Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 6, Issue 10, October -2019

Design, Analysis and Manufacturing of Braking System for an Universal Terrain Vehicle

Himanshu Borse[1], Saurabh Kharwandikar[2]

[1]UG student, Department of Mechanical Engineering, Late G. N. Sapkal college of Engineering, Nashik.
[2] UG student, Department of Mechanical Engineering, Late G. N. Sapkal college of Engineering, Nashik.

Abstract — *The paper represents the designing, analyzing and fabrication of braking system as well as suspension system for a Universal terrain vehicle that too being inside the constraints in the Rulebook provided by Rally Car Design Challenge.*

The main idea behind braking system is to design, analyze as well as to simulate the Hydraulic disc type of brakes installed on a Universal Terrain Vehicle. An UTV as the name suggests is designed to handle a vast variety of terrain than that of other conventional vehicles. The Braking system which is the most important constraint for handling has undergone a substantial amount of development in the past. Thus, the topic is focused on designing a form of mentioned braking system incorporating dynamics of the vehicle with providing optimum performance of the vehicle while minimizing driver's efforts.

Parameters like Dynamic weight transfer, Static weight distribution ratio, Pedal force, and etcetera were evaluated to attain the desired performance. As an UTV has to be stopped or slowed down more often in rough terrains, ability of the vehicle to stop efficiently and in adequate time becomes imperative. The calipers were selected by using required calculations and chosen from the systems available in market, the calculations were then validated using CATIA. The design of Brake Discs were decided using the required calculations and also the caliper mountings on SOLIDWORKS and will be manufactured later. The component designs are analyzed in ANSYS and checked whether they are compatible for our vehicle.

Keywords-*Braking system, Hydraulic Brakes, Disc Brakes, SOLIDWORKS, ANSYS, TMC, RCDC, UTV*

I. INTRODUCTION

An UTV as the name suggests is designed to handle a vast variety of terrain than that of other conventional vehicles. Rally car design challenge is an annual event held where the engineering student from all over the India designs and fabricates their own Universal terrain vehicle in order to compete with other teams. An UTV is a both on-road as well as off-road vehicle compatible to overcome any obstacle such as bumps, steep inclinations as well as sharp turns.

Braking system is one of the most imperative systems of an UTV. The most important function of braking system is to stop the vehicle running at a given speed (in our case it was 60-70 KM/Hr), within the requisite distance (15 ft. in our case).

The braking system chosen for our UTV was hydraulic braking system respecting the rule stated by RCDC.
The brakes should be sturdy enough to stop the vehicle with in minimum distance in an emergency. The driver should have good control over the vehicle throughout braking and therefore the vehicle should not skid. The brakes should have smart opposing fade characteristics i.e. their effectiveness mustn't decrease with constant prolonged application. The brakes ought to have better anti fade properties.

1.1 Concept of Hydraulic Brakes:

Hydraulic braking systems use hydraulic mediums as transfer mediums for brakes. Using hydraulic medium instead of mechanical linkages makes this type of system more efficient as well as requires less effort to stop the vehicle at higher speeds. The hydraulic system works on the principle of Pascal's Law.

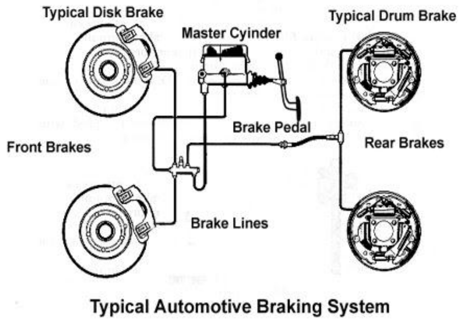


Figure1. Typical layout of Hydraulic Braking System

II. OBJECTIVES

There are many parameters which affect the performance of the UTV, though the scope of this project is limited to optimization, determination, design and analysis of braking systems and to integrate them into whole vehicle systems for best results. Some of the changes made for following reasons:

- To stop the vehicle in required time with minimum shock.
- To prevent vehicle from skidding on all types of terrains i.e. asphalt, dirt, track.
- To tackle the effect of dynamic weight being transferred on front wheels.
- To reduce the effort required from the driver to be put on the brake pedal to stop the speed of the vehicle.
- Increase the overall performance of the vehicle.
- Make the assembly as simple as possible.

