A PROJECT REPORT

ON

"INSTANTENEOUS TYRE PUMPING SYSTEM
&
DESIGN AND STRESS ANALYSIS OF REAR AXLE OF GOKART"

Submitted by

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In partial fulfillment for the award of the Degree

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Of

Prof. ATUL N MESHRAM

DEPARTMENT OF MECHANICAL ENGINEERING

ANJUMAN-I-ISLAM

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

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APPROVAL OF DISSERTATION

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Date: _____________

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Abstract

We have designed this project keeping in mind the current needs of the automobile industry. This industry has been evolving many technologies in the past and foresees further advancements in the coming years. The title of our project is ‘Design and Stress Analysis of Rear Axle of Go-kart and Instantaneous Tire Pumping System’. Both these parts of our projects are inter related with each other. Air pressure in the tire is also one of the major cause of accidents and is difficult to repair at remote places. The axle being the integral part of an automobile needs to withstand all the forces which shall act on it during its operation. ITPS has also been integrated with the automobile axle assembly so as to achieve the benefits of maintaining an optimum tire pressure system.

In the Design part, we have designed, calculated, analyzed and simulated the axle. For simulation we have chosen two software’s, namely, ANSYS and Solidworks. We have analyzed the axle for static and dynamic forces which shall act on it during operation. Results have been tabulated and necessary changes have been made. After simulation, we have fabricated it and mounted on go-kart.

In ITPS, we have developed a mechanism which will be able to maintain optimum tire pressure in the tires of a vehicle by instantaneously filling in air in the tires when there is a pressure loss in tire. This system has been developed with the help of electro-mechanics i.e. Circuit design as well as mechanical design. We have done a significant study in the on this system and highlighted the need of it in the current industry scenario.

Our system ITPS offers a wide range of benefits, some of the key benefits are low maintenance costs, easy to install, reproducible on different types of automobiles and more importantly, a safety feature in automobiles.

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Abbreviation

ITPS- Instantaneous Tyre Pumping System

OEM- Original Equipment Manufacturer

TPMS- Tyre Pressure Monitoring System

NRMS- National Road and Motorist Association

RR- Rolling Resistance

GHG- Green House Gas

Declaration

We declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Naeem Pathan　　　　　　　　　　Mir Yadgar Ali

Khan Mohammed Azim　　　　　　　　　　Sayed Idris

Date

Chapter 1 Introduction

1.1 Selection of the project

We had participated in the competition named National Go-karting Championship 2014 in the month of October. In this competition we had to fabricate go-kart on our own. From this competition we developed interest in automobile projects and hence chose the topic of Design and Stress Analysis of Axle and ITPS.

This project comprises of two segments:

1. Design And Stress Analysis Of Rear Axle Of Go-Kart
2. Instantaneous Tyre Pumping System (ITPS)

1.2 Problem Definition

Design and Stress Analysis of Rear Axle of Go-Kart: In this part of the project we have designed and analyzed the axle, which being a very integral part of an automobile and hence we have examined it in all aspects. Although we have followed the conventional design procedure to design the axle, still we have come up with results which will help the industry in all respects. In this part our focus was more laid on material selection for axle and hence we selected the most suitable material for this application. We have checked for failure of the component in different conditions of loads and with different materials. Thus, the analysis from this study will help the industry.

Instantaneous Tire Pumping System: This part of the project has been done keeping in mind the fuel economy of passenger and commercial vehicles. As per a study about 3-4% of fuel consumption of a car depends on tire pressure. If we maintain optimum tire pressure levels in the tire, we can save a lot of fuel and money spent. Therefore, by incorporating this system in modern cars and heavy vehicles, we can bring a change in the fuel economy of the vehicle. The optimum tire pressure also helps to reduce road accidents and thereby reduce chances of tire puncture.

1.3 Design Objectives

The overall goal of our design project is to develop a product that will decrease tyre wear while improving fuel economy, performance and safety of a passenger vehicle through dynamically-adjustable tire pressures. However, there are several key objectives that the team has targeted our design to meet:

1. ABILITY TO PROVIDE PROPER TYRE PRESSURE:

The ideal functional objective of our design is its capability to adjust the pressures in all four tires of a passenger vehicle to obtain the proper pressure for varying road/driving conditions.

2. MINIMIZE NEGATIVE VISUAL AESTHETICS:

Another design objective is to ensure that the product will not have a negative effect on current vehicle aesthetics. All components should be located as inconspicuously as possible.

3. ABILITY TO PROVIDE AUTOMATIC SYSTEM:

A third objective is to provide all of the said benefits to the user through an automatic system, thus minimizing user intervention.

4. LOW COST DEVICE: For both the manufacturer (OEM) and end user (vehicle owner), it is imperative to keep the price of the device as low as possible.

1.4 Axle

An axle is a central shaft for a rotating wheel. The wheel may be fixed to the axle, with bearings or bushings provided at the mounting points where the axle is supported. The axles maintain the position of the wheels relative to each other and to the vehicle body. Dead axle does not transmit power like the front axle in a rear wheel drives are dead axles. On the dead axle suspension system is mounted, so it’s also called suspension axle.

1.4.1 Type of Axle

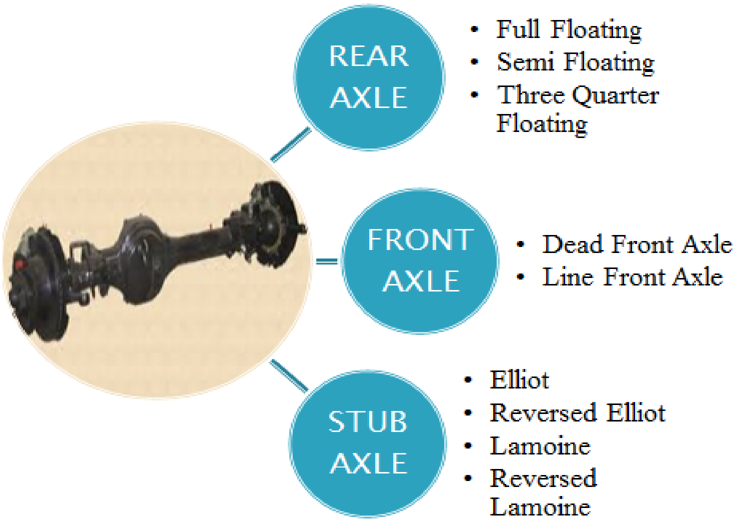


Figure 1 Types of Axle

1.4.2 Forces Acting On Axle

- Weight of the body
- Driving trust
- Torque reaction
- Side thrust

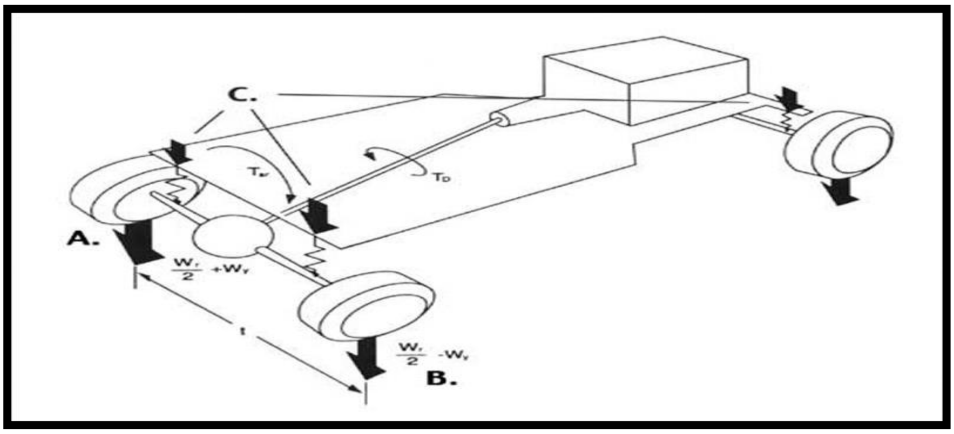


Figure 2 Forces acting on Axle

1.5 Instantaneous Tire Pumping System (ITPS)

ITPS can be considered as a predecessor of the above mentioned technologies based on the same principles. ITPS has been developed by us, whose primary objective is to maintain optimum tire pressure but it has been designed and developed in a much simpler and compact manner.

We have developed a system that is capable of automatically maintaining optimum tire pressure in a passenger vehicle. This has been achieved through use of a centralized air compressor that is placed in the engine compartment of a vehicle. This compressor is attached to a distribution block which houses outlets of air, which are connected to the wheels of vehicle. From this distribution block, the air travels via ¼" dia. hoses to a rotary joint located at each wheel. This rotary joint allows our system to pass air from the vehicle chassis to the rotating tire.

The system that we have developed can be integrated with the tire pressure monitoring systems currently found on vehicles to get best results.

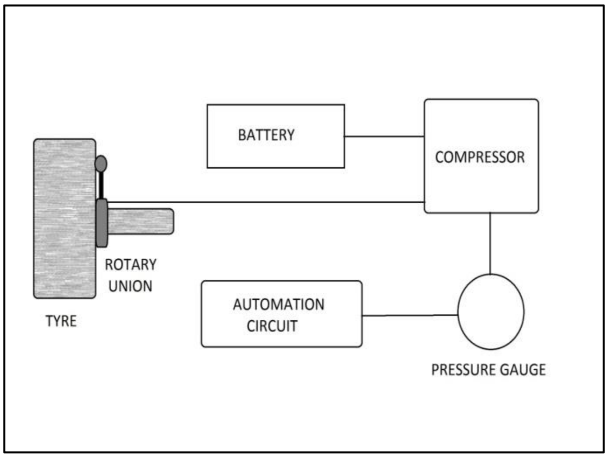


Figure 3 Layout

Figure 4 ITPS

Chapter 2 Literature Review

2.1 Loads applied to the rear axle in each load case are as follows

1) The vertical reaction forces from the ground, distributing on the semicircle of bearings by the cosine regulation

2) The forward or backward horizontal forces from the ground, distributing on the semicircle of bearings by the cosine regulation

3) The tangential forces equalizing the torque of the wheels, distributing on the end of semi-spindle sleeve

4) The nodal force equalizing the torsion around the axis of rear axle, acting on the head face of the main speed reducer housing

5) The brake pressure from the brake apparatus, distributing on the holes of the brackets of break apparatus

6) The lateral force from steering load case, acting evenly on the alignment face of bearings.

- ***Simplification of rear axle structure***

By surface modelling technique of PRO/E, the complex casting curved surface and a 3D solid model of rear axle housing are established. The geometrical model is very complex. In order to reduce calculating scale, simplification measures of non-critical structures are as follows: neglecting some casting fillet radii, small holes, some bulges and some groove etc. in uninterested region, and meanwhile treating the strength of welded connection and bolt connection as the material strength of rear axle.

