BRAKING SYSTEM FOR AN ALL TERRAIN VEHICLE

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ABSTRACT

The main objective of this paper is to explain the basic considerations which are included in the designing of the braking subsystem. Even though there are numerous mechanisms for actuating brakes pneumatically actuated disc brakes have been used for both front and rear. The entire description of terms, assumptions, cost analysis, graphs and related design pictures have been included in this paper.

Key words: Braking system; All terrain vehicle; Brakes; ATV.


1. INTRODUCTION

The main function of the braking system is Decelerate the vehicle according to our desire. The principle involved in braking is kinetic energy is converted into heat energy with the help of frictional force. The brakes in an automobile can be classified into 2 types [1]

- According to the actuating medium
- According to the application of force

1) According to the actuating medium: The brakes for vehicle can be actuated by many ways using different mediums but the most common ones are listed below:

   i) Mechanical : The brakes are actuated by means of man power.
   ii) Hydraulic : In this special liquids (eg., DOT Fluid) are used to engage the brakes.
   iii) Pnuematic : Compressed air is used to apply the brakes.
iv) Electrical: The vehicle is decelerated by means of electricity.

v) Vacuum: Vacuum is used in order to apply the brakes.

Of all the mentioned above actuating mediums hydraulic is quite popularly used in automobiles.

2) According to the application of force: In order to decelerate or stop the vehicle which is decelerate the vehicle can be applied in 2 directions:
   - Axial
   - Radial

i) Axial: The word axial is indicates that the force in order to stop the vehicle is applied axially to the wheels. eg: Disc brakes.
ii) Radial: The word radial is indicates that the force in order to stop the vehicle is applied radially to the wheels. eg: Drum brakes.

2. METHODOLOGY

2.1. Benchmarking

In the benchmarking all the OEM (original equipment manufacturer) products are compared with respect to one another. This comparison is made in different criteria that include Technical specifications, cost and availability.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Rotor Diameter(mm)</th>
<th>DER(mm)</th>
<th>Type</th>
<th>Cost(Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>60</td>
<td>DRILLED</td>
<td>460/-</td>
</tr>
<tr>
<td>2</td>
<td>180</td>
<td>75</td>
<td>DRILLED</td>
<td>750/-</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>80</td>
<td>DRILLED</td>
<td>850/-</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>85</td>
<td>DRILLED</td>
<td>1000/-</td>
</tr>
</tbody>
</table>

DER:- Disc Effective Radius
Braking System for an All Terrain Vehicle

Table 2 For Brake Fluids

<table>
<thead>
<tr>
<th>S.No</th>
<th>Brake Fluid</th>
<th>Dry Bp (Deg c)</th>
<th>Wet Bp(Deg c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DOT-3</td>
<td>205</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>DOT-4</td>
<td>230</td>
<td>155</td>
</tr>
<tr>
<td>3</td>
<td>DOT-5.1</td>
<td>200</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>DOT-5</td>
<td>200</td>
<td>180</td>
</tr>
</tbody>
</table>

In brake fluids DOT-3 is more available and less cost than other brake fluids.

Table 3 For Master Cylinder

<table>
<thead>
<tr>
<th>S.No</th>
<th>Master cylinder Diameter(cm)</th>
<th>Type</th>
<th>Cost(INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>SP</td>
<td>550/-</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>DP</td>
<td>850-1050/-</td>
</tr>
<tr>
<td>3</td>
<td>3-4.5</td>
<td>DP</td>
<td>1800-5000/-</td>
</tr>
</tbody>
</table>

SP:-Single Piston Master Cylinder  DP:-Double Piston (Tandem Master Cylinder)

2.2. Calculations

The basic considerations are:
Torque at wheels at maximum speed
Total KE of vehicle
Total weight of the vehicle including person
Through the considerations we need to find the following:
Braking torque and braking force distribution for effective braking.
Dynamic load transfer
Cog position
Weight distribution
Stopping distance VS speed graph

2.3. Now Let us Calculate the Following

i. Center of gravity
ii. Braking Torque
iii. Braking Force Distribution
iv. Caliper Dimensions Abstraction
v. Stopping Dis. Vs Speed Graph

