IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 1, January 2020, ||Series -V|| PP 13-21

Design and Development of Measurement System for Automotive Tyre Parameters

1st A. P. Thakare, 2nd A. S. Patil, 3rd V. D. Tonge
Mechanical Engineering PRMIT&R, Badnera. Amravati, India
Assistant Professor Mechanical Engineering PRMIT&R, Badnera. Amravati, India
Assistant Professor Mechanical Engineering PRMIT&R, Badnera. Amravati, India
Received 02 January 2019; Accepted 16 January 2020

Abstract: In automobile engineering under automobile components tyre are one of the important components. It is directly responsible for safety and performance of the vehicle. Tyres are one of most important parts of the vehicles, because tyre provides only connection between the vehicle and the road. Therefore, it is important to have a good understanding of the behaviour of these important parts.
The aim of this project is to improve the understanding of tyre behavior with tyre wear. Experiment are performed by to verify the correlation between tyre pressure, normal load, road conditions and its effects. Behavior of the tyre shown on the basis of the force generation between road and tyre and heat generation in tyre by using rate of change of temperature with time. How the different temperature generation performed in different controlled conditions shown on the basis of experimental collected data.
Keywords: Automobile engineering, Temperature, Tyre behavior, Tyre wear.

I. INTRODUCTION:

Tyres are one of most important parts of the vehicles, because tyre provides only connection between the vehicle and the road. It is however hard to precisely predict the actual behavior of a tyre. A tyre consist of many different components and materials. The main component of a tyre is a rubber material. The behaviour of rubber material is hard to predict, because it has viscoelastic properties and it is sensible to temperature change. The tyre behaviour is also affected by the car and environment, which continuously change. Tyre wear is one of the phenomena which is hard to predict and understand. Tyre wear can roughly be divided into two categories such as regular wear and irregular wear and this wear is directly affect the performance of vehicle and safety of the passengers.

With the tyre as the prime contact between vehicle and road, the vehicle handling performance is directly related to the tyre road contact. The tyres transfer the horizontal and vertical forces acting on the vehicle from steering, braking, and driving, under varying road conditions (slippery, road disturbances, etc.). Tyre forces are not the only forces acting on the vehicle. Other forces acting on the vehicle could be from external disturbances (e.g., aerodynamic forces from crosswind). However, the contact between vehicle and road is by far the dominant factor in vehicle behaviour and may be the difference between safe and unsafe conditions. The tyre profile serves to guide the water away from the contact area under wet road conditions, and to adapt to the road surface in order to maintain a good contact (and therefore load transfer) between tyre and road. These parameters result in tyre properties that, in combination with the vehicle, lead to vehicle performance. These requirements include many different things, such as:

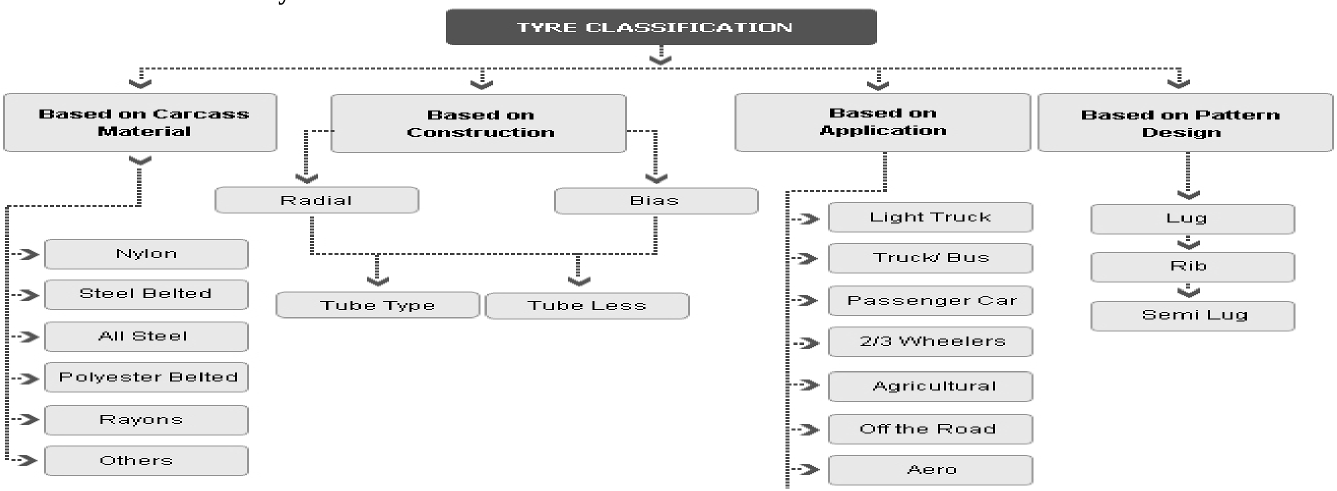
1. Good adherence between road and tyre under all road conditions in longitudinal (braking/driving) and lateral (cornering) situations.
2. Low energy dissipation (low rolling resistance).
3. Good durability and therefore, good wear resistance.
4. Tyre properties change with wear, which will in general lead to a higher tyre stiffness in horizontal and vertical direction
5. Low tyre noise, which has two aspects—the effect observed inside of the vehicle and the noise emitted into the environment
6. Longitudinal and lateral forces which are directly affect the performance of the vehicle.
7. Temperature generation in tyre lead tohysteresis losses.

