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Design and FEA analysis of Braking system

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ABSTRACT:

With the increasing technological development in the area of motors, heavy-duty vehicles have been suffering an increase in size and in load capacity. Friction brakes are to decelerate a vehicle by transforming the kinetic energy of the Vehicle to heat, via friction, and dissipating that heat to the surroundings, which produces excessive heat on lining surface. This shows increase in frictional area will definitely reduce the load on brakes by sharing the energy of the vehicle .So the above-μεντιονεδ factor is taken into account and finally reduction in inertia forces on rotating shaft by providing more frictional area is discussed on this project. We discussed about applying the frictional force on differential gear shaft also. To achieve this an inner shoe, which is less than the size of the outer shoe, is provided as per the design of the system developed with the aid of PRO-E modeling tool. This can be actuated by a specially designed cam, which will actuate both outer shoe and inner shoe respectively. During braking the outer shoe will engage previously to absorb energy in the drum before the inner shoe get actuated. When the cam moves both the shoe remaining energy in both shoes share the vehicles. This entire system is analyzed by using FEA tool ANSYS to determine the stress developed in it. These results are compared with the conventional braking system.

INTRODUCTION:

A brake decelerates a system by transferring power from it. A clutch accelerates a system by transferring power to it. The two devices in rotary applications are thus very similar as they both transmit torque whilst supporting a varying speed difference across them. Brakes take a number of forms - for example a system may drive a pump or electric generator, so the pump or generator acts as a brake on the system. However the most comon brakes employ friction to transform the braked system's mechanical energy irreversibly into heat which is then transferred to the surrounding environment. The friction mechanism is convenient since it allows force and torque to be developed between surfaces which slide over one another due to their different speeds. One of the sliding surfaces is usually metal, the other a special friction material - the lining - which is sacrificial. Wear (ie. material loss) of the lining must be catered for, and the lining usually needs to be renewed periodically. About 5% of the heat generated at the sliding interface of a friction brake must be transferred through the lining to the surrounding environment without allowing the lining to reach excessive temperatures, since high temperatures lead to hot spots and distortion, to fade (the fall-off in friction coefficient) or, worse, to degradation and charring of the lining. During braking total kinetic energy of the vehicle is transferred to heat for reducing the speed of the vehicle.Vehicle’s kinetic energy and its ability to stop is related to the co-efficient of friction between the rubbing surfaces.Maximumusable co-efficient of friction occurs between the tyre and road surface, rather than in the brakes.Brake lining material is a poor conductor of heat goes into the brake drum or disc during braking.

For all brake types, the basic parameter groups are:

- Rotor/Drum - Rotor (disc brakes) or Drum (drum brakes)
- Pad/Shoe Geometry - Dimensions and Structural properties, friction.
- Material - Thermal-engineering properties of the lining, rotor/drum used in heat transfer calculations.

LITERATURE REVIEW

Various research papers related to designing and analysing various parts under the Braking system were studied and discussed below. In some papers, the author has focused on how to calculate brake pedal geometry and how to design a pedal box keeping in mind driver safety, ergonomics, performance, and manufacturability [1]. Some papers worked on the design and analysis of pedal assembly and helped to identify various design constraints for designing the pedals, such as maintaining proper distance between each pedal from an ergonomics and ease of assembly point of view [2]. In a paper published by theUniversity of Akron [3], the author worked on determining the maximum deceleration then designingcomponents like pedal assembly and brake disc, a detailed explanation was also provided by the author for each step and challenges for designing the pedal box and brake disc was also explained. For the master cylinder and brake caliper decision matrices were made and factors for selecting these components was also explained.

Designing a two-part custom caliper is not new among formula student teams reason being, easy to design and manufacture. According to Sergent, N et al [4] calipers must be stiff, light and heat resistant Brake caliper requires acceptable stress and deflection under multiple load. A slight crack can result in instant brake fluid leak and caliper malfunction therefore, a stiff design provides better load distribution which ensures shorter brake pedal travel, ride quality and vehicle safety. Various papers, explain the process of designing and manufacturing was explained by Ingale et al [5], such as the type of seals, materials, and components used to make a custom caliper. Nikhil PratapWagh [6] in their paper explained the design and analysis process of a brake caliper, the paper describes FEM analysis such as structural and thermal which showed various stress points and hinted at possible ways of failure as well. Paper presented by Golhar, S. P et al [7] designed a hydraulic brake caliper for ATV Racing competitions. The proposed design was a 2-piston monoblock caliper. The result of this was anoptimized brake caliper that was lightweight and provided adequate braking torque for efficient braking in a hostile racing environment.

Research paper by Kush Soni et al [8] the authors discussed various calculations for brake force, braketorque, brake disc, and brake bias. Also, caliper selection and design and analysis of brake discs are performed. Mohd. Usama, GaganSinghal [9] gave an insight on developing a desired braking system for a high-performance race car for the competition. Various calculation like brake forces, clamping force, and heat dissipation by disc is discussed in this paper.

While designing brake discs various points have to be kept in mind as explained by Thuresson, A. [10] the paper explains different modes of failure one of the common reasons being improper geometric design whichgives rise to thermal judder and results in failure due to conning, butterfly or corrugated effects. The paper also explains detrimental effects of hot spots which is a result of non-uniform heat distribution in the disc which causes stress concentration and ultimately failure.

Development of Disc Brake Rotors for Heavy- and Medium-DutyTrucks with High Thermal Fatigue Strength

Brakes on heavy- and medium-duty trucks sustain thermal and mechanical loads that are much greater than on small-sized vehicles, which discourages disc brakes in heavy-duty trucks. A heat crack initiates and propagates through repetition of local and average thermal stress cycles. The thermal fatigue strength of a disc therefore can be improved if the propagation of heat crack is properly controlled. Improving the material's resistance against crack propagation does reducing the amount of thermal stress. More practically, improving the thermal conductivity and increasing resistance against compressive stress at high temperatures will reduce the amount of thermal stress, while resistance against crack propagation, when nickel and earth rare material cerium are added.