III. MAIN COMPONANTS OF BRAKING SYSTEM

3.1 Brake Rotor

The design of brae rotor started with the decision about the outer diameter (OD) of the rotor. The Requisite calculations were done to determine the required (OD) to compensate for the brake torque generated during braking. The other important factor while designing the brake rotor was the pitch circle diameter. As most of the load is acting at the pivoted area of the rotor which is near the pitch circle diameter of the rotor, the most efficient strength can be obtained from the rotor design if the pivot point as well as the PCD coincides.

For designing of the brake rotor, the software used was SOLIDWORKS. After the designing of the rotor, the design was tested for thermal loads in ANSYS. The analysis is required in order to determine whether the design is optimum or not.

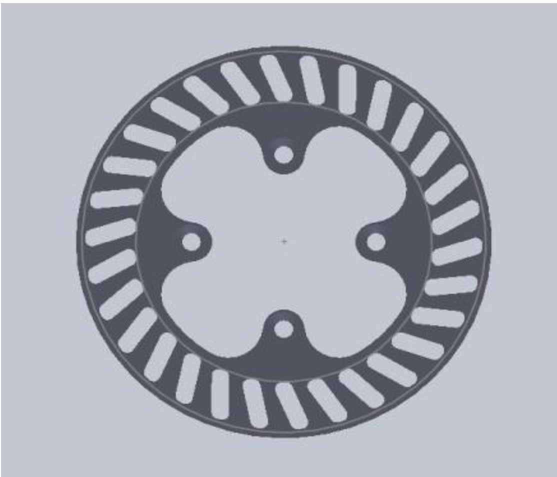


Figure2. Brake Rotor design

Figure3. Actual manufactured Brake Rotors

3.1.1Material selection for brake rotor-

Chemical Properties-

Table1. Comparison for material selection of brake rotor based on chemical properties

	SS410	SS420	SS430	SS440A
Carbon (%)	0.15	0.15	0.12	0.6
Manganese (%)	1	1	1	1
Silicon (%)	1	1	1	1
Chromium (%)	11.50-13.50	12-14	16-18	16-18
Sulfur (%)	0.03	0.03	0.03	0.03
Phosphorous (%)	0.04	0.04	0.04	0.04

Physical Properties-

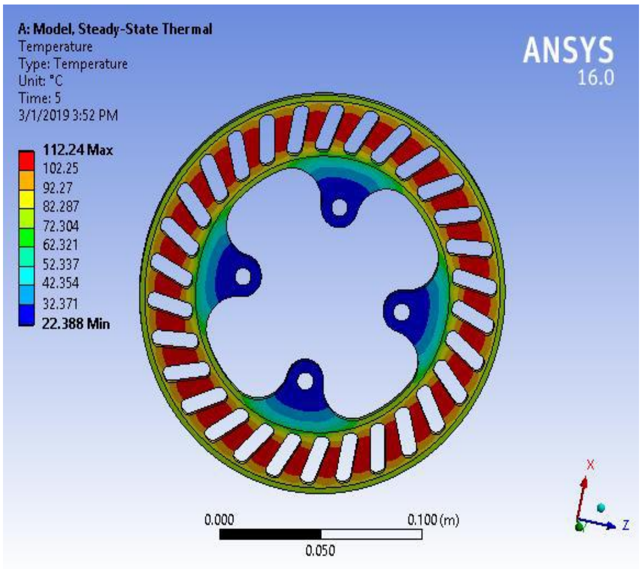
Table2. Comparison for material selection of brake rotor based on physical properties

	SS410	SS420	SS430	SS440A
Density	7.65 g/cm3	7.74 g/cm3	7.7 g/cm3	7.77 g/cm3
Specific Gravity	7.65	7.73	7.7	7.74
Melting Range	1482-1532^{o}C	~1460^{o}C	1425-1510^{o}C	1399-1510^{o}C
Thermal Conductivity (W/m K)	14.4 24.9	14 24.2	14 24.2	14 24.2

From the above chart it is evident that the material SS410 was best suited for the manufacturing of brake rotors. Due to the sufficient strength of the material as well as lesser cost as compared with others, SS410 was the most compatible material for our system.