An equivalent model is established to simulate the interference fit between semi-spindle sleeve and the axle housing with the contact nonlinear function of ANSYS. The average fitting pressure is 20Mpa, and the average stress is 80Mpa, so the connection strength is enough. Furthermore, this kind of pre-stress is only near the fitting interface. Therefore, two components joined each other by interference fit can be regarded as a continuous body too. A simplified geometry model of rear axle is imported into ANSYS, and then the ideal analytical model could be established by the powerful finite element modelling technique of ANSYS software.[1]

2.2 Material Selection

The choice of materials plays an important role in the decision-making process of the manufacturing organizations. The materials affect many aspects of a product and the manufacturing process too. The improper selection of material can result in a defective final product, which may cause fatal injury. Thus, if satisfactory results are to be expected, immense importance must be given for proper selection of the materials. There are numerous choices and various criteria influencing the selection of material for a particular application. These criteria range from mechanical, electrical, and physical properties to corrosion resistance and economic considerations of the materials. The large number of available materials, together with the complex relationships between various selection parameters, often makes the selection process a difficult task. The problem of selecting a material for an engineering application from among two or more alternatives on the basis of several criteria can be treated as a multi-criteria decision-making (MCDM) problem.[2]

2.3 Corrosion fatigue influencing factors

- Stress amplitude:

With higher amplitudes the mechanical effect of loading is prevailing and there are more cracks (multiple cracking). With lower amplitudes the corrosive effect becomes more important.

- Materials strength:

Corrosion fatigue in the active state results in numerous micro-notches at the surface thus higher strength steels are more endangered due to their higher notch sensitivity.

- Non-metallic inclusions:

Manganese sulphides play an important role if corrosion fatigue occurs, especially if pitting corrosion is regarded. (In contrast to normal fatigue, where Mn-inclusion does not affect crack initiation/ growth so much.)[3]

2.4 Tyre Pressure Monitoring System

Proper tire inflation pressure improves fuel economy, reduces braking distance, improves handling, and increases tire life, while under inflation creates overheating and can lead to accidents. Approximately 3/4 of all automobiles operate with at least one underinflated tire. The main causes of under inflation are natural leakage, temperature changes, and road hazards. Drivers typically do not check tire pressure unless they notice unusual vehicle performance. Visual checks are often insufficient to determine under inflation.

DIRECT TPMS

Tire inflation is identified through pressure sensors in a direct TPMS. A low-cost, simple direct TPMS consists of a sensor fitted on the tire valve stem, which changes its colour when the pressure drops. This sensor has low accuracy and cannot communicate data to the driver. Alternatively, a more sophisticated version of a direct TPMS consists of sensors, radio frequency transmitters and receiver, and a warning system. Each tire's pressure is measured and transmitted through its sensor and transmitter. The transmitted signals are received, decoded, and processed by the receiver to trigger the warning system through an alarm lamp, audible alarm, voice, or pressure display.

INDIRECT TPMS

An indirect TPMS predicts tire pressure drop using an observer coded in software and thus does not require tire pressure sensors. Available indirect TPMSs are based on wheel speed measurements. When the tire pressure decreases, the vehicle's weight causes the tire's diameter to decrease, which causes the tire to rotate at a different rate than when it is at full pressure.[4]

2.5 Tire Pressure and Fuel Efficiency

As an automobile travels, the surface of the tire and the road come into contact and must be continually peeled apart. In addition, each surface (both the tire and the road) is deformed slightly so that in effect, the wheel is rolling uphill. These effects combine to produce a rolling resistance. A ratio of 1:5.3 or more than a 2% is found for the effect on fuel economy for every 10% change in rolling resistance for highway driving and a ratio of 1:9.6, or about a 1% fuel economy change for every 10% change in rolling resistance for urban driving

This is because inflation pressure determines tire stiffness, which has a significant influence on the contact area of the tire and pressure distribution over the contact surface. Thus, as pressure in the vehicles tires is reduced, the rolling resistance increases over the road because the surface contact area and virtual hill height is increased. When the rolling resistance is increased it takes more energy (fuel) to get the automobile to go the same distance. The relationship between tire pressure, rolling resistance, and fuel economy is complex and dynamic and is dependent on several other factors, including vehicle type and load, road and environmental conditions.

Overall, rolling resistance makes up a relatively small percentage of the losses in a typical vehicle; it accounts for about 4% of a vehicle’s energy expenditure at low speeds and about 7% at highway speeds (TRB, 2006). However, these modest losses are substantial when in the context of the entire U.S., where automobile travel accounts for the largest source of energy use and GHG emissions, with petroleum combustion causing 2,438 Tg (106 tons) CO2 or 43% of the emissions in 2004 (EPA, 2006a). Globally the situation is similar, where in 1990 the transportation sector was responsible for some 25% of the world’s energy use, and 22% of the global CO2 emissions (IPCC, 1996).[5]

2.6 Under Inflated Tires

Under-inflated tires can potentially result in:-

- Reduced vehicle handling
- Increased braking distance
- Increased likelihood of blowouts
- Increased tire wear
- Increased fuel consumption

In addition to road safety consequences, under-inflated tires are associated with environment costs such as increased greenhouse gases associated with lower kilometers per tire and higher fuel consumption and disposal problems.

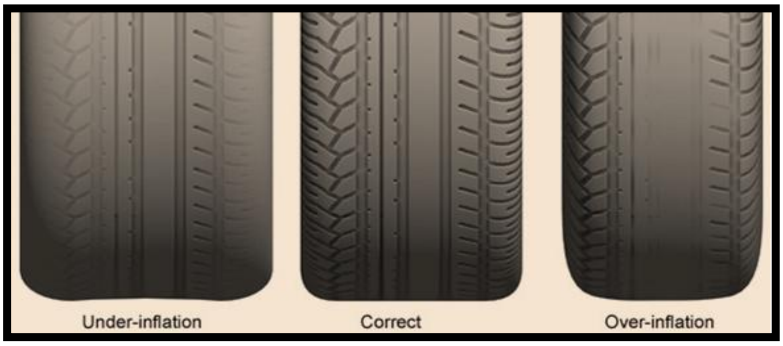


Figure 5 Under Inflated Tyres

A tyre that contains air at 220 kPa at 20 degrees C will have a little over 241 kPa at 38 degrees C – even if the vehicle has not been driven. Conversely, when seasons change and temperature drops, tyres lose pressure. The same tyre that held 220 kPa at 20 degrees C will have about 193 kPa at 0°C and when temperatures are in the subzero range, the loss in the tyre pressure will be even greater. These temperature effects need to be taken into account in the design of tyre pressure monitoring devices.

- **Skidding/loss of control in a curve**

Low tyre pressure generates lower cornering stiffness because of reduced tyre stiffness. When the tyre pressure is low, the vehicle wants to go straight and requires a greater steering angle to generate the same cornering force in a curve. The maximum speed at which an off-ramp can be driven while staying in the lane is reduced by a few mph as tyre inflation pressure is decreased. An example provided by Goodyear shows that when all four tyre’s are at 30 psi the maximum speed on the ramp was 38 mph, at 27 psi the maximum speed was 37 mph, and at 20 psi the maximum speed was 35 mph while staying in the lane. Having only one front tyre under-inflated by the same amount resulted in about the same impact on maximum speed. But, the influence of having only one rear tyre under-inflated by the same amount was only about one-half of the impact on maximum speed (a 1.5 mph difference from 30 psi to 20 psi).

Increased braking distance

Tyres are designed to maximize their performance capabilities at a specific inflation pressure. When tyres are under-inflated, the shape of the tyre’s footprint and the pressure it exerts on the road surface are both altered. This degrades the tyre’s ability to transmit braking force to the road surface. The relationship of tyre inflation to stopping distance is influenced by the road conditions (wet versus dry), as well as by the road surface composition. Decreasing stopping distance is beneficial in several ways. First, some crashes can be completely avoided. Second, some crashes will still occur, but they occur at a lower impact speed and so reduce the severity of the crash and the injuries suffered.[6]

2.7 Tire Inflation Pressure Monthly Loss Rate

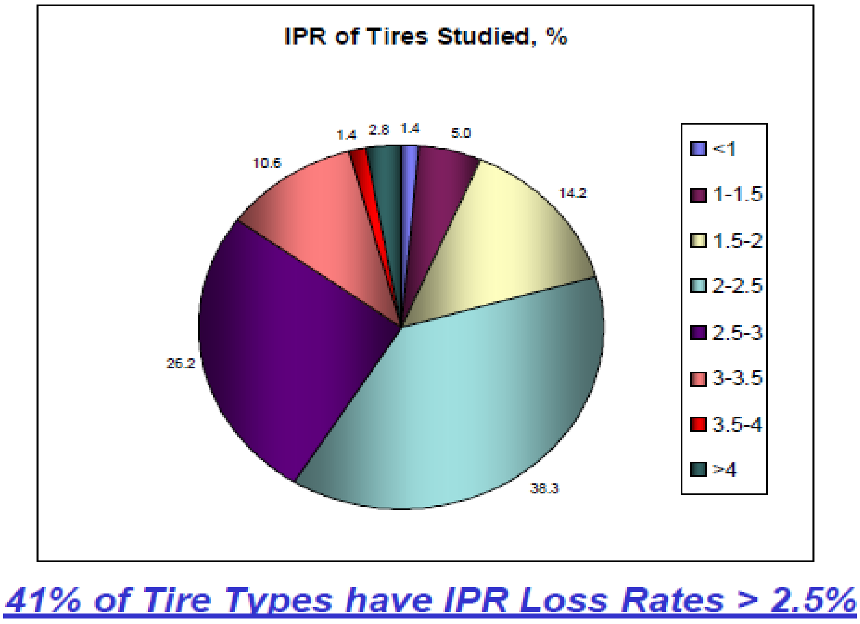


Figure 6 Tire Inflation Pressure Loss Rate

A 1993 NRMA study of tyre conditions found that only 17% of the 3012 tyres surveyed were at the correct pressure and had no other fault. This review did not find any more recent surveys in Australia.