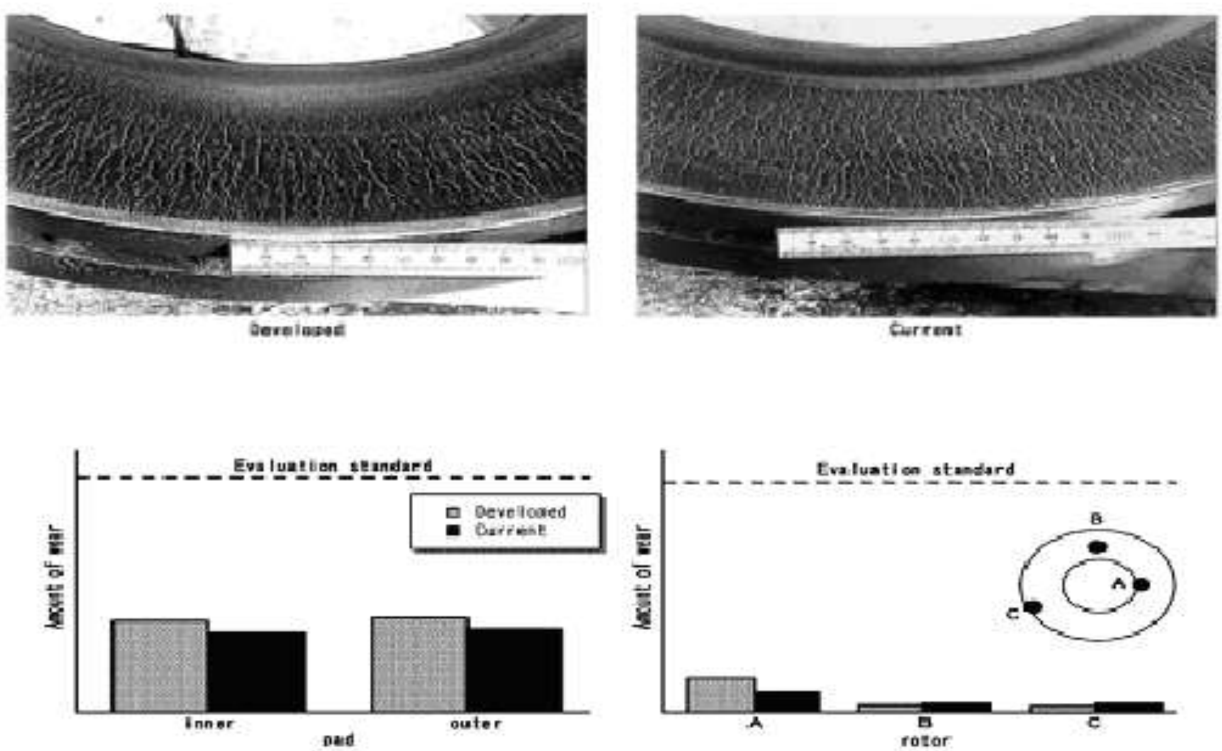

Figure 1 - Comparison of crack formation

Methodology

Computer aided design or CAD has very broad meaning and can be defined as the use of computers in creation, modification, analysis and optimization of a design. CAE (Computer Aided Engineering) is referred to computers in engineering analysis like stress/strain, heat transfer, and flow analysis. CAD/CAE is said to have more potential to radically increase productivity than any development since electricity. CAD/CAE builds quality form concept to final product. Instead of bringing in quality control during the final inspection it helps to develop a process in which quality is there through the life cycle of the product. CAD/CAE can eliminate the need for prototypes. But it required prototypes can be used to confirm rather predict performance and other characteristics. CAD/CAE is employed in numerous industries like manufacturing, automotive, aerospace, casting, mold making, plastic, electronics and other general-purpose industries. CAD/CAE systems can be broadly divided into low end, mid end and high-end systems.

DESIGN OF BRAKING SYSTEM

VEHICLE SPECIFICATIONS:

Ashok Leyland Comet – Alpsv 4/31

Total bhp	= 81 kW
Over all length	= 8.069 m
Over all width	= 0.025 m
Wheelbase	= 4.216 m.
Front overhang	= 1.412 m.
Rear overhang	= 2.441 m.
Wheel radius (r)	= 0.5385 m
Weight	
Front axle	= Unladen Weight 2060 kg
Rear axle	= Unladen weight 1660 kg
Rear axle	= Laden weight 10200 kg
Total	= Unladen Weight 3720 kg
Front axle	= Laden weight 5460 kg
Total (m)	= Laden weight 15660 kg

MATERIAL SPECIFICATIONS:

In a braking system friction is the main parameter, which absorbs the energy of the system. A material, which has high friction co-efficient, is employed. A material which having high friction co-efficient is asbestos. Asbestos is the generic name for a group of six naturally occurring fibrous silicate minerals, including serpentine mineral chrysotile. Asbestos minerals possess a number of properties useful in commercial applications, including heat stability, thermal and electrical insulation, wear and friction characteristics, tensile strength, the ability to be woven, and resistance to chemical and biological degradation. This asbestos is combined with the fibers to increase its wear resistance and heat stability in braking application. Generally, asbestos is mounted on the steel member to withstand high compressive force created in a braking. So steel c60, which is used in high force application, is selected in brake shoe. Usually, the highest temperature-is created in the brake drum, so drum should have highest wear resistance in thermal loading. Cast iron is suggested as brake drum material.

S.NO	COMPONENT	MATERIAL
1	DRUM	CAST IRON
2	SHOE	STEEL c60
3	LINING	ASBESTOS
4	CAM SHAFT	STEEL c60
5	HUB	STEELc60
6	MAIN SHAFT	STEELc60

Table: 1 – selection of materials

PROPERTY	ASBESTOS	STEEL C60
Young's Modulus (E)(N/m^2)	$1.86*10^{11}$	$2.05*10^{11}$
Density (ρ)(kg/m^3)	2500	7830
Tensile Strength (σ_y)(N/m^2)	$41 *10^6$	$420 *10^6$
Co-efficient of friction (μ)	0.4	0.3
Thermal conductivity (K)(W/mk)	0.1105	53.6
Specific heat (c)(J/kgk)	816	465

Table: 2 - Properties of materials

SPRING STIFFNESS CALCULATION:

A spring is used in a brake shoe for retraction purpose of shoe to its previous position when there is no braking force. So for frequent uses of brakes we have to determine the stiffness of the spring and the deflection of spring for particular loading condition. We determine the spring stiffness by using the spring testing machine for different loading condition.