Center of gravity

COG of the vehicle is found in all 3 co-ordinates by assuming a simply supported beam with point loads on it. The vehicle is viewed from different views (i.e top, side and front views) and the COG is determined in the following way.[2]
Cog along longitudinal axis at a distance of 75.80 cm (29.84’’) from the front wheels.
Cog along lateral axis at a distance of 66.03cm (25.99’’) from the left wheels.
Cog height from the ground=54.665 cm (21.5’’)
Cog location is in the ratio of 56:43
Total weight of the vehicle including driver=293kg’s
Load distribution ratio is 42.6: 57.3
**Braking force distribution**

Without proper braking force distribution either front or rear wheel gets locked. If only front wheel locks vehicle looses its direction control. If only rear wheel locks vehicle looses its Directional stability and starts yawing. So to avoid these conditions we need to distribute the braking force such that four wheels lock together this depends on load transfer at given speed.

Total Braking force (front) \( BF_f = K_{bf} \times \text{Braking force (total at wheels)} \) (3)

Similarly total Braking force (rear) \( BF_r = K_{br} \times \text{Braking force (total)} \) (4)

Now let us calculate the their ratios and we get

\[ K_{bf} / K_{br} = (b+h (\mu+fr))/ (a-h (\mu+fr)) \] (5) [3]

Where

- \( K_{br} \) and \( K_{bf} \) are braking force coefficients.
- \( b \) = distance of cg from rear wheels longitudinally=56.27cm
- \( a \) = distance of cg from front wheels longitudinally=75.80cm
- \( h \) = height of cg from ground=54.66cm
- \( f_r \) = rolling friction coefficient=0.05

By substituting all we get ratio as 0.7

Substitute all these values in above equation we get

\[ K_{bf} = 0.7 \] and \[ K_{bf} + K_{br} =1 \]

So, \[ K_{br} = 0.3 \]

From newton’s second law of motion:

\( (\text{Braking force})BF = m \times a \)

\[ v^2-u^2 = 2as \]

\[ a = v^2/2s \]

\[ BF = mv^2/2s \] (6)

Here \( m \) = Total mass of the vehicle including driver 293 kgs

\( v \) = velocity of the vehicle 16.67 m/s²

\( s \) = stopping distance ( It is assumed that the vehicle needs to be stopped with in 3 meters)

We get Total BF= 13,570.24 N.

Now from eq(3)and eq(4)

We get \( BF_f = K_{bf} \times \text{Braking force} \)

\[ = 0.7 \times 13570.24 = 9499.168N \]

\( BF_r = K_{br} \times \text{Braking force} \)

\[ = 0.3 \times 13570.24 = 4071.073N \]

\( BF_f \) and \( BF_r \) are braking forces required to lock front two wheels and rear two wheels simultaneously.

\( BF1=BF2=BF_f/2=4749.584N. \)

\( BF3=BF_r= 4071.073N \)

From eq (2)

Total KE = \( (BF_f r1+BF_r r2) \times 0 \)

54,289 = (9499.168 x 0.08 + 4071.073 x 0.22) x 0

\( r1= \text{effective disc radius of front}=80mm \)

\( r2= \text{effective disc radius of rear}=220mm. \)

\[ \theta = 32.79 \text{ deg} \]
Caliper Piston Dimensions Abstraction (by fixing pedal ratio, master cylinder)

For front wheels
B. force (wheels) = 9499.168N
For each wheel B. force = 4749.58 N
B. force (wheel) = \( \mu \times \) B. force (disc)
B. force (disc) = \( \frac{4749.58}{0.7} \)
= 6785.12 N
B. force (disc) = 2\( \mu \times F_c \)
\( F_c = \frac{6785.12}{(2 \times 0.4)} \)
= 8481.4 N (clamping force developed at caliper)

(Suppose if caliper has two pistons then)
For each piston clamping force = 4240.5 N
Pedal ratio = 6:1 [4]
Master cylinder piston diameter \( D_1 = 1.9 \) cm
Maximum pedal force = 100 lbs = 441.45 N
Force at master cylinder push rod = \( 441.45 \times (\frac{l_1}{l_2}) \) (pedal ratio)
\( = 441.45 \times (6/1) \)
\( = 2648.7 \) N