Figure illustrates a breakdown of the incidence of over or under inflation relative to vehicle manufacturer recommended pressure. Only 7% of the tyres surveyed had inflation pressures which were identical to the recommended pressure.[7]

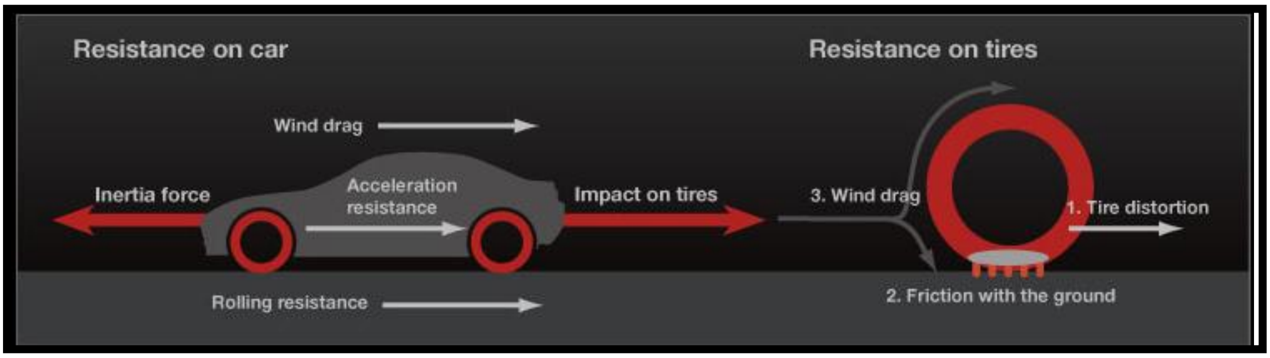


Figure 7 Resistive forces acting on the vehicle and tire

2.8 Contribution of the tire rolling resistance to fuel consumption

Tire rolling resistance is defined as the force required to maintain the forward movement of a loaded pneumatic tyre in a straight line, on a flat road, at a constant vehicle speed when no wind resistance is present. The tyre losses may be attributed to three broadly classified mechanisms:

I. Friction or scrubbing between tyre and roadway,

II. Aerodynamic drag of the rolling wheels,

III. Hysteretic loses of tyres due to cyclic stressing of the rubber compound.

Friction or scrubbing losses occur due to slippage at the tyre-road interface due to tangential forces and due to the difference in the Young's modulus and radii of curvature of rolling bodies in contact, resulting in shear tension and causing shear friction. However, scrubbing has low impact on the RR as it has been found to be hardly affected by lubrication of the surfaces in contact. Though not much of the wheels are exposed in the direction of travel for a passenger car, the aerodynamic drag from the wheels can vary considerably based on the overall design of the tyre carcass and wheel hub. However, under normal operating conditions, majority of the tyre loss can be attributed to hysteresis of the tyre rubber element

Studies have shown that tyre RR has considerable impact on vehicle fuel efficiency. Fuel consumption improvements up to 4 % for urban driving and 7 % during highway driving have been estimated in theory. An estimation by Auto-industries and other sources show that for a 10 % reduction in RR, fuel efficiency could be improved up to 2 %[8]

Importance of having appropriate tyre pressure

The main motivation for properly inflated tyre is to distribute the vehicle load evenly across the tyre footprint thereby providing good contact with the road, passenger comfort, responsive handling and uniform tyre wear. It should be remembered that it is the air pressure inside the tyre that supports the weight of the vehicle. Two situations can arise with improperly inflated tyres namely, under-inflated and over-inflated.

In the case of under-inflated tyres, the tyre life could be reduced considerable if the tyre pressure is maintained low for long periods of time. Tyre manufacturers Michelin and Goodyear have claimed a reduction in tyre life of up to 30 % if tyres are operated 20 % below recommended pressure. Tyre also bends and distorts more, resulting in over-heating and increased RR. In a test conducted by tiretrack.com [4], it was even found that the vehicle was a few seconds slower around a track on under-inflated tyres, with drivers reporting a detached feeling from the vehicle in the corners.

For the over-inflated case, the tire could sustain damage when riding over road surface irregularities such as potholes and bumps. Passenger comfort is also marginally compromised. Increasing the tire pressure results in a decrease in tire-road contact area, resulting in slightly poorer traction and braking capabilities. Figure 11 shows typical tire wear patterns observed for an under-inflated, recommended and over-inflated tire. An under-inflated tire tends to wear at the shoulders more than at the center, since the pressure is not sufficient at the tire center to bear the load. For over-inflated tires, the wear is severe along the center due to bulging of the tire structure at high pressures.[9]

Contribution to Fuel Consumption

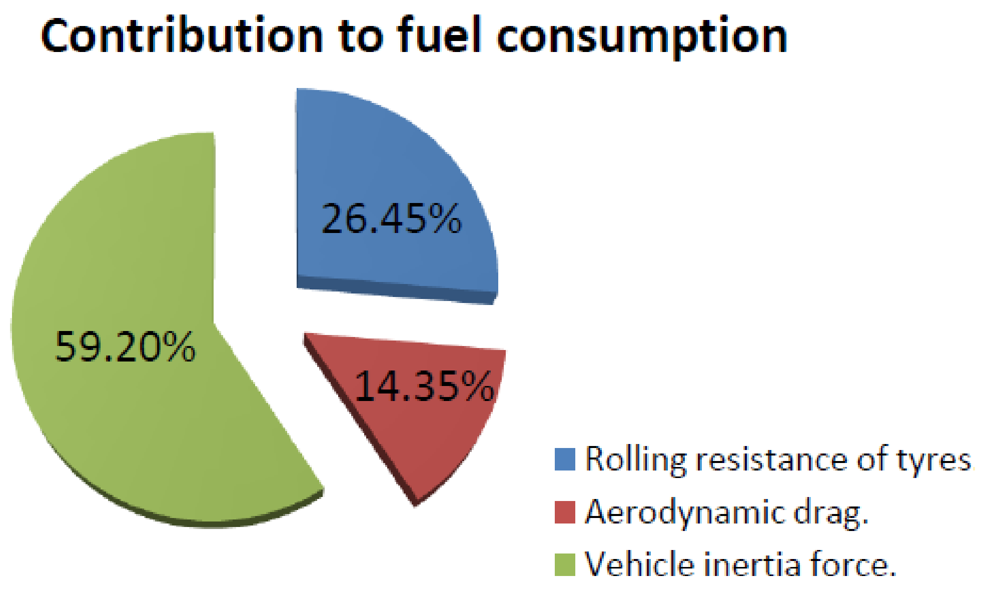


Figure 8 Contribution to fuel consumption

It can be clearly seen that the RR of tires contribute to nearly 27 % of the overall fuel consumption. Thus, any attempt at improving the fuel economy of a vehicle, without major vehicle redesign or resorting to exotic materials, should begin at the tires. However, the entire 27 % may not be accessible for improving the vehicle's fuel efficiency with the current materials and technologies used in pneumatic tires. Also, any changes made to the tires to reduce its RR should not affect the tires performance.

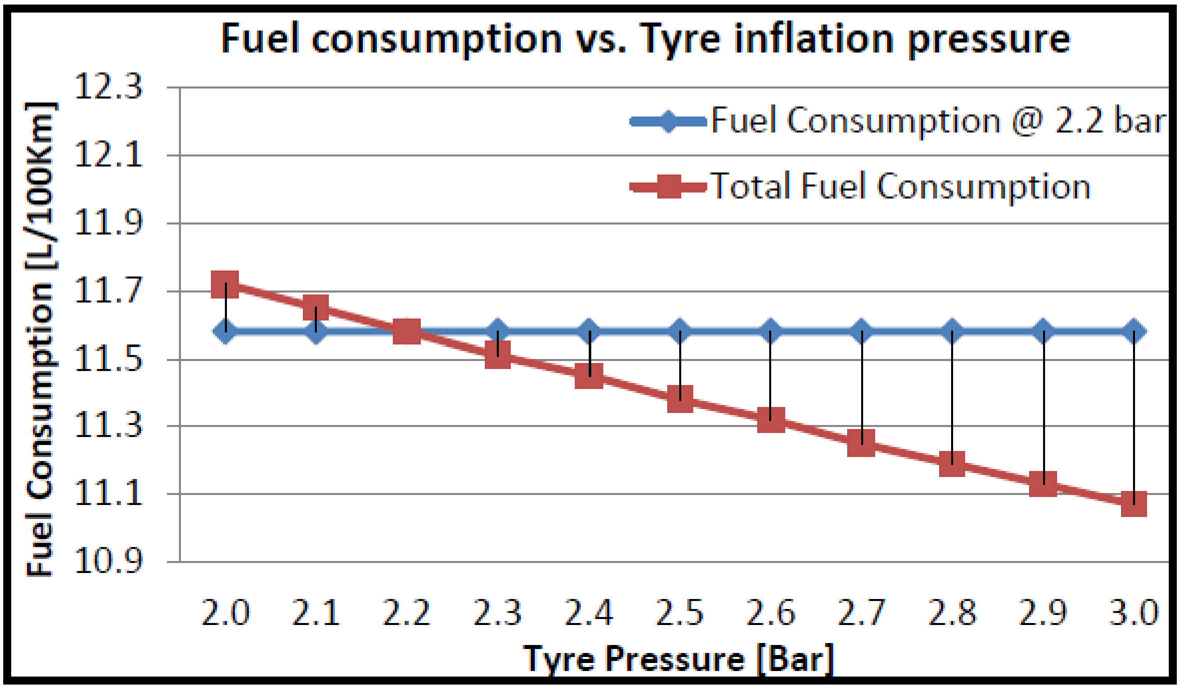


Figure 9 Fuel Consumption vs. Tyre Inflation Pressure

Figure 2.5: Fuel Consumption vs. Tyre Inflation Pressure

The blue lines (diamond markers) correspond to the fuel consumption at nominal pressure of 2.2 bar. The red curves (square markers) show the actual variation of fuel consumption with tire inflation pressure. It can be seen that the fuel consumption reduces with increase in pressure. This is consistent with the findings in literature review. Between the pressure range of 2 bar and 3 bar fuel reduction of 5.2 % was observed. Here, it was assumed that the loaded tire radius increases by 16 mm between pressure of 2 bar and 3 bar.

In reality, it may not possible to achieve such high value since the losses due to slippage has not been included. When the tire losses were included in the simulation for the NEDC city cycle at an inflation pressure of 2.2 bar, the fuel consumption increased from 11.68 L/100km to 11.71 L/100km, indicating an increase of only 0.25%.