Specifications of spring:

Mean Radius of Spring (R) = 11.875mm

Coil Diameter (d)= 3.5mm

Poisson ratio (1/m) = 0.3

Shear stress (τ) = $(16*W*R)/ (\pi*d^3)$

Young's modulus (E) = 2G(1 + (1/m))

Rigidity modulus (G) = $(64*W*R^3*n)/(\delta□*d^4)$

Stiffness = Load / deflection

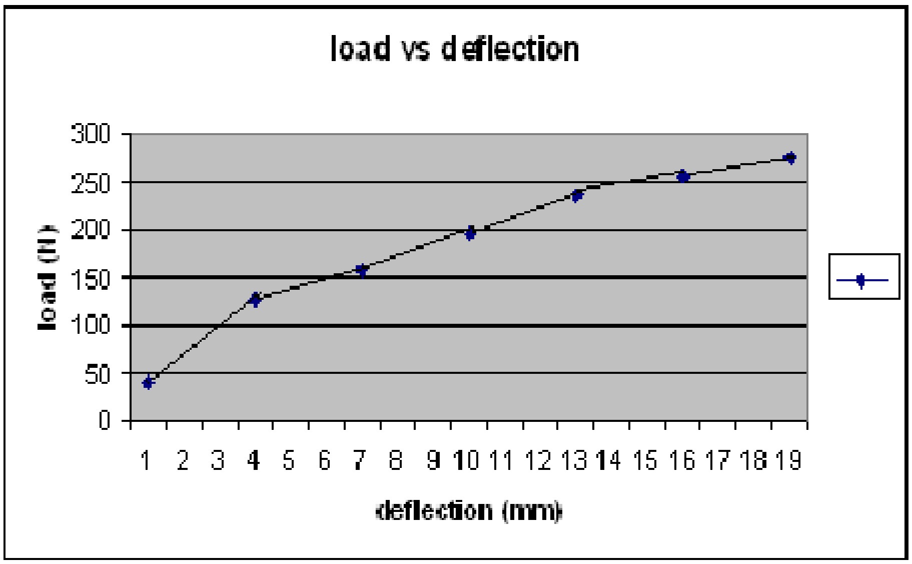

Chart 1: - load vs. deflection

Table: 3-spring stiffness calculation

S.no	Deflection (m)	Load (N)	Shear stress $*10^6$ (N/m^2)	Young's Modulus $*10^6$ (N/m^2)	Rigidity Modulus $*10^6$ (N/m^2)	Stiffness (N/m)
1	0.003	39.24	55.35	971490	373650	0.01308
2	0.006	127.53	179.89	3157424	1214394	0.02126
3	0.009	156.96	221.41	3886064	1494640	0.01744

4	0.012	196.2	276.75	4844580	1863300	0.01635
5	0.015	235.4	332.05	5828108	2241580	0.01569
6	0.018	255.06	359.78	6314854	2428790	0.01417
7	0.021	274.68	387.45	6800612	2615620	0.01308

6.3 FORCE CALCULATION:

DESIGN SPECIFICATION:

Co efficient of friction (μ) = 0.4

Maximum effective pressure (pm) = 400000 N/m2

Moment arm of actuating force (C) = 0.25 m

Lining angle (θ) = 100°

For outer shoe:

Inner radius of brake drum (r1) = 0.2 m

Distance from the center of the drum to the shoe pivot (a1) = 0.15 m

Center angle of heel from the pivot (θ1) = 40°

Center angle of toe from the pivot (θ2) = 140°

For inner shoe:

Outer radius of shaft (r2) = 0.055m

Distance from the center of the drum to the shoe pivot (a2) = 0.065 m

Center angle of heel from the pivot (θ1) = 40°

Center angle of toe from the pivot (θ2) = 140°

Area of outer shoe (A1) = 100*0.108*0.2*(π/180) = 0.037 m2

Area of inner shoe (A2) = 100*0.10*0.055*(π/180) = 9.599*10-3 m2

Total area (A) = area of outer shoe + area of inner shoe = 0.037+9.599*10-3 = 0.0465 m2

BRAKING FORCE ON REAR WHEEL:

Moment of frictional force (Mf)

= (μ*pm*b*r1) [r1 (cosθ1 – cosθ2) + (a1 (cos2θ2 –cos2θ1) /4)]

= (0.4*400000*0.108*0.2) [0.2(cos40–cos140) + (0.15(cos280-cos40)/2)] =1058.9 Nm

Moment of normal force (Mn)

= (pm*b*r1* a1)/2 [(θ2-θ1) + (sin2θ1-sin2θ2)/2)]

= (400000 *0.108*0.2*0.15)/2 [(140-40)*(3.14/180) + (sin80-sin280)/2] =1769.1 Nm

Braking force (P) = (Mn-Mf) / C = (1769.1 – 1058.9) / 0.25 = 2840 N

Braking moment for outer shoe (Tb1) =μ*pm*b* r12 (cos θ1-cos θ2)

=0.4*400000*0.108*0.22 (cos40-cos140) =1058.9 Nm.

Braking moment for inner shoe (Tb2) =μ*pm*b*r22 (cos θ1-cos θ2)

=0.4*400000*0.1*0.552 =74.2 Nm.

