity are desirable for the automotive brake disc, therefore, their lowest value is considered as 100 and scaled values are calculated using equation (2).

$$\text{Scaled property} = \frac{\text{Minimum value in the list} \times 100}{\text{Numerical value of property}} \dots (2)$$

Other values in Table 4.4 are rated in proportion. The scaled values and performance index (γ) are given in Table 4.5 which was calculated using equation below:

$$\text{Scaled property} = \frac{\text{Minimum value in the list} \times 100}{\text{Numerical value of property}} \dots (3)$$

$$\text{Material performance index, } \gamma = \sum_{i=1}^{n} \beta\, i\, \alpha\, i$$

Where β is the scaled property, α is the weighting factor and i is summed over all the n relevant properties.

	1	2	3	4	5
Properties materials	**Compressive strength**	**Friction coefficient**	**Wear rate**	**Thermal capacity**	**Specific gravity**
GCI	**1293**	**0.41**	**2.36**	**0.46**	**7.2**
Ti-6AL-4V	**1070**	**0.34**	**246.3**	**0.58**	**4.42**
TMC	**1300**	**0.31**	**8.19**	**0.51**	**4.68**
AMC 1	**406**	**0.35**	**3.25**	**0.98**	**2.7**
AMC 2	**701**	**0.44**	**2.91**	**0.92**	**2.8**

Table 4.3 Resultant table for all the parameters

Now our project main objective comes into picture AMC 3 will be compared with all above five earlier braking material:

Name of material	**compressive strength**	**Friction coefficient**	**Wear rate**	**Specific heat**	**Specific gravity**
AMC 3	**1195 MPa**	**0.38**	**2.67 (*10^{-6} mm^3/ N/m)**	**0.88 (KJ/Kg-k)**	**3.01(Mg/m^3)**

Table 4.4 Final details of AMC3

Scaled Properties						
	1	**2**	**3**	**4**	**5**	**PERFORMANCE INDEX (γ)**
GCI	99	93	100	47	38	81.0
Ti-6AL-4V	82	77	0.96	59	61	49.5
TMC	100	70	29	62	58	56.0
AMC 1	31	80	73	100	100	79.0
AMC 2	59	100	81	94	96	88.6

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AMC 3	91.92	86.36	88.38	89.79	89.70	89.2

Table 4.5 Scaled value of properties of each material and corresponding performance index

The performance index showed that the technical capability of the material without regard to the cost. However, if there are a large number of properties to be considered, the importance of cost may be emphasized by considering it separately as a modifier to the material performance index (γ). It is also important to consider the cost of material before making any final design or ranking. Therefore, in this study, the figure of merit (FOM) M is calculated before ranking using the equation (4):

$M = \gamma / C_{P*}$density of material ………… (4)

where C_P=Total cost of the material per unit weight

MATERIAL	RELATIVE COST	PERFORMANCE INDEX (Γ)	FIGURE OF MERIT	RANK
GCI	1	81.0	11.25	3
Ti-6AL-4V	20	49.5	0.56	6
TMC	20.5	56.0	0.58	5
AMC 1	2.7	79.0	10.84	4
AMC 2	2.6	88.6	12.17	2
AMC 3	2.6	89.2	11.39	1

Table 4.6 Cost and Figure of Candidate Material

5. CONCLUSION:

The material selection methods for the design and application of automotive brake disc are developed. Functions properties of the brake discs or rotors were considered for the initial screening of the candidate materials using Ashby's materials selection chart. The digital logic method showed the highest performance index for AMC 3 material and identified as an optimum material among the candidate materials for brake disc.In the digital logic method, the friction coefficient and density were considered twice for determining the performance index and the cost of unit property. This procedure could have overemphasized their effects on the final selection. This could be justifiable in this case as higher friction coefficient and lower density are advantageous from the technical and economical point of view for this type of application. Several confronts must be surmounted in order to strengthen the engineering usage of AMC 3 or AMC's such as processing methodology, influence of reinforcement, effect of reinforcement on the mechanical properties and its corresponding applications. The major conclusions derived from the prior works are

- SiC reinforced with Al and Cu MMCs have higher wear resistance than other MMCs.
- SiC reinforced with Al and Cu MMCs are suitable materials for brake materials as they have high wear resistance.
- The wear resistance of SiC reinforced with Al, Cu MMC is higher than other reinforced MMC.
- AMC 3 exhibits high thermal conductivity and a low thermal expansion co-efficient.
- The wear resistance and compressive strength of AMC 3 is high.

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