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DESIGN AND DEVELOPMENT OF BRAKING SYSTEM OF AN ALL-TERRAIN VEHICLE

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***Abstract*— The Study titled "Design and Development of Braking System of an All-Terrain Vehicle" is to find out the most efficient braking system for an all-terrain vehicle. For this, various parameters are considered. In the modern-day automobiles are an essential part of day-to-day life, the requirements of each person are different. Some demands for a high-performance machine while others require a comfortable ride. Today's engineering helps in achieving all the aspects of a safe, reliable and fast vehicle. With the change in time, the need for an all-terrain vehicle (ATV) has gradually increased. This research paper includes the parameters for the efficient disc, calipers, and master cylinder position for effective braking. The research focused on disc, master cylinder position. The designs provide the durability which is the primary requirement for an all-terrain vehicle. The all-terrain conditions require effective braking and all wheels locking at the instant time. This research paper also includes the optimization of braking system for minimum stopping distance and locking all four tires simultaneously. The SolidWorks struct-static analysis and simulation was carried out to obtain a better braking system which can provide the best-in-class arrangements for the customer.**

Key Words: **Brake, All-terrain vehicle, Design, Development, Analysis.**

I. INTRODUCTION

An ATV is capable of running on all the terrains e.g., muddy, rocky, gradient pavement, sand, etc. It usually consists of 4 wheels or may have more than 4 wheels with independent suspensions in front & rear wheels. An automobile, motor car or ATV is a wheeled motor vehicle used for transporting passengers, which also carries its own engine or motor. ATVs have evolved over the years. First ATV ever created was called the Jigger (pronounced as Jigger) and was invented by a Canadian named John Gower who was tired of trudging through the snow in the frozen Alberta while cutting his firewood. He wanted to create a machine to move and travel through the outdoors, whatever the terrain. The original prototype of the machine was created in year 1960 and was run by a couple of chain saw engines (one engine on each side of the machine to run that sides of tire) operating on a throttle-controlled belt and clutch system. By the time the design came out for the production, the Jigger looked like a small boat of fiberglass with six balloon tires that also acted as the suspension for the machine. This ATV was able to go 30 mph on land and 8 mph in the water, traversing any terrain and giving 10 horsepower.

II. METHODOLOGY

The Process which we followed for design and fabrication of Braking system involves these following steps:

- Analysis of Previous Year's Vehicle
- Design Validation
- Defining the Objective for New vehicle.
- Braking system parts fabrication.
- Market Survey for the Components used.
- Braking system Assembly

2.1 Analysis of Previous Year's Vehicle

Table-1: Previous Year's Braking Parameters [2]

BRAKING PARAMETERS (2019)	
Rotor size	190mmFRONT/200mm REAR
Rotor material	SS420
Rotor thickness	6mm
Calliper piston dia. and manufacturer	20mm
Master cylinder type	Tandem master cylinder
No. of master cylinder	1
Dia. of master cylinder piston and TMC length	24.95mm and 100 mm

2.2. Objective for New Vehicle
The brakes the most important safety systems on the vehicle. The car uses four-disc brakes, one on each front and rear wheel, to bring the vehicle to a quick and safe stop regardless of weather conditions or topography.
The vehicle should have two different independent hydraulic systems and it is actuated by a single brake pedal. The pedal directly actuates the master cylinder without any cable. All customized brake pipes are to be used and to mount it securely along the roll cage or along other members.

2.3. Market Survey
After doing market Surveys, following components were selected.
a) Willwood Master Cylinder (single port)
b) SS410 Material Rotors
c) stainless Steel Customized Brake Lines
d) DOT 4 Brake Fluid

Table-2: Year 2020 Braking Design Parameters

DESIGN PARAMETERS (2020)	
Rotor size	170mm front /200mm rear
Rotor material	SS410
Rotor thickness	4mm
Calliper piston dia. and manufacturer	29mm TVS
Master cylinder type	Single port master cylinder
No. of master cylinder	2
Dia. of master cylinder piston and TMC length	19.05mm and 100 mm

2.3.1 ROTORS:
Mostly the discs of brakes are made of pearlitic gray cast iron. This is because, the material has low price and good anti- wear properties. Cast steel discs have also been used in some cars, which wear still less and provide higher coefficient of friction; but the drawback in their case is the less uniform frictional behavior. [3]

Two types of discs have been employed in various makes of disc brakes, i.e., the solid or the ventilated type.
Disadvantages of ventilated type discs:
i. Usually thicker and even sometimes heavier than solid discs.
ii. In case of panic braking conditions, they are liable to wrap.
iii. Dirt accumulates in the vents, which reduce cooling, resulting in wheel imbalance.
iv. Expensive.
v. Difficult to turn. During Turning it produces vibrations which reduces the life of the disc

Customized disc was designed and manufactured for the following reasons:
1. PCD of the holes in the disc matches the PCD of the hub.
2. Thickness (4mm) of the disc is not too high. So, disc can be turned safely.
3. Outer diameter is 170 mm which is in accordance with our required front design.
4. The disc can be safely turned to 200mm which was as per rear design.

After turning, the thickness of the disc was reduced to 4mm since the clearance between the brake pads was 6mm.
NOTE: -
•After detailed study and analysis, a customized brake disc was chosen.
• It was made of Stainless Steel of grade 410.