REACTION AND FRICTIONAL FORCE CALCULATION:

For outer shoe:

Frictional force on braking moment (Tf1) = Tb1/r = 1058.9/0.5335= 1984.8N

Normal force (Fn1) = Mn / a1 = 1769.1/0.15= 11794 N

Frictional force (Ff1) =Mf / r1 = 1058.9/0.2 = 5294.5 N

For inner shoe:

Frictional force on braking moment (Tf2) = Tb2/r = 74.2/0.5335 = 140 N

Normal force (Fn2) = pm*b*r1*θ

= 400000*0.1*0.055*100*3.142/180 = 3840 N

Frictional force (Ff2) = μ* Fn2 = 0.4*3840 =1535 N

Friction on road surface:

Reaction force (Rr) = 51000 N

Frictional force (Fr) = μ Rr

= 0.6* 51000 = 30600 N

Total frictional force (TFR)

=(2*30600)+(4*1984.8)+(4*140)+(4*3840)+(4*1535)+(4*11794)+(4*5294)

=159553.2 N

FRICTIONAL FORCE ON FRONT WHEEL:

Reaction force (Rf) = 27300N

Total frictional force (TFF) = μ Rf

= 0.6* 27300 = 16380 N

Reaction and frictional force for conventional case:

Total frictional force (TFR) = (2*30600) + (4*1984.8) + (4*11794) + (4*5294)

=137493.2 N

Retardation of the vehicle (f) = (TFR +TFR)/m

= (159553.2+32760)/15660=12.28 m/s2

Retardation of the vehicle (f) in conventional case = (TFR +TFR)/m

= (137493.2+32760)/15660 =10.87 m/s2

SKID DISTANCE CALCULATION:

$S = V^2 / (2*f)$

Speed (u) (km/hr)	Deceleration (f) (m/sec^2)		Skid distance (S) (m)	
	Conventional System	Modified System	Conventional System	Modified System
50			7.84	8.86

70	10.87	12.28	15.64	17.67
100			31.4	35.47

Table: 4-Skid Distance Calculation

ASSEMBLY AND DETAILING OF BRAKING SYSTEM:

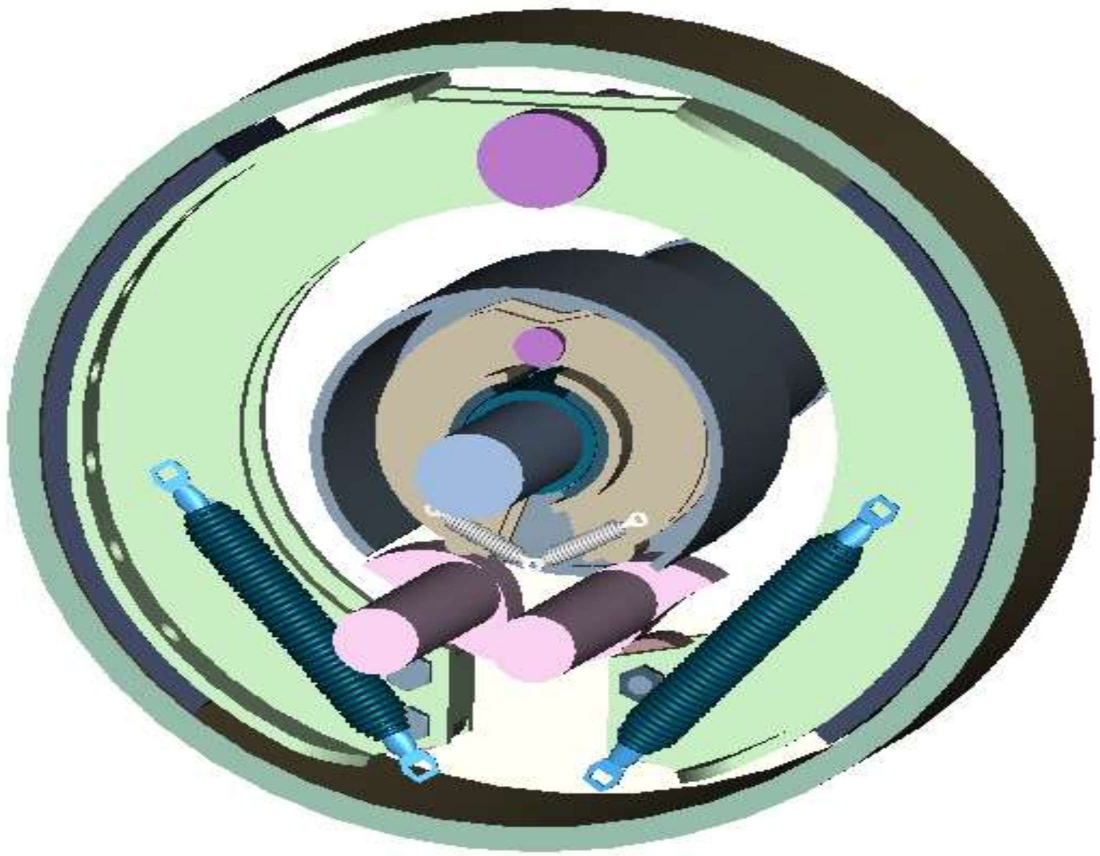

Figure: 2- Assembly view of modified braking system

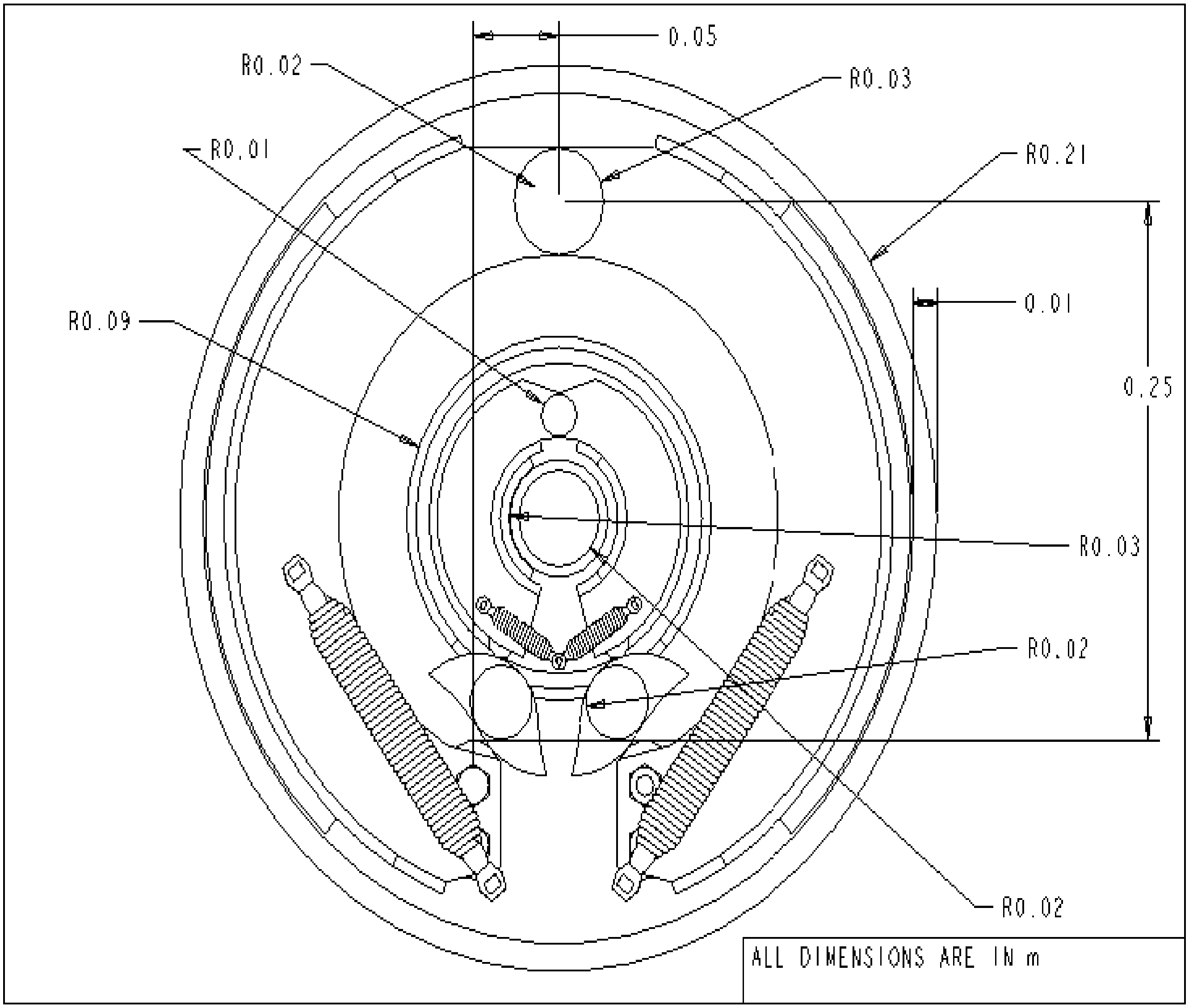

Figure 3 – Detailing of assembly view

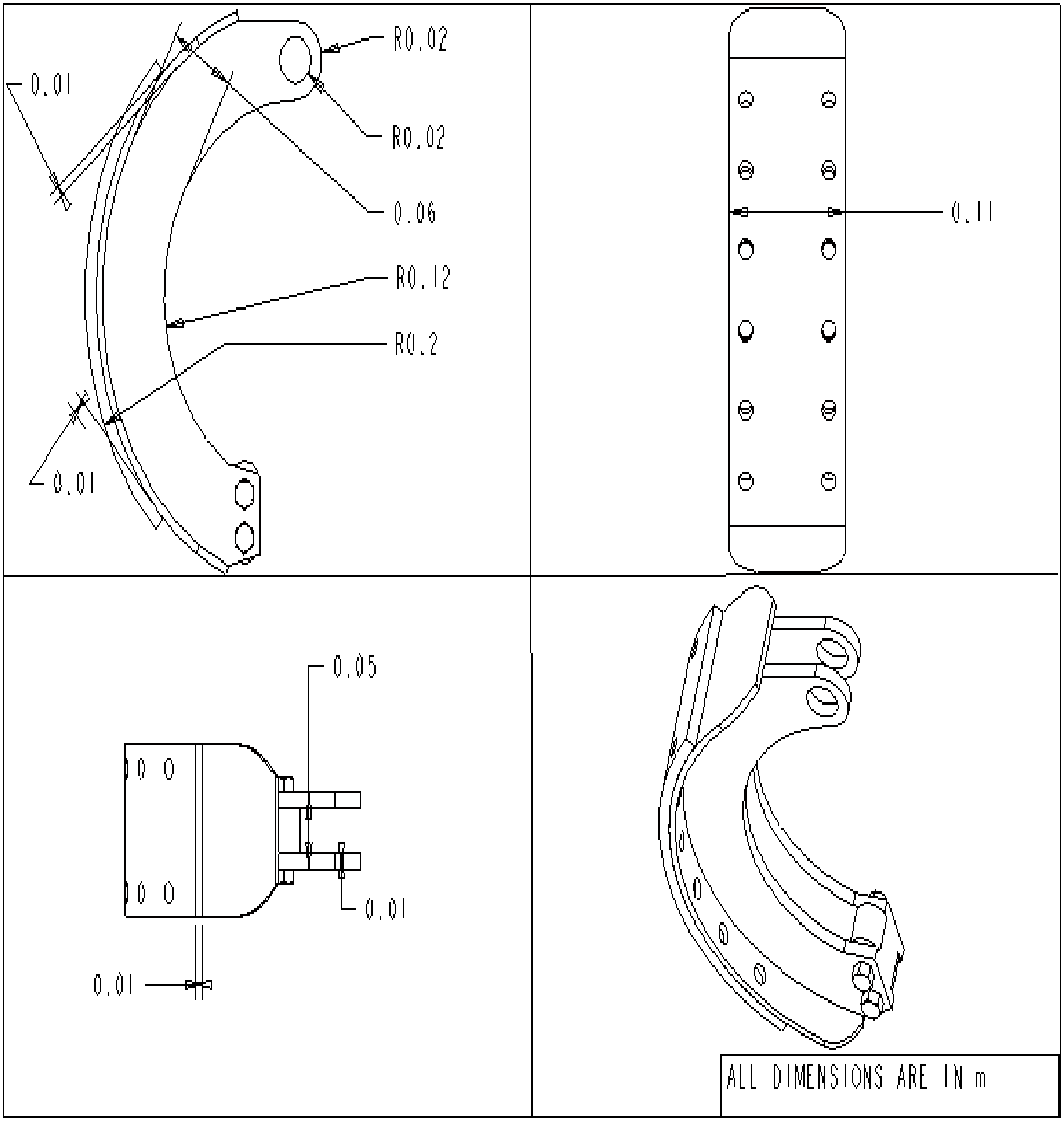

Figure 4 - Detailing of outer shoe

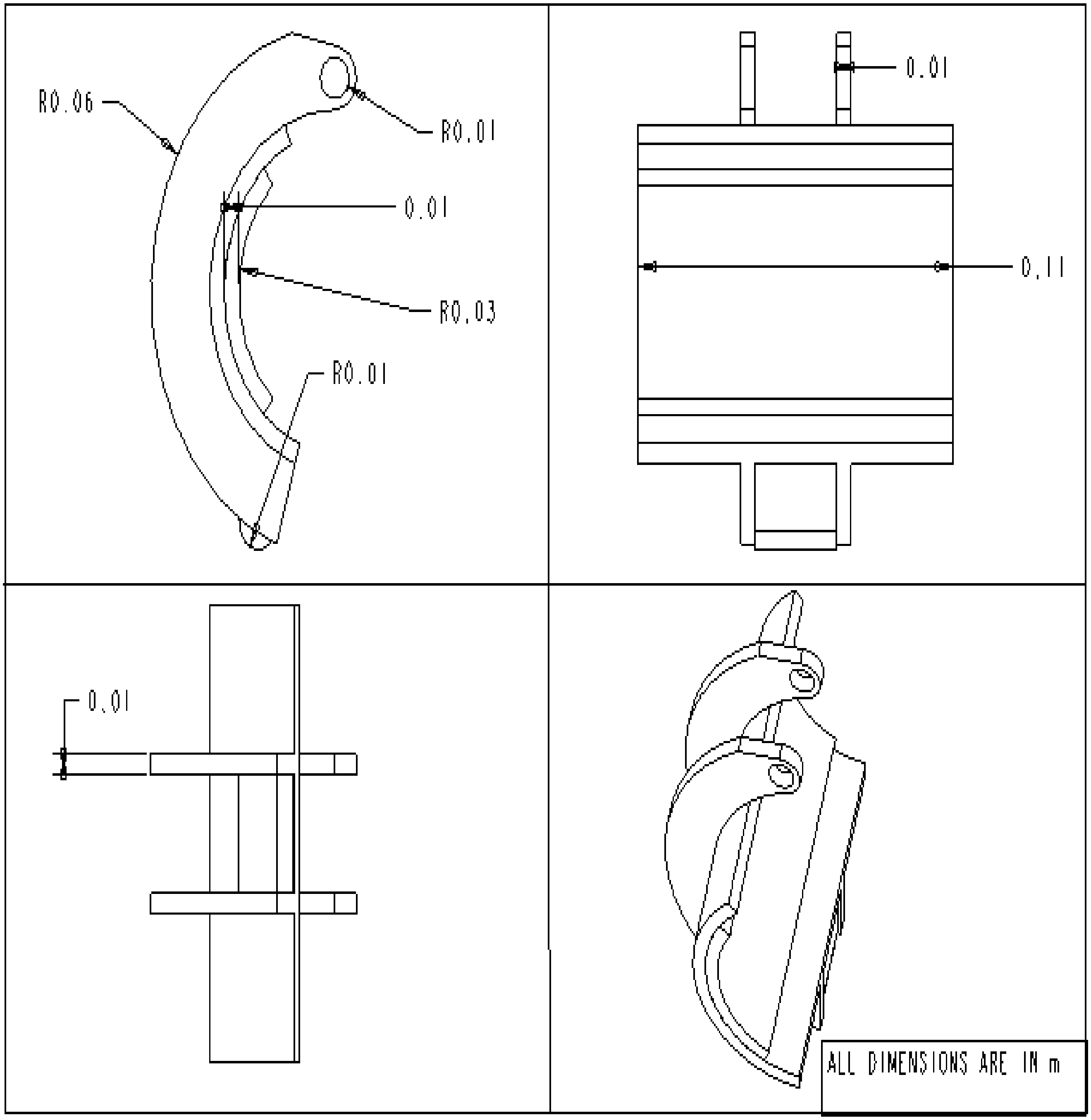

Figure 5 - Detailing of inner shoe

Cam maximum rotation angle = 9°

Cam maximum displacement = 2mm

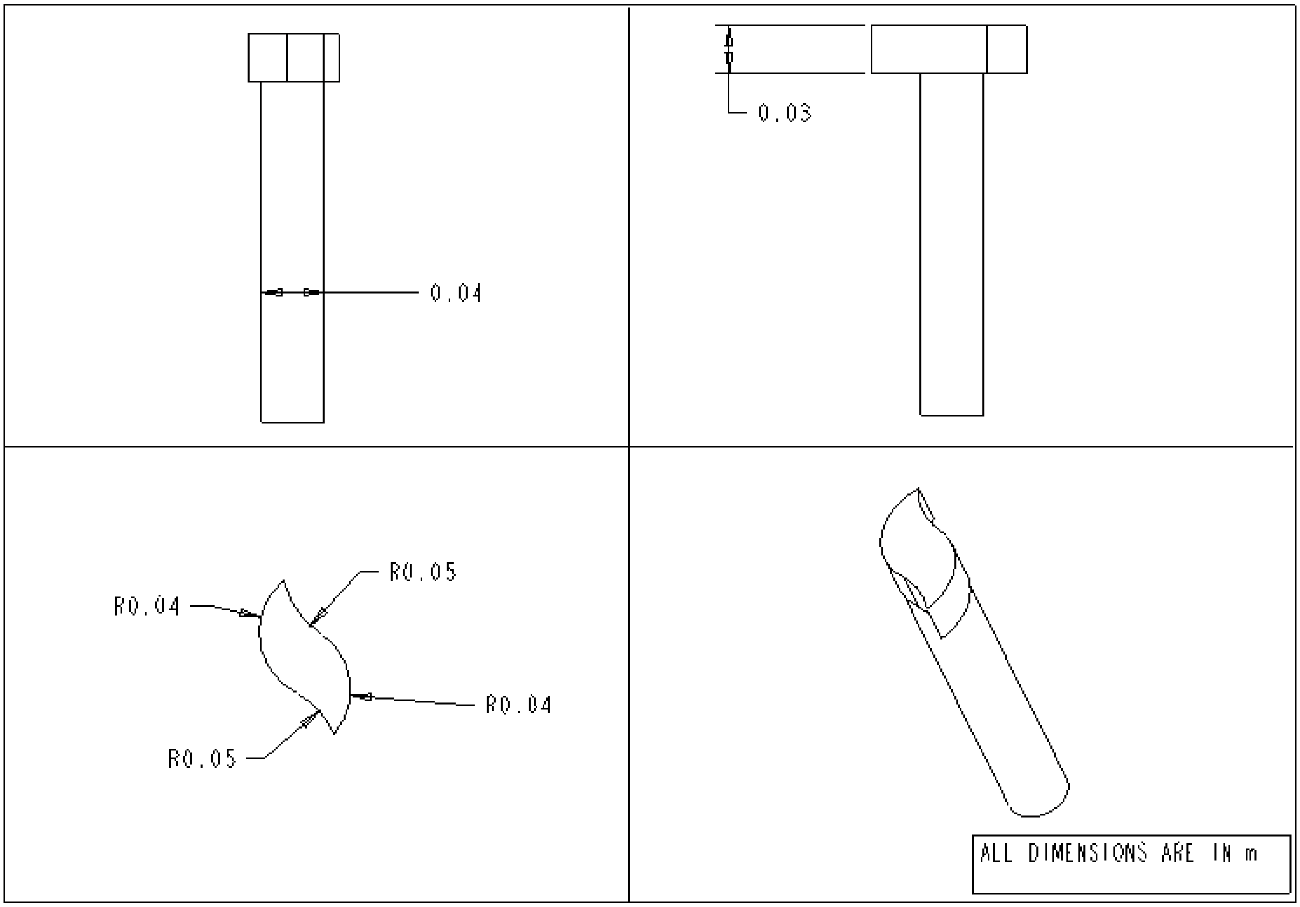

Figure 6 - Detailing of cam shaft

DESIGN ANALYSIS OF BRAKING SYSTEM:

Finite element method

FEA is attributed to the fact that the finite element method is perhaps the most popular numerical technique for solving engineering problems. The method is general enough to handle any complex shape or geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the finite element method analysis requirement of today's complex engineering systems and designs were closed form solutions of governing equilibrium equations are generally not available. In addition, it is an efficient design tool by which designers