The reduction in fuel consumption with the increase in pressure can be observed even beyond 3 bars. However, this will be at the expense of reduced ride quality, poor traction and increased uneven tire wear.[10]

2.9 Automatic Tyre Inflation Management

Table 1 Benefits of ATIM

Fuel benefit (L/100 km)	GHG benefit (g CO2-e/km)	Economic benefit ($/100 km)
0.19%□□ (saving 0.23 L/100 km)	0.19%□□ (saving 3 g CO2-e/km)	0.19%□□ (saving $0.15/100 km)

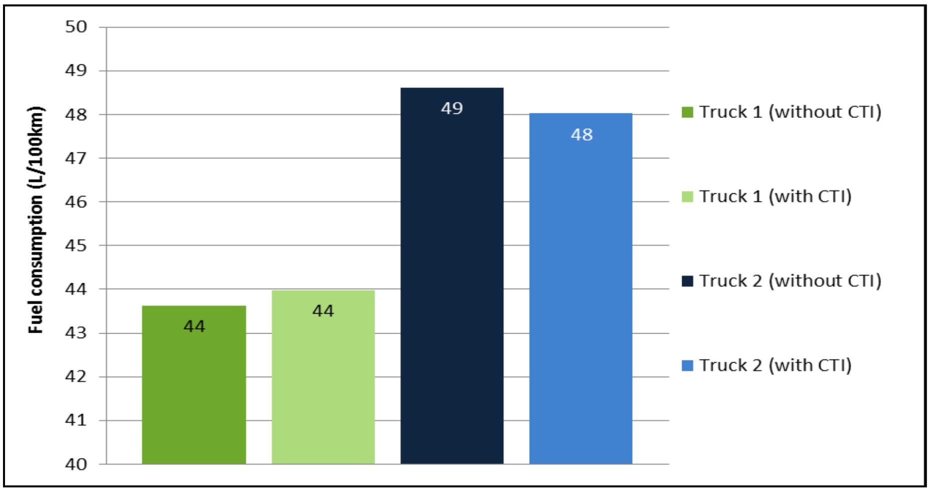


Figure 10 Fuel Consumption

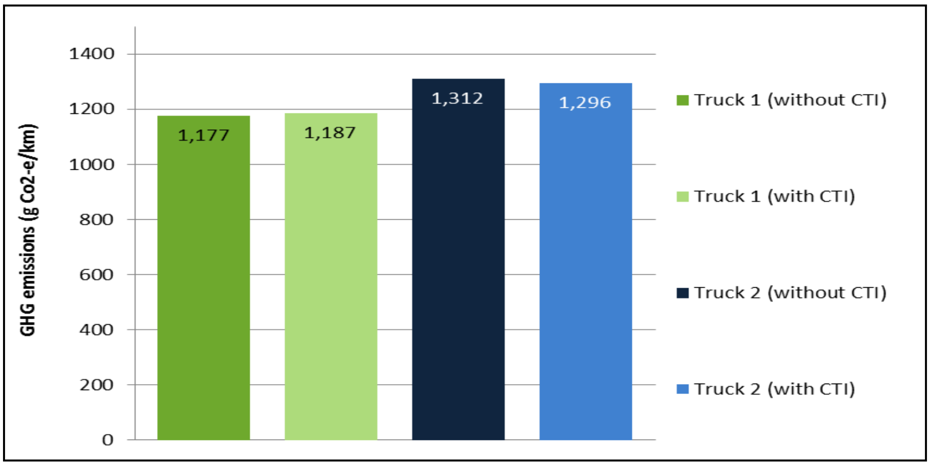


Figure 11 GHG Emissions

2.10 Existing Systems

Tire Pumping systems are the systems which are developed with the aim of maintaining automatically so as to avoid effects of under or over inflated tyres. .

Tire Inflation Systems were first tried onto commercial and military vehicles in the year 1942. The Czech military truck Tyre inflation and deflation system was designed to maintain pressure even after multiple bullet punctures.

Numerous technologies were developed and introduced in the industry pertaining to similar results. Namely, Central Tire Inflation System(CTIS), Automatic Tyre Inflation System, Self Inflating Tyres, Halo Tire Inflator, Mechanized Air filling System.

2.10.1 Central Tire Inflation System

It is a system to provide control over the air pressure in each tire of a vehicle as a way to improve performance on different surfaces. Another function of the CTIS is to maintain pressure in the tires if there is a slow leak or puncture.

Figure 12 CTIS deployed on a trailer 1 CTIS deployed on a trailer

2.10.2 HALO Tire Inflator

Halo Tire inflator is a very revolutionary concept introduced by Aperia Technologies, California. This system works pretty much to achieve the same objective but it has been designed in a very compact and modulated fashion. Thus overcoming the drawbacks of CTIS. It is easy to use and install.

Figure 13 HALO Tire Inflator

2.10.3 Self-Inflating Tires

SIT is a newer technology developed by CODA development in the year 2008. It is still in the nascent stage but has yielded excellent results. SIT uses the energy of the wheel to self-inflate the tyres as needed, keeping the tires always at optimum pressure level.

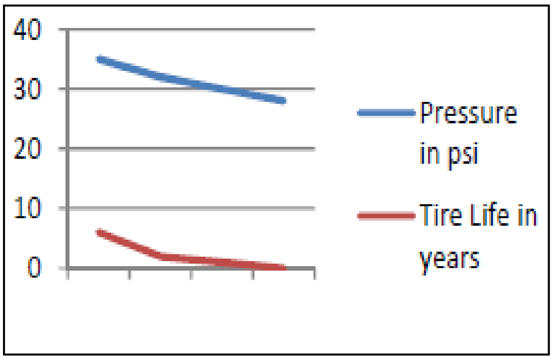


Figure 14 Self Inflating Tire

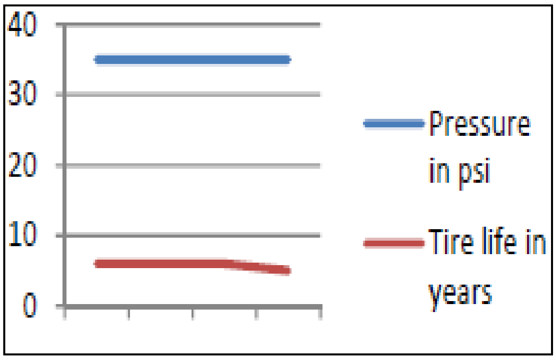


Figure 15 Tyre Pressure vs Life

The two graphs show a comparison between the pressure level in tire and the life time of the tire before and after using the system. The manufactures say that the maximum life time of a tire is mostly around 6 years.

Figure 1- Before using the system, the pressure level is not maintained properly. Due to this improper maintenance of the tire, the life time of the tire falls rapidly. This causes the early replacement of tire. The under inflation also causes more wear and tear of the tire. This under inflation allows punctures to occur easily.

Fig 2- After using the system, the pressure level is maintained properly. The tire is filled with optimum air. Thus the life time of the tire is maintained properly. As it is filled with optimal air the Probability of puncture is greatly reduced.

2.10.4 Automatic Tyre Inflation System

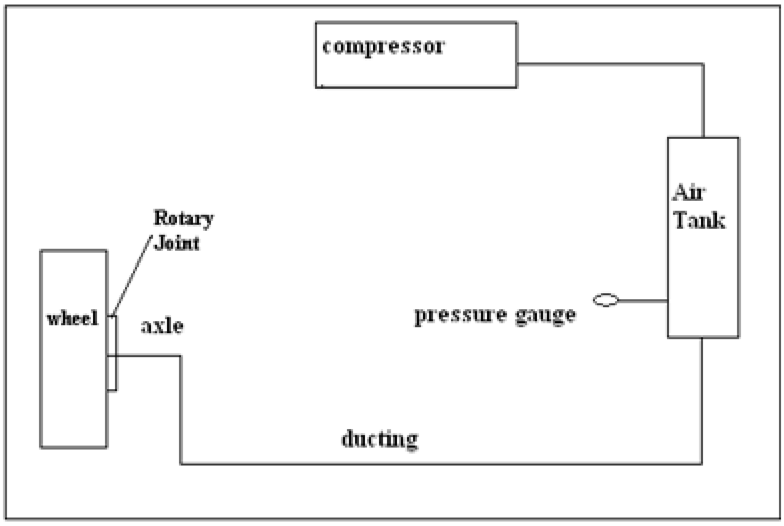


Figure 16 Automatic Tire Inflation System

In the process of automatic tyre Inflation system, the compressor is used to compress the air. The air is taken from the atmosphere and compressed it at required pressure. There is ducting which is used connect to the compressor outlet port and one end of the rotary joint. The compressed air is supplied to the rotary joint through the ducting. Two Pedestal bearings are used to support the axle of the assembly. Bearings are fixed to the rigid supports via nuts and bolts. The axle is rotate on which wheel or rim is mounted on one end. One end of coupler is connected to axle and other end is connected to rotary joint. There are electronic sensors are used to detect the tyre pressure with the help of pressure gauge. When the pressure in the tyre reduced below the required level then the sensors senses the pressure level and send feedback signal to compressor for maintaining pressure level of the air in the tyre.[10]

3. Chapter 3 Report On Present Investigation

3.1 Design of Rear Axle

3.1.1 Aim

To design an axle that can handle all the stresses and forces that will transmit onto it during static as well as dynamic conditions.

3.1.2 Forces Transmitted onto Axle

1. SINGLE POINT LOADS:

These will act onto the axle from chassis at both the ends. It will include passenger weight as well as vehicle weight.

Location: 100 mm from both ends

Magnitude: 760 N

2. ENGINE TORQUE/ MOMENT:

This force will act at the center of the axle, transmitted from the sprocket which is connected to the engine via chain drive.

Location: 600 mm

Magnitude: 10.8 Nm

3. BENDING FORCE:

This force will be acting on the entire length of the axle and will lead to sagging of axle.

Location: At the center of the axle, 600 mm

Magnitude:

4. SIDE THRUST:

This force will be transmitted onto the axle when the vehicle is executing a turn.

Location: At both ends of the axle.

Magnitude:

3.1.3 Material Selection

We have chosen the material EN30A according to the British Standards and is 30 Ni 4Cr 1 according to Indian Standards (IS).

Table 2 Properties of the material EN30A

MATERIAL	30 Ni 4 Cr 1(EN30A)
% C	0.35-0.45
%Si	0.1-0.35
%Mn	0.4-0.7
%Ni	3.9-4.3
%Cr	1.1-1.4
Tensile Strength	155 Kgf/mm^2
Yield Strength	130 Kgf/mm^2
Brinell Hardness Number(HB)	444

3.1.4 Calculations

Shafts are designed based on

A. Strength

B. Rigidity / Stiffness.

DESIGN OF SHAFTS BASED ON STRENGTH IS AGAIN DONE ON

- Shafts subjected to TWISTING LOADS / TORQUE
- Shafts subjected to BENDING ONLY.

➢ Shafts subjected to TORQUE AND BENDING

1. **DESIGN OF SHAFTS SUBJECTED TO TWISTING MOMENT / TORQUE ONLY**

We have the general Torsion equation as **T / J = T / r**

Where,

T = Torsional moment / Twisting Moment / Torque - N-mm

J = Polar Moment Inertia of cross sectional area about the axis of rotation – mm^3

T = Torsional Shear stress of the shaft – MN / mm^2

r = Radius of the outer most fabric from the axis of the rotation

= d/2, where d = dia. of the shaft.