Nomenclature: -

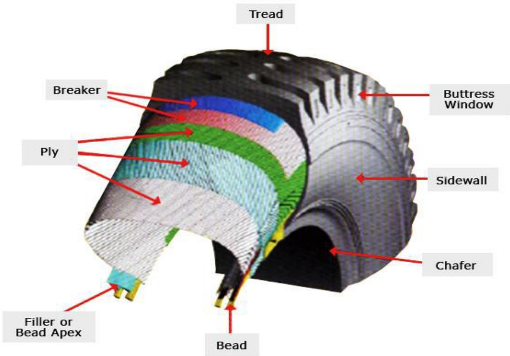
Objectives: -
To understand the tyre behaviour with different conditions.
To understand the effect of inflation pressure on rate of change of temperature with time.
Minimize the friction between road and tyre to helps tyre life improvement.
To understand the effect of longitudinal force on input torque requirements.

Fx	Drive force/ Brake force/ Longitudinal force, N
Fy	Lateral force, N
Fz	Tire load /Normal load on wheel, N
Mx	Overturning moment, Nm
My	Moment about the wheel axis, Nm
Mz	Self-aligning moment, Nm
Vx	Velocity in Longitudinal direction, m/s
Vy	Velocity in lateral direction, m/s
V	Resultant velocity, m/s
α	slip angle,
ω	Angular velocity of wheel, rad/sec
Fr	Rolling resistance force, N
γ	Camber angle,
Ta	Axle torque / Torque required to drive the wheel, Nm
Tb	Breaking torque, Nm