can perform parametric design studies by considering various design cases (different shapes, materials, loads, etc) analyzing them and choosing the optimum design.

The finite element method is numerical technique for obtaining approximates solutions to engineering problems. This method is adopted in the industry as a tool to study stresses in complex airframe structures. The method has gained popularity amid of both researches and practitioners.

Modeling features in ANSYS

ANSYS 9.0 was used to create the solid model of the alternator. The solid model was developed in successive stages using the following features available in the package.

1. Key point creation
2. Line formation
3. Area generation
4. Volume generation

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. The analysis guide manuals in the ANSYS documentation set describe specific procedures for performing analyses for different engineering disciplines.

OVERVIEW OF POST PROCESSING:

Post processing means reviewing the results of an analysis. It is probably the most important step in the analysis, because we are trying to understand how the applied loads affect your design, how good our finite element mesh is, and so on.

The solution phase calculates two types of result data:

Primary data consist of the degree-of-freedom solution calculated at each node: displacements in a structural analysis, temperatures in a thermal analysis, magnetic potentials in a magnetic analysis, and so on.

Derived data are those results calculated from the primary data, such as stresses and strains in a structural analysis, thermal gradients and fluxes in a thermal analysis, magnetic fluxes in a magnetic analysis, and the like. Derived data are alsoknown as element solution data, except when they are averaged at the nodes. In such cases, they become nodal solution data

RESULT COMPARISON:

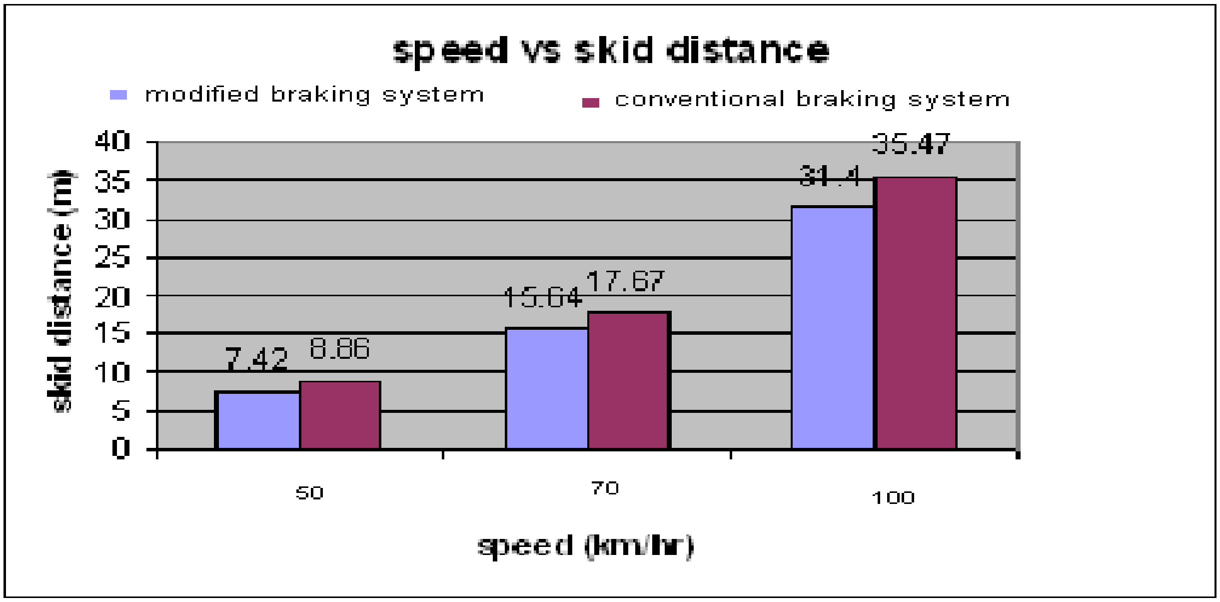

Chart 2- speed Vs. skid distance

The chart 2 shows about the comparison between speed and skid distance for different speeds 50 km/hr, 70 km/hr and 100 km/hr