Also $J = \pi d^2 / 32$

$$T = \frac{\pi d^3}{32} \times \frac{\mathbf{T}}{d/2} = \frac{\pi d^3}{16} \times \mathbf{T}$$

Then r = d / 2 & $J = \frac{\pi \times d^2}{32}$

$$\text{Then } T = \frac{\pi \times d^2 \times 2}{32}$$

$$= \frac{\pi \times \mathbf{T} \times d^3}{16}$$

$$d^4 = \frac{16 \times T}{\pi}$$

Therefore, $d^4 = \frac{16 \times 10.8 \times 10^3}{\pi}$

d= 15.31 mm

We also know that Torque T is given by $T = \frac{P \times 60}{2 \pi n}$

Where P = Power generated / transmitted in kW &

n = Revolutions per Minute (r. p.m)

2. DESIGN OF SHAFTS SUBJECTED TO ONLY BENDING MOMENT

We have the General bending equation $\frac{M}{I} = \frac{\sigma}{r} \quad y$

Where

M = Bending Moment – N-mm

I = Second moment of area / Moment of Inertia – mm^2

σ = Bending Stress – N / mm^2

r = radius of the shaft = d/2,

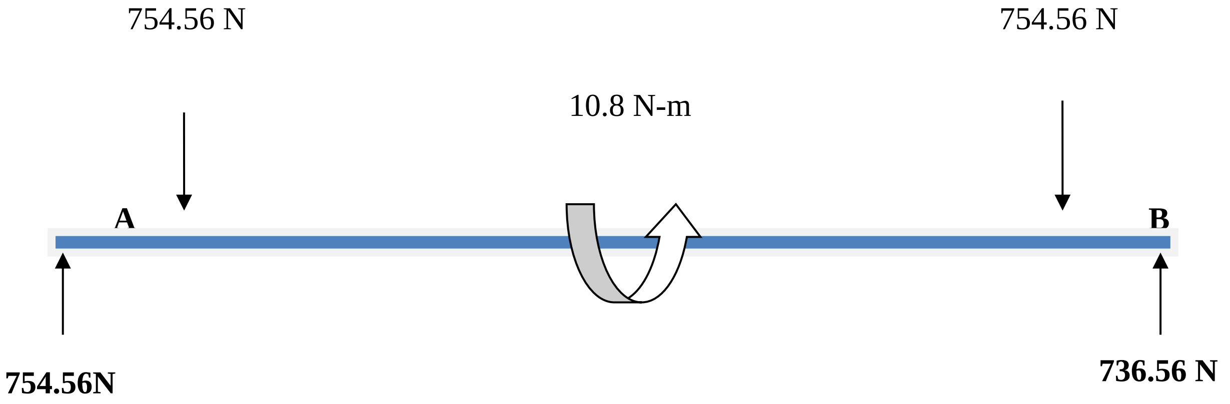
d = dia. of the shaft

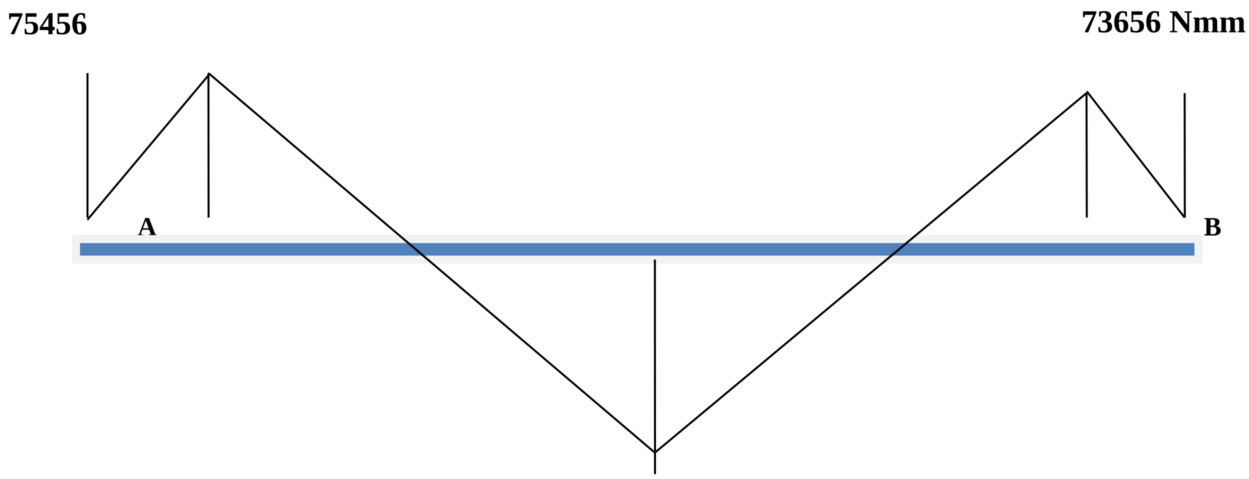
Also I of a solid shaft = $\pi d^3/64$FOS= 3

Then $\frac{M}{\Pi d^3 / 64} = \frac{\sigma}{d/2}$ (or) $\frac{M =}{32} \sigma \pi d^3$ ……….. Eqn. (1)

To calculate bending moment of the axle, we have to consider axle as a beam and find the bending moment of the beam.

The FBD of the axle is





From the bending moment diagram we have calculated maximum bending moment to be M= 75456 N-mm

Therefore,

$$d^3 = \frac{32 \times M}{\pi\ \sigma}$$

$$d = \frac{32 \times 75456}{\pi \times 310}$$

d= 13.53 mm

3. Shafts subjected to both twisting & Bending Moments.

- The shaft must be designed on the basis of two moments simultaneously.
- Materials are subjected to elastic failure when subjected to multiple forces.

Maximum shear stress theory – Guests theory – Used for ductile materials

We have, for a solid shaft, the max. shear stress (τ_{max}) is given by

$$T_{max.} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\,(T)^2} \quad \text{……… eqn. II}$$

$\tau_{max} = 0.5 \sqrt{(2x155)^2 + 4x\ (10800)^2}$

$\tau_{max} = 163.38\ N/mm^2$

σ = Bending stress – MN / mm^2 **τ** = Shear stress MN / mm^2 D = Diameter of the shaft.

But we have $\sigma = \sigma_b = \frac{32\ M}{\pi d^3}$ & $\tau = \frac{16\ T}{\pi d^3}$

Substituting these values in eqn (II) $\tau_{max.} = \frac{1}{2} \sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left|\frac{16T}{\pi d^3}\right|^2}$

$= \frac{1}{2} \frac{16}{\pi d^3} \sqrt{(2M)^2 + 4\ (T)^2}$

$\tau_{max.} = \frac{1}{2} \frac{16}{\pi d^3}\ 2 \sqrt{M^2 + T^2}$

Therefore, $d^3 = \frac{16 \times \sqrt{(75456^2 + 10800^2)}}{\pi \times 163.38}$

Therefore, d= 19.58 mm

After checking the shaft diameter from all the three methods, we have chosen the diameter of shaft as **d= 25 mm.**

3.1.5 CAD Modeling

Model name: rod

Current Configuration: Default

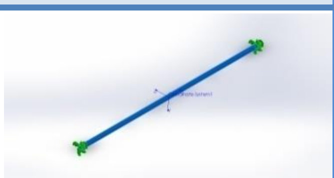
Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
 Boss-Extrude1	Solid Body	Mass:4.62403 kg Volume:0.000589049 m^3 Density:7850 kg/m^3 Weight:45.3155 N	C:\Users\Nawaz\Desktop\azim\rod.SLDPRT Apr 16 16:41:15 2015

Figure 17 cad model of axle

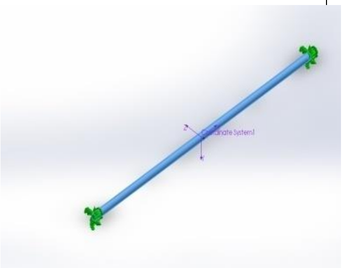
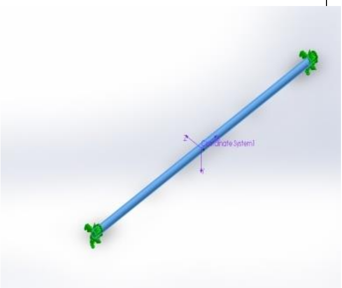
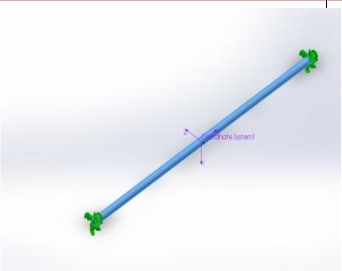
Load name	Load Image	Load Details
Remote Load (Direct transfer)-1		**Entities:** 1 face(s) **Type:** Load(Direct transfer) **Coordinate System:** Coordinate System1 **Force Values:** ---, ---, -745.56 N **Moment Values:** ---, ---, --- N·m **Reference coordinates:** 500 0 0 mm **Components transferred:** Force
Remote Load (Direct transfer)-2		**Entities:** 1 face(s) **Type:** Load(Direct transfer) **Coordinate System:** Coordinate System1 **Force Values:** ---, ---, -745.56 N **Moment Values:** ---, ---, --- N·m **Reference coordinates:** -500 0 0 mm **Components transferred:** Force
Remote Load (Direct transfer)-3		**Entities:** 1 face(s) **Type:** Load(Direct transfer) **Coordinate System:** Coordinate System1 **Force Values:** ---, ---, --- N **Moment Values:** -10.8, ---, --- N·m **Reference coordinates:** 0 0 0 mm **Components transferred:** Moment

Figure 3.3: loads on axle

3.1.6 Fabrication

Stress Analysis has shown the axle is safe under the corresponding conditions so the axle is mounted on the go-kart

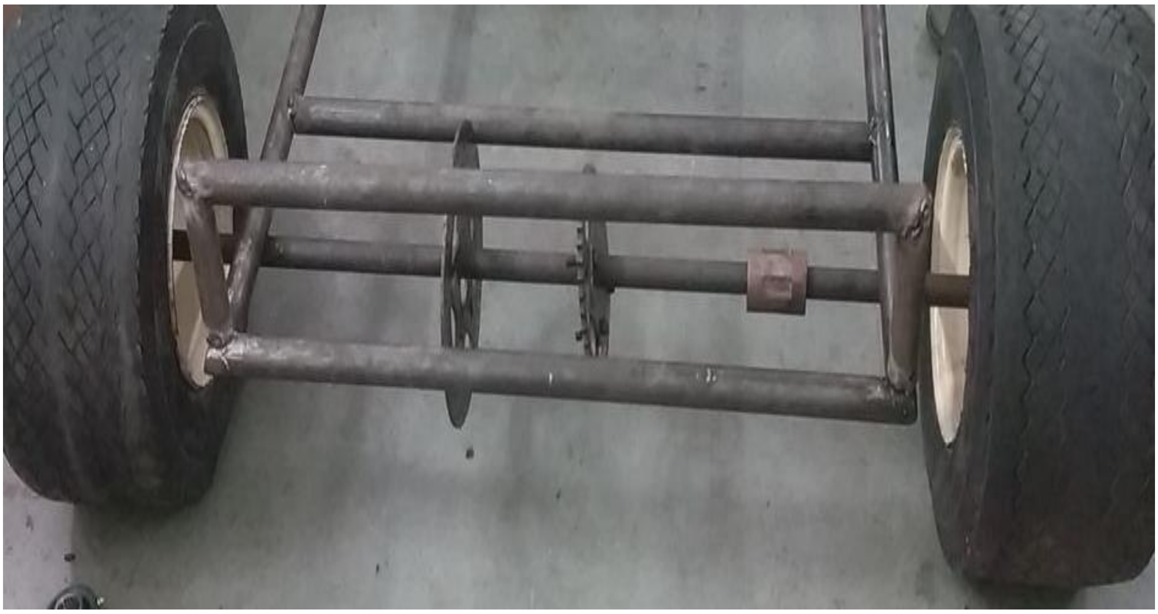


Figure 18 Axle mounted onto the wheels 1

3.2 Instantaneous Tire Pumping System

3.2.1 Aim / Objective

- The main need or objective of this system is to maintain optimum tire pressure in all tires of a vehicle.
- By achieving the above foresaid condition, we can overcome many difficulties or problems associated with the tire inflation pressure of an automobile.
- Our main objective of designing this system was to develop a compact apparatus which can be easily handled and incorporated into a vehicle.
- Lastly, it has been developed keeping in mind the aesthetic and ergonomic conditions.