3.1.2 Analysis of Brake Rotors

The analysis of brake rotor is done in order to verify whether the design is compatible for the application for which it is made. For this, ANSYS software is used. This software does Finite Element Analysis (FEA) in order to verify the design. In this case, as the chances of static failure are very less, the only analysis done was steady state thermal analysis.



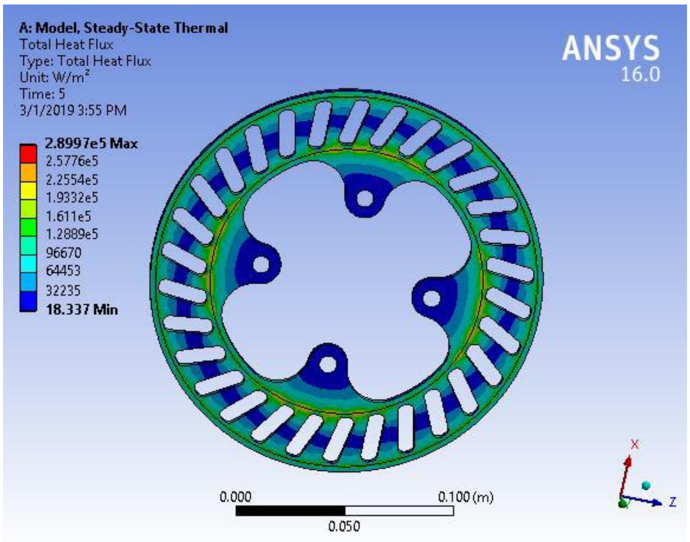


Figure4. Total thermal analysis of Brake rotors in ANSYS

3.2 Selection of Brake Calipers

Table3. Comparison for selection of brake calipers

CALLIPER SELECTION				
COMPANY	**BRAKE PAD AREA**	**FLOAT / FIXED**	**WEIGHT**	**BORE OF PISTON**
Willwood GP 200	0.34	Fixed	408 g	31.75
Wildwood PS-1	0.36	Fixed	423g	28
Vespa	0.49	fixed	408g	25
Pulsar	0.28	float	598g	26 mm

While selecting the brake calipers, first preference was using calipers of Pulsar. However, due to the bulky structure of the caliper body and requisite complex design for mounting of the caliper, it was not easy. Calipers of Willwood were good for the braking for they provided as well as for their easy structures. However, their cost made it difficult for use. Which is why, calipers of Vespa were selected as they were compatible for mounting for easier designs as well as they provided requisite braking power.

Figure5. Vespa Brake caliper

3.3 Selection of brake fluid

Table4. Comparison for selection of brake fluid

COMPARISON BETWEEN BRAKE FLUID			
Characteristics	DOT 3	DOT 4	DOT 5
Dry boiling point	205^0C/401^0 F	230^0C/ 446^0F	260^0C/500^0F
Wet boiling point	140^0C/284^0F	155^0C/311^0F	180^0C/356^0F
Viscosity at 1000C	Moderate (max 1500 mm^2/s)	More (1800 mm^2/s)	Less (900 mm^2/s)
Stability at high temperature	less	moderate	more
Reaction with water	hygroscopic	hygroscopic	hydrophobic
application	Regular vehicle	Racing and off-road vehicles	Military vehicles

There are mainly three types of brake fluids, DOT3, DOT4 and DOT5. The most widely used brake fluids are DOT3 and DOT4. These brake fluids are Glycol and glycol ether based whereas the DOT5 type of brake fluid is silicon based. Although DOT5 type of brake fluid has larger dry boiling point as well as it is compatible for heavy duty applications. However, as the weight of our UTV was not exceeding 500kg and the terrain in which the UTV was running did not have the temperature above 35^0C, the DOT4 type brake fluid was considered to be most competent for our UTV as it had higher dry boiling point and was much more viscous than DOT3.