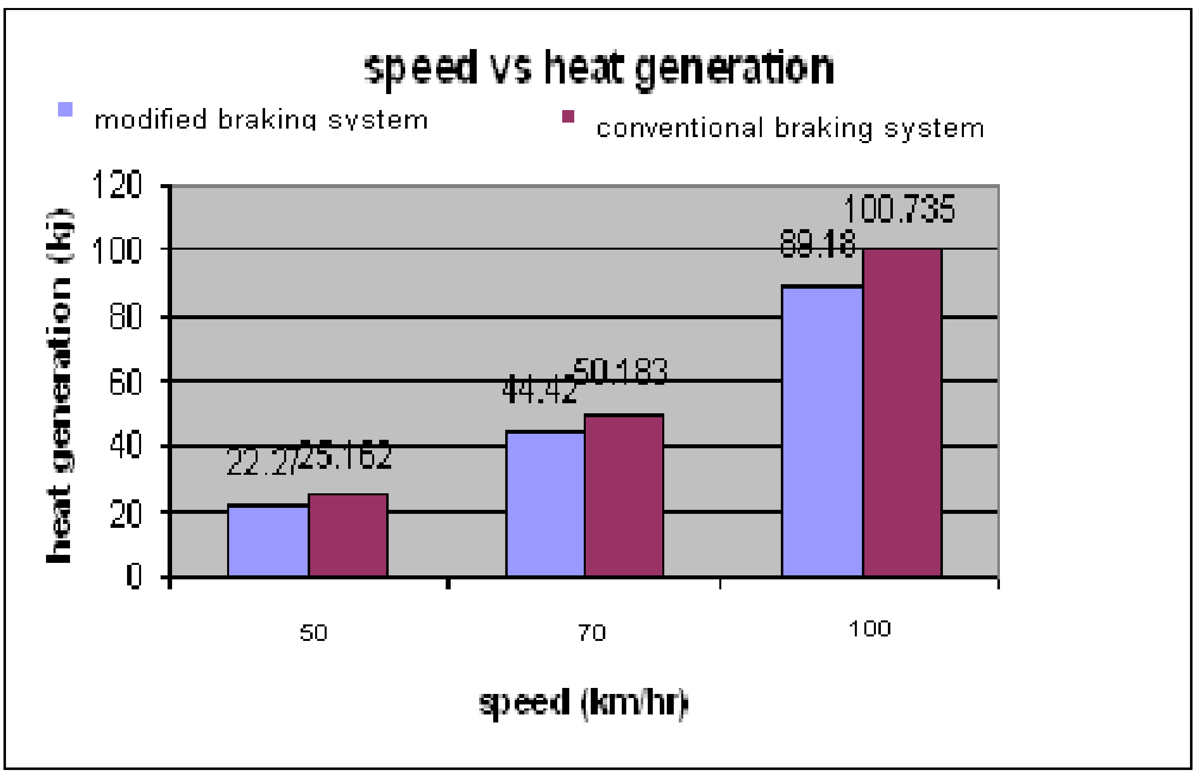

Chart 3- speed Vs. heat generation

The chart 3 shows about the comparison between speed and heat generation for different speeds 50 km/hr, 70 km/hr and 100 km/hr.

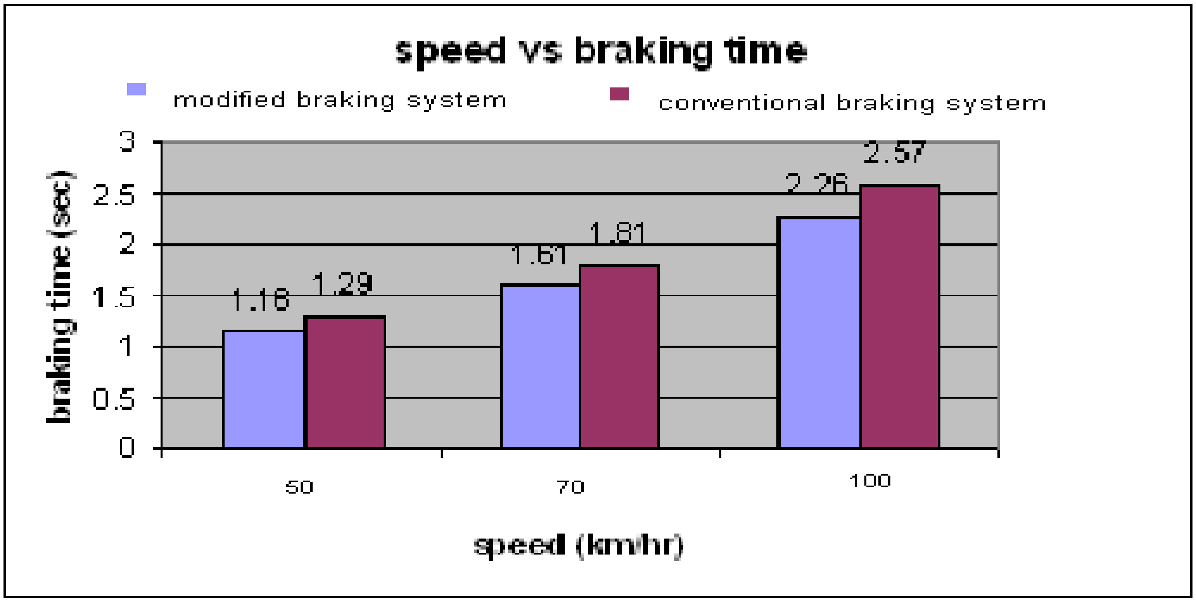

Chart 4- speed vs braking time

The chart 4 shows about the comparison between speed and braking time for different speeds 50 km/hr, 70 km/hr and 100 km/hr

CONCLUSION:

In this modified braking system we increase the frictional area of braking by providing an additional brake shoe. This is different from the conventional braking system of heavy–duty vehicle. We achieved reduction in skid distance, reduction in heat generated in the rear drum surface and reduction in braking time theoretically. Further fabrication of the system will approach closer to the theoretical values determined.

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