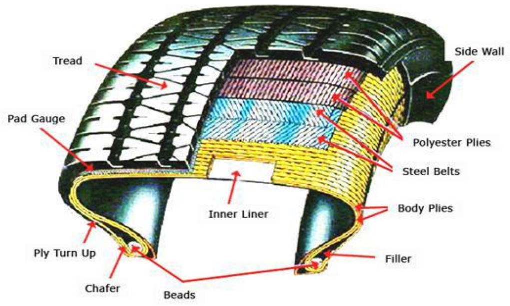
1.1. Basic classification of tyre: -



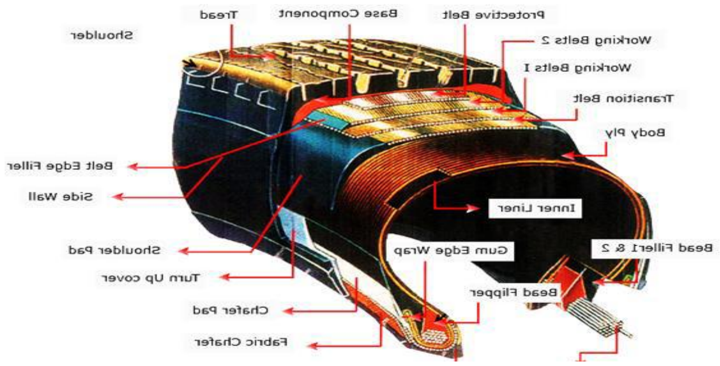
1.2. Truck Bias Tyre: -



1.3. Radial (PCR) Tyre: -



1.4. Truck Radial Tyre: -



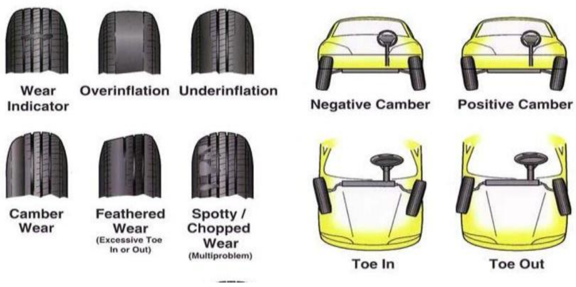
Tread: The portion of the tyre, which comes in contact with the road, is called the tread. It is designed to provide the necessary traction, wear resistance, and allow for low heat buildup and low noise.
Side Walls: These are the layers of appropriate thickness of rubber compound applied on both sides of the tyre carcass between the beads and tread.
Plies: Plies are reinforcing members of the tyre, which are made from rubber coated fabric (Rayon, Nylon, Steel, Polyester etc.
For bias tyres Nylon is the most commonly used fabric whereas Polyester is used for Passenger radial and steel for truck radials.
Bead: Layers of rubber coated high tensile steel wires formed into inextensible loops.

II. TYRE WEAR: -

The most important tire parameters acting on wear are the first one is to different stiffness which determine the shape, stress and slip in the contact patch second one is the rubber volume available for wear, which is correlated to geometrical characteristics of both tire (width, diameter) and tread (rubber thickness and the tread pattern percentage) and third one is the material characteristics of the tread such as friction and abrasion. The inflation pressure of the tires also has a great influence on wear and worn profile. Basically, tire wear having following classification

2.1 Causes Of Tire Wear

1. Air Pressure /Inflation Pressure
2. Heat / Temperature generation
3. Balance Issues
4. Bent Wheels
5. Alignment



2.2 Abnormal Wear Patterns

1. **One Shoulder:** If only one of the shoulders is excessively worn, the cause is usually alignment, specifically incorrect camber.
2. **Both Shoulders:** cause is under inflation
3. **Centre Rib:** Due to over inflation.
4. **Scalloping/Feathering:** when all the tread blocks on one shoulder develop a wear pattern in which one block edge is higher than the other
5. **Spot Shoulder:** If one of the shoulders is excessively worn in only one spot.
6. **Lateral Wear:** alignment issue, specifically an incorrect toe setting.

III. TYRE FAILURE

1) Under Inflation

Tyre that are under inflated flex more in the sidewall. Excessive flexing causes them to heat up far beyond normal operating temperatures. This problem is compounded when driving at highway speeds during hot weather for long period of time. When tyre gets excessive hot, rubber begins to degrade which if driven long enough, leads to rapture in a side wall of a tyre or tread separation**.**

2) Caused by Over inflation

Overinflating tyre increases ride harshness and may increase a tyre's vulnerability to damage caused by potholes and curbs. Tyres that are under inflated or over inflated can affect your tyre life, driving comfort, traction and braking. Likewise, over inflation can reduce tyre life, reduce grip and create irregular wear.

3) Driving at Speed

Driving at high speeds has a greater chance of causing tyre damage than at low speeds. If contact is made with a road hazard, it has a greater chance of causing tyre damage. Driving at speed will cause the tyre a greater buildup of heat, which can cause tyre damage. It can also contribute to a sudden tyre destruction and rapid air loss if the tyres are not properly maintained. Make sure the speed rating on the tyres matches the vehicle requirements and your driving habits.

4) Rapid/ Irregular wear due to mechanical issue

Misalignment or worn suspension parts are another primary reason tyre does not wear evenly. The tyre will completely worn on one side, or in one area of the tyre but perfectly good with other area of the tyre.

IV. METHODOLOGY

Many research papers have been published and reviewed likewise for formulation tyre wear and developing forces, in the present study experimental model is modelled and analyse with experimental results, the methodology is likewise.