3.4Master cylinder

The master cylinder is an enclosed container which acts as an actuator which transfers the hydraulic force exerted by the driver towards the brake caliper through brake lines.

The difference between usual master cylinder and tandem master cylinder is that in tandem master cylinder, there are two piston enclosed inside two separate housings made inside a single cylinder. The main advantage of tandem master cylinder over conventional master cylinder is that the two separate housings acts as two different systems. Hence, even If one of the brake lines fails, the other housing maintains the hydraulic pressure inside refusing the system to fail completely.

For our UTV, the TMC used was M800, which is an OEM TMC manufactured by Maruti. This TMC was manufactured by Maruti with purpose of use in Maruti 800. After the multiple iterations of calculations, the M800 TMC was considered compatible for our UTV.

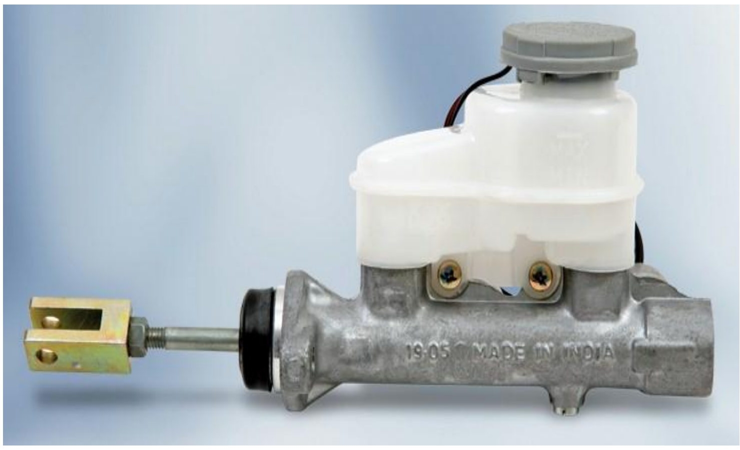


Figure6. M800 Tandem Master Cylinder

3.5 Brake pedal

The brake pedal acts as a lever to transfer the force applied by the driver to the TMC in order to apply the brakes. The brake pedal performs one of the crucial tasks in braking system as it is the only source for the driver in order to stop the vehicle or reduce the speed.

The efforts required by the driver and the force exerted on the TMC is decided by the leverage ratio of the pedal. Leverage ratio is the ratio of the distance between the fulcrum of the pedal to the centre of the footrest and the distance between the pushrod of TMC to the fulcrum of the pedal.