3.2.2 Components Used For System

- Pneumatic tire
- Axle assembly
- Pneumatic pipes(”)
- Rotary union(1/4”)
- Tire inflator(300psi, 12v)
- Connectors
- Teflon tape
- 12v battery
- Billet

Figure 19 Circuit Assembly

For circuit

- 3v dc motors(2 nos)
- 3v battery(2 nos)

- Copper wire
- 50 psi pressure gauge
- Board
- Insulation Tape

3.2.3 Construction

- The system consists of a rotary union which has been attached to the axle of a wheel, through a threaded screw. The main feature of a rotary union is that it operates with its one port stationary and the other rotating.
- This will serve as the inlet port of union as well as the air.
- The outlet of the union will be connected to a 4" pneumatic pipe via connector.
- The end of the pipe will be connected to a billet which will serve as a secure connection with the tire inlet.

Figure 20 Air Inlet

Figure 21 Air Outlet

- The billet has a locking mechanism, once locked it will not come out of its position, until and unless required.
- The axle has been made hollow only for the portion along which the air will be passed from the inlet to the outlet.
- The inlet port will be hidden inside the wheel assembly. The axle will be made hollow only from the inlet to the outlet.
- Specific care has been taken to avoid weakening of the axle assembly due to hole length.
- The inlet of air will be secured by a connector, to which a 6” pneumatic pipe will be attached.
- The pipe will be connected to the compressor outlet via pressure gauge which will be sensing the pressure of the tire.
- The whole assembly of this system can be easily mounted on chassis of a vehicle and can be easily configured with a TPMS system which is a common feature in modern automobiles.

3.2.4 Working

- Reduced air pressure will be sensed by the pressure gauge and it will activate the circuit.
- The circuit will connect the 12 V battery and will supply current to the tire inflator.
- The inflator will send the air from the duct to the inlet at the axle.
- The axle being hollow will pass on the air to the outlet of axle port, which is also the inlet of the rotary union.
- The union will take inlet from stationary port and will supply air from the outlet port, which is rotating with the wheel.
- The outlet of union is a pipe and billet arrangement, which finally fills the air into the tire.
- This whole arrangement comprises of ITPS system.
- The system can be incorporated with all the wheels of a vehicle but for demonstration purpose we have done it on a single wheel.

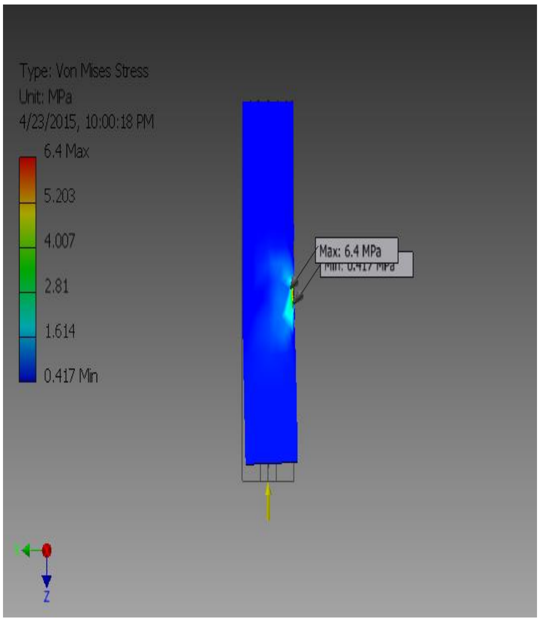


Figure 22 Stress Analysis SAFE

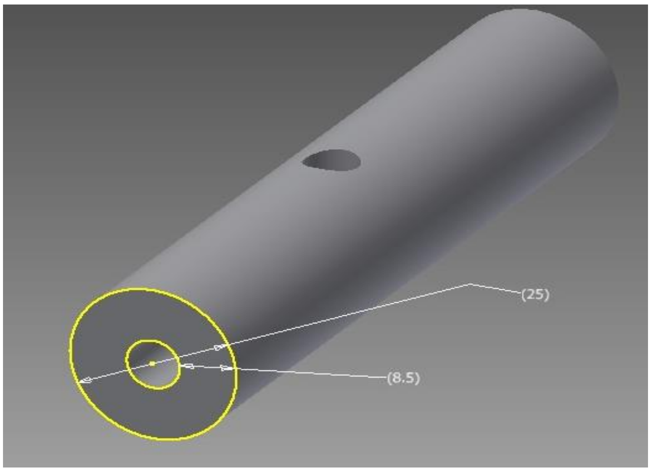


Figure 23 Shaft Model

3.2.5 Circuit Diagram

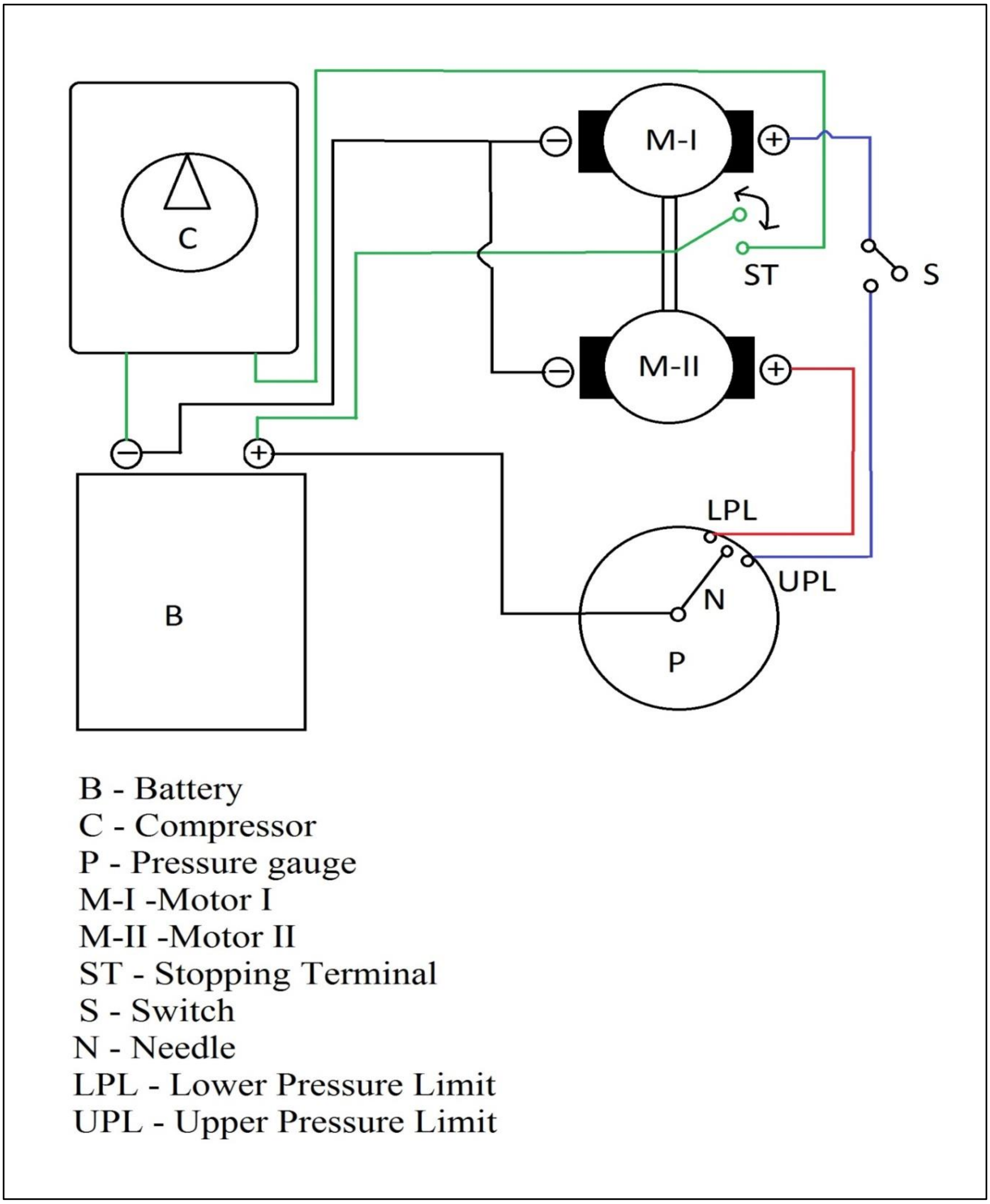


Figure 3.10 Circuit Diagram

3.2.6 Working of Circuit

- Initially when the vehicle is in running condition, the ITPS system does not come into pressure.
- Only when the tire starts to lose its pneumatic pressure, the system will be activated.
- The drop in pressure of the tire will be sensed by the pressure gauge included in the circuit.
- This circuit is designed using 2 3V Dc motors. These are attached to each other and on their intersection is a copper strip.
- When the copper strip touches the terminal, the circuit is in on position.
- The circuit sends signal to the battery to supply current to the tire inflator.
- Once the tire inflator is switched on, it supplies air to the tire, through a series of ducts attached to the chassis of the car.
- As soon as the tire attains optimum air pressure levels, the pressure gauge attains the reading.
- The pointer touches the terminal and hence cuts the inflator from the circuit.
- The same sequence of operations are performed every time when there is a difference in tire pressure levels.