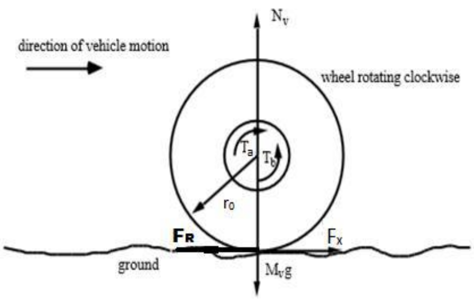
1. The research paper of various wear models has been studied and been tried to vary its parameters to obtain new results.
2. The contact mechanics between the tyre and road is studied; the contacting angle variation, pressure and load variation is studied and likewise the analytical results were obtained; books of vehicle dynamics are studied regarding that aspect.
3. For the modelling of the equation the force and moment of forces are substitute with the tyre radius to obtain modelled equation.
4. The Longitudinal force (tractive force) is an important parameter in the tyre model equation so the equation is modelled on that parameter in order to know the effect it causes on the vehicle performance and friction coefficient.
5. Load, Pressure intensity, speed are important parameters in the equation, so for that many equations were studied and modified likewise to obtain new modelled equation.

Parameters which are studied; depend on tyre life are given below

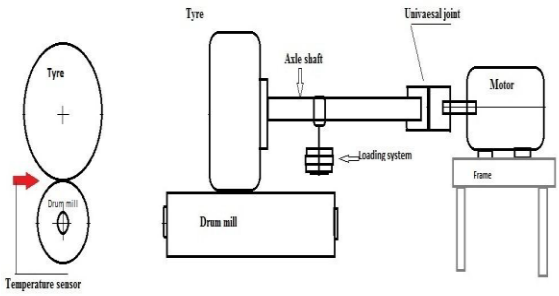
1) Longitudinal force/ Driving force (Fx)
2) Lateral force (Fy)
3) Normal force (Fz)
4) Vertical load
5) Rolling resistance force (Fr)
6) Wheel torque (T)
7) Turning moment (Mx)
8) Rolling resistance moment (My)
9) Aligning moment/Align torque (Mz)
10) Slip angle (α)
11) Camber angle (γ)

12) Cornering stiffness
13) Braking/Driving stiffness
14) Cornering stiffness coefficient
15) Braking stiffness coefficient
16) Longitudinal slip (percentage slip)
17) Longitudinal slip velocity
18) Dynamic rolling radius of wheel
19) Static loaded radius
20) Harshness
21) Thump
22) Sizzle
23) Tread noise
24) Tread depth
25) Tread contact length
26) Deflection (static)
27) Driving force coefficient
28) Tractive force

4.1 Formulation of forces in tyre investigation



4.2 Experimental Investigation



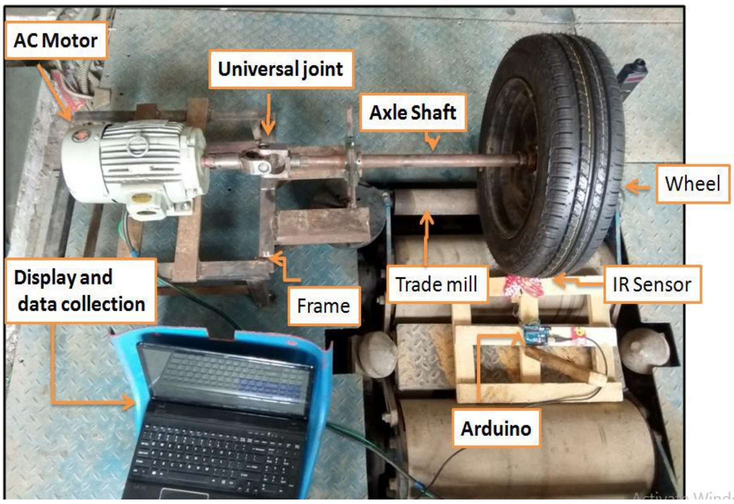
Tire Testing

Tire testing aims at the full identification of the functions that is of the relationship between the motion and position of the rim and the force and moment exchanged with the road in the contact patch.
rim kinematics ⇐⇒ force and moment

V. EXPERIMENTAL PROCEDURE

The setup consists of Tyre wheel, AC Motor, trade mill or drum, temperature measuring sensor, tachometer, loading system, power shaft, data collection system etc. In this experimental setup wheel is connected to motor shaft by using coupling and tends to rotate the wheel. When the power was given by motor to the wheel it tends to rotate the wheel over the trade mill by assuming same conditions as per when wheel is moving on road. Under controlled conditions, due to rotation of wheel some forces and moment will develop which will responsible to decide the life of the wheel or tyre. When the wheel rotate over the drum or trade mill at the contact point between the wheel and drum longitudinal force will developed which will responsible to movement of wheel and gives the idea about the force generation at contact point. Forces generation at contact patch leads to generation of heat because of friction. Heat generation (ie. Increase of temperature) will be responsible for the hysteresis loss and it will affect on the life of the tyre. This temperature will be recorded by using contactless infrared temperature sensor with the help of LABVIEW Software. From the above collected data, we can compare the different tyres at different control conditions.