In our case, the leverage ratio was 6:1

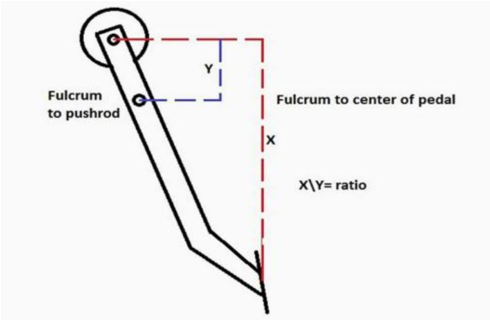


Figure7. Leverage ratio

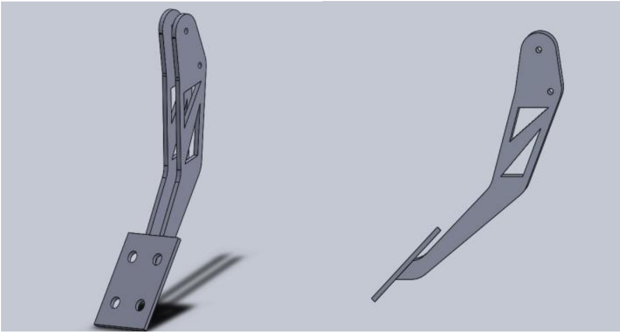


Figure8. Brake pedal

IV. CALCULATIONS FOR BRAKING SYSTEM

Statics-

The weight ratio of the vehicle is 60:40 Weight of the Vehicle =W= **5880 N** Wheelbase = L = **1955.8 mm**
Wheel track = **1473.2 mm**
L1=Longitudinal Distance of centre of gravity from front axle= **1295.4 mm**
L2=Longitudinal distance of centre of gravity from the rear axle=**812.8 mm**
The weight on the front and the rear axle in the static conditions can hence be calculated
Front axle static load: w1 = (W x L2) / L= **2352 N**
Rear axle static load:w2 = (W x L1) / L = **3528 N**
The weight ratio of the vehicle is 60:40 Weight of the Vehicle =W= **5880 N** Wheelbase = L = **1955.8 mm**
Wheel track = **1473.2 mm**
L1=Longitudinal Distance of centre of gravity from front axle= **1295.4 mm**
L2=Longitudinal distance of centre of gravity from the rear axle=**812.8 mm**
The weight on the front and the rear axle in the static conditions can hence be calculated.
Front axle static load: w1 = (W x L2) / L= **2352 N**
Rear axle static load:w2 = (W x L1) / L = **3528 N.**

Dynamics-

Height of centre of gravity = h = 762 mm
Coefficient of Friction between Road and tires =μr = .6 Radius of the tyre = 317.5 mm
Frictional Force on vehicle = Ff = μrN = μrW = 3528 N
Inertial Force Due to deceleration (d) = Fi = md
Ff = Fi
3528 = 600 x d
d = 5.88 m/s2 d/g = 0.6
For designing the braking system, we will have to calculate the dynamic weight transfer using the formulae as given below:
Front axle dynamic load = wfd = {W(L2 + (d/g)h)}/L =5101.1 N
Rear axle dynamic load = wrd = {W(L1 + (d/g)h)}/L =778.9 N
Amount of frictional torque required on the wheels to stop the vehicle
Frictional torque required at front wheels = Tf = μr x wfd x R
=971.759N-m
Frictional torque required at rear wheels = Tr = μr x wrd x R
=**148.38 N-m**

V. DESIGN VALIDATION

For validation of the design i.e. whether the design is efficient and is able to perform efficiently or not, practical approach was considered. In order to determine whether the vehicle stops within the requisite distance or not, actual braking tests were performed, after the complete fabrication of the system, in various iterations.

The results of these iterations proved the design to be efficient, reliable and trustworthy for its performance in all terrains.

Table5. Trials for design validation

Iteration	Speed (Km/Hr)	Stopping Distance (Ft.)
1	45	7.2
2	30	6.13
3	53	7.85
4	60	13.77
5	70	14.8
6	55	8
7	80	15.2
8	40	7
9	65	14.1
10	73	15

The above table shows the trials that were taken for the validation of the braking system. From ten iterations, it was evident that the designed braking system was almost completely safe as well as efficient for the use in Universal Terrain Vehicle.

CONCLUSION

A thorough study of the objectives for the system as well as the constraints provided in the rulebook of RCDC was done. With respect to these studies, the requisite calculations were done and the detailed market research was done to make the system efficient in terms of performance as well as in terms of economy.

After the requisite calculations, the designing of the system was done for fabrication in SOLIDWORKS. After the complete fabrications of the system, it was evident from the various tests that the objectives of stopping the vehicle in the required distance, keeping the system as simple as possible, improve the drive comfort by reducing the shocks while braking were successfully achieved. The overall designed and manufactured braking system for the UTV was working perfectly for better performance the Universal Terrain Vehicle.

REFERENCES

[1]. Rally Car Design Challenge rulebook 2019
[2]. 'McGraw-hill series' Machine design book.
[3]. V. B. Bhandari, 2007 'Design of Machine elements'.
[4]. Design Data book- automobile engineering – Kirpal Singh.
[5]. Tushar Patil, Vishal Dange,Shubham Desale, Abhishek Kulkarni, Bhushan Kharkar, Design, Analysis and manufacturing of brake and transmission sytem for all terrain vehicle, International Journal of Advance Engineering and Research Development (IJAERD), Volume 5, Issue 06
[6]. Design of Braking System of BAJA Vehicle, Vivek Singh Negi , Nayan Deshmukh , Amit Deshpande.
[7]. Rudolf Limpert, Brake design and Safety, Society of Automotive Engineers, 2011.