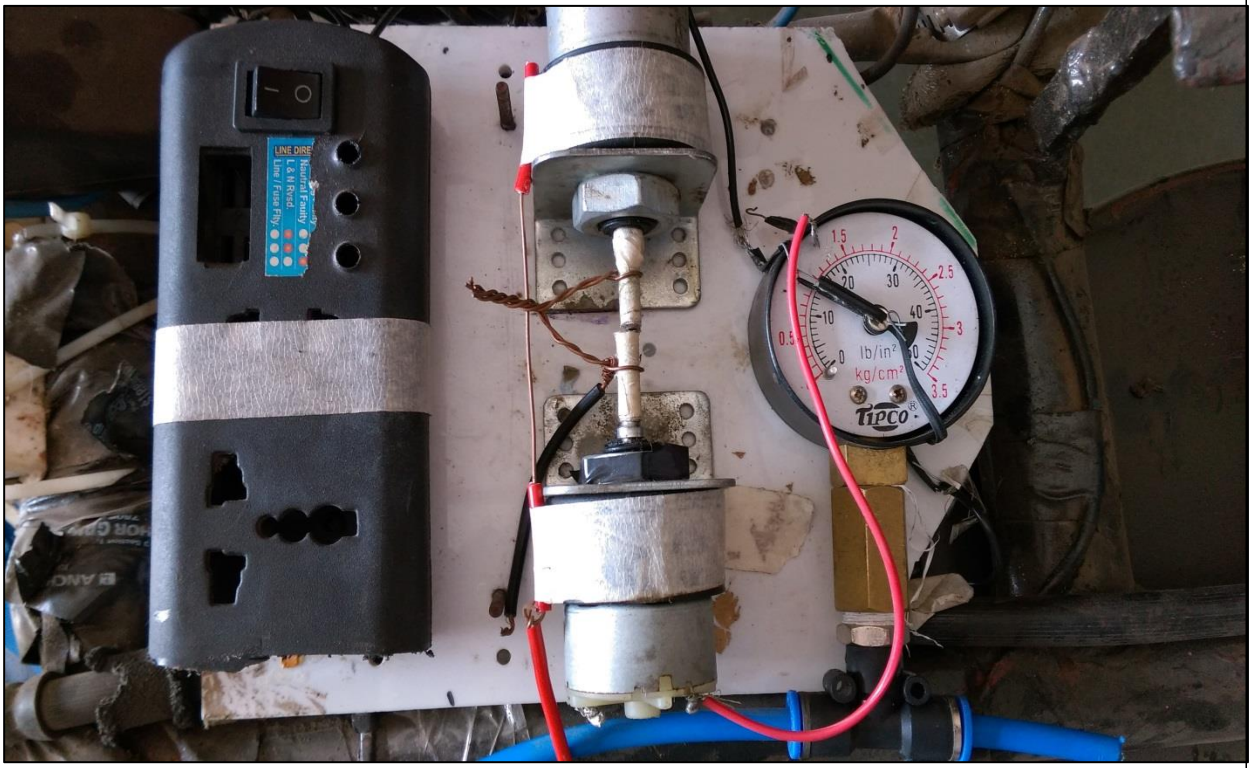


Figure 3.11 Circuit

Chapter 4 Results and Discussions

4.1 Stress Analysis

The stress analysis of the axle is done on SOLIDWORKS Software and the following results are obtained

4.1.1 Mesh Information

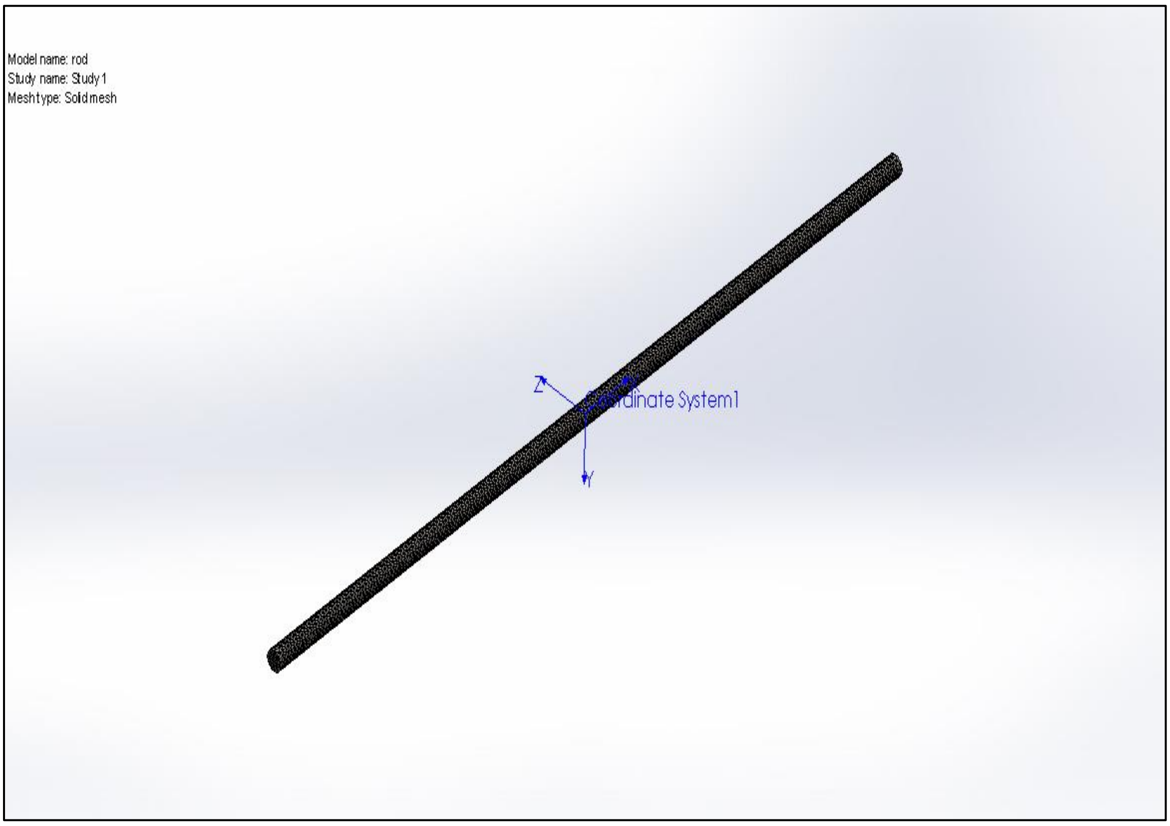


Figure 24 Mesh View

4.1.2 Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	21509.8 N/m^2 Node: 39945	2.77563e+008 N/m^2 Node: 34524

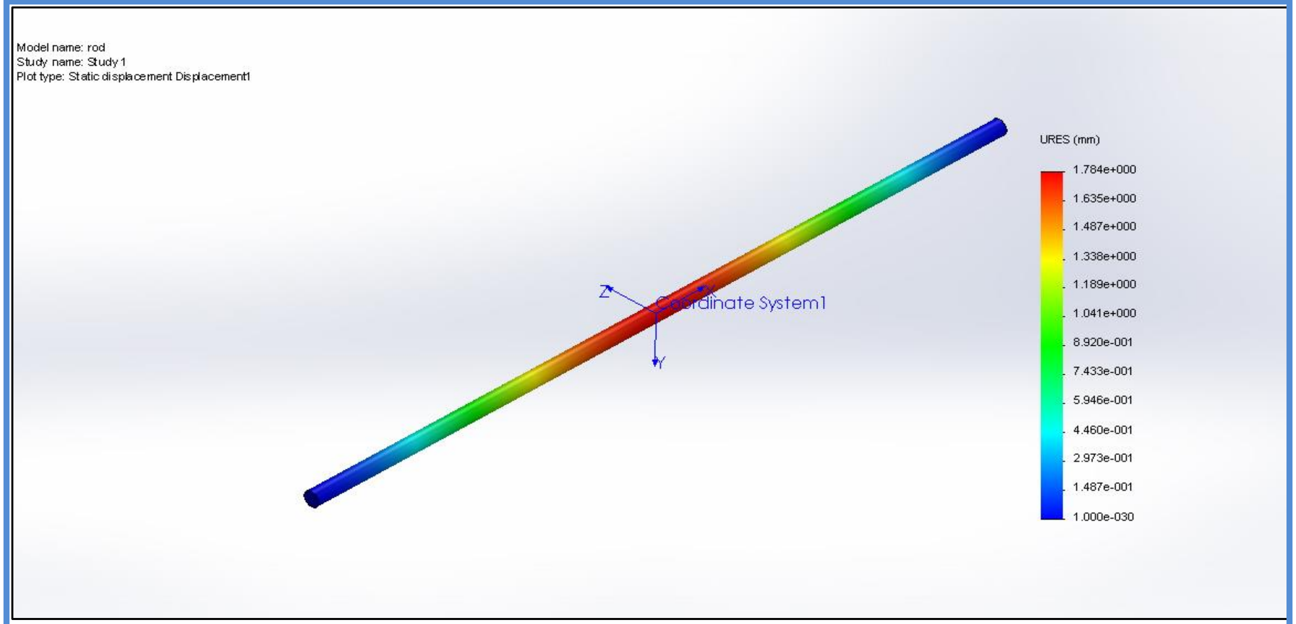


Figure 25 Von Misses Stress

4.1.3 Resultant Forces

Reaction Forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1488.41	0.0613098	0.0466919	1488.41

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N·m	0	0	0	0

4.1.4 Stress Analysis on ANSYS Software

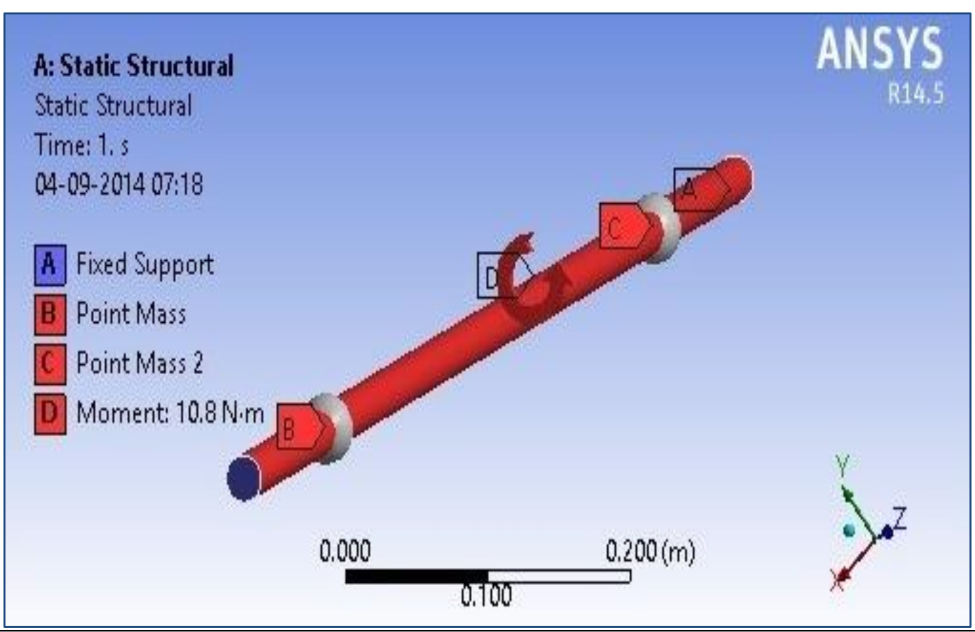


Figure 26 Geometry of Axle

Object Name	*Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	EN 30 A
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	2.54e-002 m
Length Y	2.54e-002 m
Length Z	1.2 m
Properties	
Volume	6.0805e-004 m³
Mass	4.7799 kg
Centroid X	9.6216e-020 m
Centroid Y	-1.2829e-019 m