Tyre testing aims at the full conditions of the three functions that is of the relationship between the motion and position of the rim and the force and moment exchanged with road in contact patch.



5.1. Assumptions under experimentation

1. Steady state conditions ie.Mz=0
2. Pure slip conditions
3. (ie. Setting camber angle γ =0)
4. Spin (ϕ)= 0
5. Slip Angle ie. α = 0
6. Constant input power supply condition

5.2. Parameters under calculations

1. Longitudinal force/ Tractive force
2. Input torque required to drive the wheel
3. Rolling resistance of the tyre
4. Coefficient of friction
5. Rate of change of temperature with time

VI. TEST METHODOLOGY

This test method describes a laboratory procedure for determining the forces and temperature generation of tyre during rotation. Tyres are usually tested in pairs under nominal controlled laboratory conditions. The principal areas of experimental attention in using this type of system to measure forces and temperature described. The coefficient of friction may also be determined.

For the test, one or more than of tyre are tested. One, a tyre which is under standard pressure condition rotate over circular trade mill or drum with above assumptions.

1. The new tyre specimen is rotate over the drum at a specified load. Force results are reported as requirement of input power. When different wear out tyre are tested, it is recommended that each tyre be tested in same conditions.
2. The amount of forces and temperature is determined by measuring of different tyre before and after the test. If linear measures of temperature are used, are determined by any suitable metrological technique, such as electronic infrared temperature sensor.
3. Measures of temperature are leads to hysteresis losses which is directly affects on the efficiency of the vehicle. Increase in temperature means increase in hysteresis losses tend to increase in power requirement by decreasing efficiency of vehicle.

4. Temperature results are usually obtained by conducting a test for a selected tyre and for selected values of pressure, load and speed.
5. The contact between the tyre and drum for experimentation is area of contact patch.
6. First readings are calculated on basis of pressure constant and variable load and vice versa.
7. The experiment is performed on no load and loads of 90,120,150,180,210,240 N with of tyre at 32 PSI, 25 PSI, 20 PSI, and 15 PSI.
8. The time of experimentation is set for 4 minutes (240 sec) for each test sample, longer the time of experimentation more reliable results are obtained.
9. All the readings procured are shown on the "LabVIEW" software from where we get all the values of temperature.
10. All the readings of longitudinal forces, Torque requirement, rolling resistance, coefficient of friction force are calculated by analytically.
11. The graphs are obtained which helps to study the characteristics of the parameters obtained during the test.

VII. RESULTS AND DISCUSSION

Tests was conducted for new tyre by applying different loads of 90 N, 120 N, 180 N, 210 N and 240 N. Also, different Pressure at 32 PSI, 25 PSI, 20 PSI and 15 PSI, we got coefficient of friction and longitudinal force and rate of increase of temperature. The tabulated result represents the mean value of coefficient of friction and Longitudinal force and rate of increase of temperature. To get more accurate results, readings can be noted in equal interval of time and average of those noted readings will provide good results. The output results for same have been tabulated below:

Tyre testing in each condition numerous data has been obtained. The rate of change of temperature with time are shown in figure 6.3 at 90 N load with 15 PSI, 20 PSI, 25 PSI, 32 PSI pressure conditions. At 32 PSI pressure, rate of change of temperature with time is observed that 0.0065 , at 25 PSI pressure it was 0.0069 , at 20 PSI pressure it 0.008 , and at 15 PSI pressure it observed 0.01058 . From the above results and observations here we can conclude that rate of change of temperature is directly depends upon the inflation pressure. The rate of change of temperature with time is maximum at 15 PSI pressure ie. Under inflation pressure condition and minimum at 32 PSI pressure ie. Standard normal pressure. At starting of the rotation of wheel friction was more lead to sudden increase in temperature was observed and after some time it varies linearly with time.