From the Pascal’s law we have
Where
\( D_1 \) = master cylinder piston diameter
\( D_2 \) = caliper piston diameter
\( D_2^2 / D_1^2 = (F_c) / \) master cylinder push rod force
\( = \frac{(4240.5)}{2648.7} \)
\( = 1.6 \)
\( D_2/D_1 = 1.26 \)
\( D_2/1.9 = 1.26 \)
\( D_2 = 2.4 \)

With the help of the above value obtained we decided to use double piston caliper for each front wheel of each piston of diameter = 2.8 cm because it is the nearest OEM caliper piston diameter available in the market.

By substitution the above values we get B. torque at each wheel (front) = 759.9 N-m

For rear wheels
B. force (wheels) = 4071.073N
As we have opted for inboard braking the entire braking force is not distributed
B. force (wheel) = \( \mu \times \) B. force (disc)
B. force (disc) = \( \frac{4071.073}{0.6} \)
= 6785.12 N
B. force (disc) = 2\( \mu \times F_c \)
\( F_c = \frac{6785.12}{(2 \times 0.4)} \)
piston Clamping force= 8481.4N

Again from Pascal’s law we have

\[ D_2^2 = \frac{F_c \times D_1^2}{\text{push rod force}} \]

\[ = \frac{8481.4}{2648.7} \]

\[ D_2^2/D_1^2 = 3.2 \text{cm (for each piston)} \]

\[ D_2/D_1 = 1.78 \text{ cm} \]

\[ D_2/1.9 = 1.78 \]

\[ D_2=1.78 \times 1.9 = 3.38 \]

We decided to use double piston caliper for each rear wheel of piston diameter = 3.44cm (near by 3.38cm)

**Stopping Distance Vs Speed**

During the above calculations we have assumed that the stopping distance is 3 meters however it varies for different speeds. The relation between the stopping distance and speed is given by the equation

\[ BF = \frac{mv^2}{2s} \]

As we have the total braking force value now

\[ s = \frac{mv^2}{(2*BF)} \]

where

- \( m \) = mass of the vehicle including driver
- \( BF \) = braking force
- \( v \) = velocity

By substituting the values we can get the below graph:

![Graph 1 Stopping distance Vs Speed](image-url)
3. CONCLUSIONS
By using the Above calculations and knowing the advantages of disc brakes compared to drum brakes, pneumatically actuated disc brakes of below specification have been used for both front & rear of an All Terrain Vehicle.

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Part Name</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brake Pedal</td>
<td>6:1 ratio</td>
</tr>
<tr>
<td>2</td>
<td>TMC</td>
<td>Bore=1.9cm</td>
</tr>
<tr>
<td>3</td>
<td>Front side caliper</td>
<td>Bore=2.8cm</td>
</tr>
<tr>
<td>4</td>
<td>Rear caliper</td>
<td>Bore=2.0 cm</td>
</tr>
<tr>
<td>5</td>
<td>Front Rotor</td>
<td>Diameter=190mm</td>
</tr>
<tr>
<td>6</td>
<td>Rear Rotor</td>
<td>Diameter=240mm</td>
</tr>
<tr>
<td>7</td>
<td>Couples</td>
<td>4-way, 2-way</td>
</tr>
<tr>
<td>8</td>
<td>Pressure switches</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Brake fluid</td>
<td>DOT-3</td>
</tr>
<tr>
<td>10</td>
<td>Brake liners</td>
<td>1.5mts</td>
</tr>
<tr>
<td>11</td>
<td>Brake Hoses</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Brake light</td>
<td>Rectangular Type</td>
</tr>
<tr>
<td>13</td>
<td>Banjo Bolts</td>
<td>14 No. Type</td>
</tr>
<tr>
<td>14</td>
<td>Cu washers</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1** Front Disc Brake

**Figure 2** Rear Inboard Braking
REFERENCES

[1] https://me-mechanicalengineering.com/brake-system-classification/