2.3.2 CALIPER:
Fixed type caliper was used in the design. Fixed type caliper doesn't move but has piston(s) arranged on opposing sides of the rotor. Fixed caliper is preferred for their performance, but are more expensive than floating one. [4]

Table 3 Dimensions of brake caliper

S.NO	Caliper	No of piston	Arrangement of piston	Diameter of piston
1	Pulsar front	2	Single side	21
2	Tvs	2	Single side	29
3	Maruti 800	1	Single side	60
4	Pulsar	1	Single side	40
5	General calliper	2	Single side	40

2.3.3 MASTER CYLINDER:
The two system can be split front to rear, so that the front brakes operate independently from one circuit and the rear brakes from the other, or they can be split diagonally so that one front wheel is paired with the rear wheel on the opposite side in one brake circuit and vice versa in the other. When first circuit leaks, the pressure between the primary and secondary

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cylinders is lost. The primary cylinder directly contacts the secondary cylinder. The master cylinder act as if it has only one piston. The second circuit functions normally, but the driver has to press the pedal further to activate it. Only two wheels have pressure. The braking power is severely reduced. An ABS Master cylinder was not used because an ABS system was not used. It cannot be used else all the four wheels will not lock at the same time.

1. It has small piston diameter.
2. it has four outputs.
3. Easy to mount.
4. It is smaller in length so travel is less.

2.3.4 BRAKE CIRCUITS:

Cross linked hydraulic split was not used because in case of a failure one front wheel and one rear wheel would lock at the same time increasing the chances of skidding towards left to right. Diagonal split hydraulic systems are commonly selected on front wheel drive vehicles, but our vehicle is rear wheel driven. A diagonal split system requires more tubing and more connections than front rear
Split system.

2.3.5 BRAKE FLUIDS:

DOT 4 brake fluid was used. It is inexpensive, and available at almost all gas stations, department stores, and any auto parts shops.

Table 3 Brake fluid comparison [1]

	Dry Boiling Point	Wet Boiling Point	Composition
DOT 3	205°C/401°F	140°C/284°F	Glycol ether
DOT 4	230°C/446°F	155°C/311°F	Glycol ether/borate ester
DOT 5	260°C/500°F	180°C/356°F	Silicon
DOT 5.1	260°C/500°F	180°C/356°F	Glycol ether/borate ester

3.3.6 BRAKE LINES:

Metallic brake lines were used and metallic connectors and banjo bolts are used to join and complete the circuit as stated under Article 34 for Braking Systems in the BAJA SAE India Rulebook 2019. [1]

3.4 CALCULATIONS-

Master cylinder bore = 19.05 mm

Figure 1: Front Assembly

Stroke = 25mm
Assume pedal ratio = 6:1
Assume pedal is placed 5degree from the vertical (due to ergonomics) F_p = 250N
$F_{bp} = F_p \times (L1 / L2)$
=1500N
Where: -
F_p = pedal force by driver
F_{bp}= force output from brake pedal assembly
Pmc = Fbp / Amc
$= (1500 \times 10^4) / 2.85$
$=526.3 \times 10^4$bar
Where:
P_{mc} = pressure in master cylinder
A_{mc} = area of master cylinder = 2.85
$F_{cal} = P_{mc} \times P_{cal} \times$ no. of cylinder[2]
$=52.63 \times 10^5 \times 4.90 \times 10^{-4} \times .2$
=5157.74N
Where:-
F_{cal} = force in caliper
P_{cal} = pressure in caliper
Fdamp = 2 × Fcal
= 10315.48
Where:-
F_{damp} =damping force
F_{fric} = .38 × 10315.48
F_{fric} = 3919.844
Where:-
F_{fric} = friction force
Tr = Ffric × reff
=3919.844 × 0.077
=301.82N
Ftyre = Tr / reff
= 301.82 / .2862
F_{tyre} = 1054.60N
Where:-

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T_r = torque on rotor
r_{eff} = effective force on rotor F_{tyre} =
force on one tyre Force on all tyre =
F_{tyre} * 4 = 1054.60 * 4
=4218.42av=F/mv
a_v = 4218.42 / 252
a_v = 16.73 m/s2
Where:-
av=deceleration
t = 16.73/11.11
t = 1.5 Sec
Stopping Distance
S.D. = $(11.11)^2$ / 2×16.73
S.D. = 3.68m
Where:
t = timeS.D. = stopping distance
Total mass of vehicle = 252 k
Sprung mass = 188.82kg
Kerb weight=187kg
Unsprung mass = 63.18kg

Load transfer-
= (a_v × weight × height from ground) / (diameter of wheel base× 9.81) [1]
= (7.66 × 252 × 27.71) / (59.45 × 9.81)
= .6482
Load transfer at front axle
= .6482 × 100
=64.82%load
Load transfer at rear axle
= 100-64.82%
=35.18%load

III. CONCLUSION

The objective of designing effective braking system for an all-terrain vehicle is accomplished with the application of engineering principles and with the use of Simulation Software, we are able to design a vehicle's braking system with optimal performance. The Design is validated in all dynamic conditions and effective changes are done for the betterment of it . This paper shows the method by which the braking parameters are selected and calculated.
Braking system involves many factors and other parameters of the vehicle such as suspension, weight distribution. All of these should be kept in mind while calculation is done. Braking system optimization is iterative in nature where different iterations are done on software's and manually before deciding the best solution, which fulfills the vehicle requirement and objective.
Calculation of braking system are not straight forward there are lots of unknown variables that's why we need to assume certain parameters about the geometry and then perform the iterations and check if at that assumption the system meets the objective or not.
Based on the performance and requirements of the vehicle the way of calculations can vary and should meet the objective.
This paper shown the methods we used to calculate the values for our vehicle according to our vehicle design and we meet the entire objective we set for our vehicle.

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