Table 3Force on Axle

Object Name	*Point Mass*	*Point Mass 2*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	
Applied By	Remote Attachment	
Coordinate System	Global Coordinate System	
X Coordinate	1.1412e-019 m	
Y Coordinate	5.4683e-020 m	
Z Coordinate	0.2 m	1. m
Location	Defined	
Definition		
Mass	76.45 kg	
Mass Moment of Inertia X	0. kg·m²	
Mass Moment of Inertia Y	0. kg·m²	
Mass Moment of Inertia Z	0. kg·m²	
Suppressed	No	
Behavior	Deformable	
Pinball Region	All	

Object Name	*Fixed Support*	*Moment*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	2 Faces	1 Face
Definition		
Type	Fixed Support	Moment
Suppressed	No	
Define By		Vector
Magnitude		10.8 N·m (ramped)
Direction		Defined
Behavior		Deformable
Advanced		
Pinball Region		All

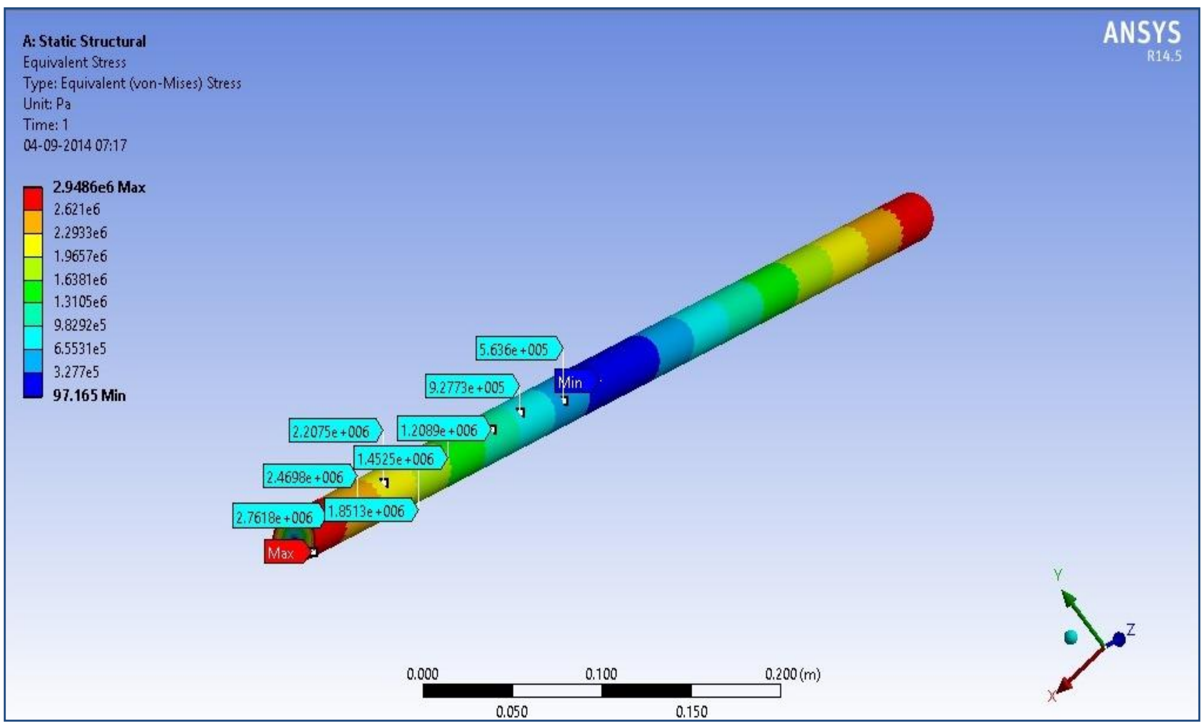


Figure 27 Stress Analyis

Table 4 Ansys Results

Object Name	*Equivalent Stress*	*Total Deformation*	*Directional Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent (von-Mises) Stress	Total Deformation	Directional Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			Y Axis
Coordinate System			Global Coordinate System
Integration Point Results			
Display Option	Averaged		
Results			
Minimum	97.165 Pa	0. m	-6.294e-006 m
Maximum	2.9486e+006 Pa	6.294e-006 m	
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		

4.2 Instantaneous Tire Pumping System

The ITPS system was tested and checked for its claims in both static as well as dynamic conditions.

We made the following observations:

- The system's construction was found to be effective and working in actual scenario or road conditions
- The system's claims were that it can fill air in the tires of a vehicle during motion of vehicle were found to be true.
- The system pumps air from the compressor and via pneumatic pipes into the axle hub assembly.
- The air comes out from the assembly and from the rotary union it makes it way to the tire.
- The passage of air has been made of very narrow diameter, to avoid lesser strength to axle due to hollow cavity.
- The pressurized line was also checked for leakages and the system was effective there also.
- The minimum set pressure for tyre has been kept to 16 psi and the maximum has been kept to 18 psi.
- The maximum time required to fill in air from lowest permissible pressure reading to required optimum pressure was found to be 3 minutes.
- The air pressure is not allowed to fall below or rise above the stated limits.
- The circuit designed for automatically switching on and off the compressor was also found to be working

To summarize the above mentioned points, we can say that ITPS system has met its claims and is working effectively within the specified limits. It is a revolutionary concept with many inherent advantages and thereby is much superior to the current existing inflation systems in the market.

4.2.1 Advantages of ITPS are mentioned below

- Easy installation(Retro Fit)
- Durable
- State of the art system which can be installed in any automobile
- Reduced tyre blowouts since tyres remain at the proper inflation level at all times.
- Low maintenance cost and time efficiency.
- Reduce human efforts.
- Increase the vehicles engine efficiency
- Better Fuel Economy
- Increase the life span of tyre
- Avoids accidents and fatality.
- Safety feature for all modern vehicles
- Low Initial cost as compared to existing systems in the market

4.2.2 Applications

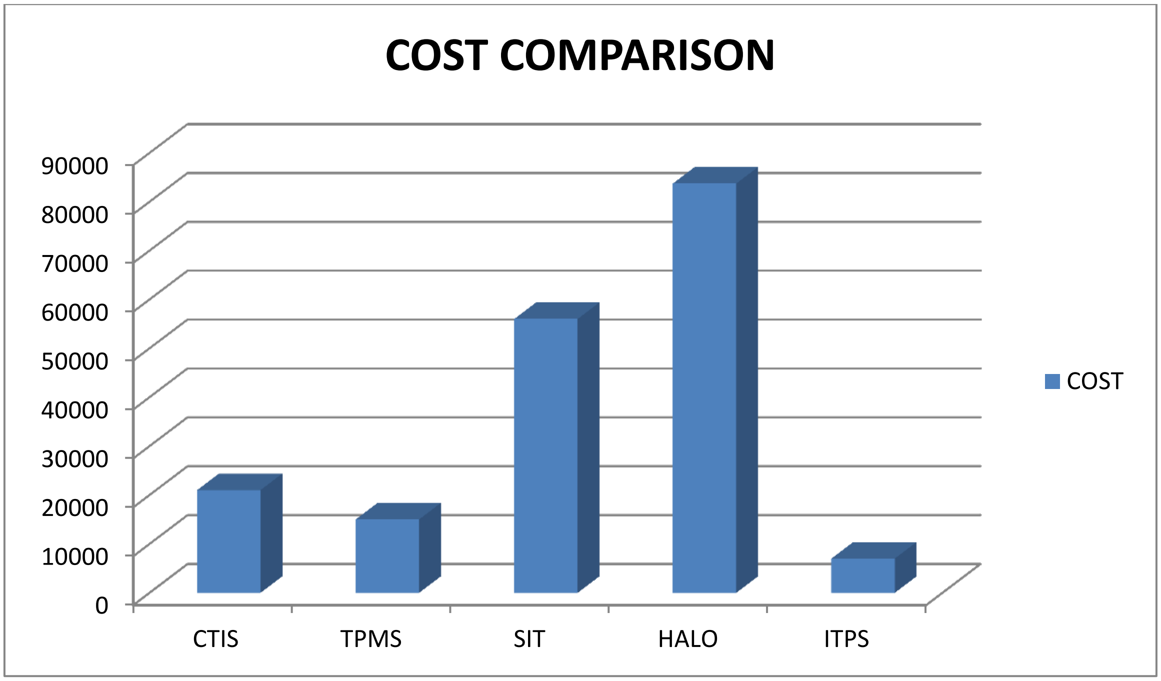
- Passenger vehicles are the first consumer segment to which this system is targeted to.
- Commercial or heavy vehicles.
- Military Vehicles
- All-Terrain Vehicles
- Earthmovers or Heavy Machines
- Special purpose vehicles

4.2.3 Cost Comparison

The industry has already worked on this concept and developed certain systems which fulfill the objective of maintaining optimum tyre pressure. Although these systems are more robust and reliable but they come with some inherent disadvantages.

Table 5 Cost Comparsion

Sr no.	Name of the system	Cost of installation
1	Central tyre inflation system	₹21000
2	Tyre pressure monitoring system	₹15000
3	Self-inflating tyres	14000x4= ₹ 56000
4	Halo tyre inflator	20930x4=₹83720
5	Instantaneous tyre pumping system	₹7000



Chapter 5 Conclusion and Future Scope

5.1 Axle

- The axle was designed and modeled successfully in CAD software
- The CAD model was simulated for checking the material selection and design adopted
- The axle model was found to be safe in both the software. The principal stresses were found to be within the prescribed limits.
- The axle design has been made more safe and robust
- The material selected in our project satisfies all the conditions of dynamic and static forces.
- The Axle was fabricated and mounted on the Go-kart.

5.2 ITPS

- The model was successfully built and incorporated in the vehicle
- The mechanism is dynamically stable and met its claims of maintaining optimum tire pressure automatically.
- The axle assembly used in ITPS was also simulated and its deflection was within permissible limits.
- The model of ITPS met its claims and was successfully implemented in the vehicle. The System is found to be cheaper than the systems presently available in the market.
- The ITPS system can be considered as a benchmark technology in automobile field
- It can be customized and made more efficient according to the application

5.3 Future Scope

- The idea presented by us through the ITPS system has although been implemented by companies in the industry but it still has to be made more robust and r3eliable system for it to commercialize successfully.
- The ITPS system can be integrated with the existing Tire Pressure Monitoring Systems(TPMS) so as to get reliable input of data and thereby increase the effectiveness of the system.
- The ITPS system plays a major role in saving fuel costs and increasing tire and hence it saves money as well as energy, thereby meeting the need of the hour.
- The ITPS system can also be developed for commercial or heavy vehicles using the same ideas but increasing the range and strength of the mechanism.
- This mechanism being cost effective can attract customers at a faster rate than the others and hence it needs to be developed by companies across the globe.
- Although this idea is in infant stages, still it can be worked upon to bring in improvements in design and detailing of the system. It can be made more robust and compact and reliable by increasing sensitivity of the apparatus.
- After mentioning above points, we can say that ITPS system can be regarded as a mandatory safety and additional feature for an automobile and hence it should be made mandatory by the Government to install them on all vehicles

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