For the above fig.6.4 at normal load 120 N, Temperature against time it was observed that with increase in temperature with time and increase in temperature with decrease of pressure ie. inverse proportionality exists between the temperature and the pressure. It observed that rate of change of temperature with time at 32 PSI was 0.00691 , at 25 PSI pressure 0.00691 , at 20 PSI pressure 0.009 , and at 15 PSI pressure 0.01275 . From the above results and observations we can conclude same as per above case.

For the above fig.6.5 at normal load 150 N, the rate of change of temperature with time at 32 PSI was 0.007833 , at 25 PSI pressure 0.009583 , at 20 PSI pressure 0.01083 , and at 15 PSI pressure 0.01391 .

For the above fig.6.6 at normal load 180 N, the rate of change of temperature with time at 32 PSI was 0.0095 , at 25 PSI pressure 0.0105 , at 20 PSI pressure 0.01141 , and at 15 PSI pressure 0.0155 .

For the above fig.6.7 at normal load 210 N, the rate of change of temperature with time at 32 PSI was 0.00991 , at 25 PSI pressure 0.01133 , at 20 PSI pressure 0.01266 , and at 15 PSI pressure 0.01675 .

For the above fig.6.8 at normal load 210 N, the rate of change of temperature with time at 32 PSI was 0.01025 , at 25 PSI pressure 0.01150 , at 20 PSI pressure 0.01308 , and at 15 PSI pressure 0.01783 . Design and Development of Measurement system for Automotive tyre parameters by Nilesh P. Mohokar Page 53

From the above discussion and observed data we can say that rate of change of temperature with time is maximum at minimum pressure ie. Undear inflation pressure 15 PSI at 240 N is 0.01783

VIII. CONCLUSIONS

1. Longitudinal force is proportional to Normal load and inversely proportional to inflation pressure, speed; increases of these parameters causes requirement of input torque to increase.
2. Rate of change of temperature with time is proportional to load, inflation pressure.
3. Rate of change of temperature with time minimized for increased load by maintaining the inflation pressure of the tyre.
4. The rate of temperature generation which causes hysteresis losses which leads to wear increment, reduces the life of tyre which can be optimized by maintaining the inflation pressure of the tyre.
5. Measures of temperature are leads to hysteresis losses which is directly affects on the efficiency of the vehicle. Increase in temperature means increase in hysteresis losses tend to increase in power requirement by decreasing efficiency of vehicle.

FUTURE SCOPE

1. The measurement of this research is carried out with a single tyre and it is not irrefutable clear if the above studies are really appears so for further check it will be give better result by testing different tyre with same conditions.
2. A possible research might be measuring the lateral force and its effects by using camber and slip will improve the good understanding of tyre behavior and its life.

REFERENCES

[1]. Hyun Baek and Jong-Wook Jang.(2015), Design of Tire Surface Check System with the Laser Sensor, IJCA Vol.8, No.3 (2015), pp.9-14
[2]. MingyuanBian, Long Chen, YugongLuo, and Keqiang Li (2014), A Dynamic Model for Tire/Road Friction Estimation under Combined Longitudinal/Lateral Slip Situation, SAE 2014-01-0123, 2014, doi:10.4271/2014-01-0123.
[3]. Virkar D S1 and Thombare D G, Parametric Study And Experimental Evaluation Of Vehicle Tire Performance, IJMER
[4]. Yeong-Jyh Lin, Sheng-Jye Hwang (2004), Temperature prediction of rolling tires by computer simulation, Elsevier 67 (2004) 235–249
[5]. Frank L. Roth and William L. Holt (1944), Measuring The Rate Of Wear Of Tire Treads, National Bureau of Standards, Volume 32, February 1944
[6]. Theunis R. Botha and P. Schalk Els (2015), Digital image correction techniques for measuring tyre road interface parameters, longitudinal tyre slip ratio measurement, doi.org/10.1016/ jterra.2015.05.003
[7]. Flaviofarroni, RaffaeleLamberti, NiconMancinelli, Francesco Timpone (2017), A tool for smart and interactive identification of Magic Formula tyre model parameters from experimental data acquired on track or test rig, https://doi.org/10.1016/j.ymssp.2017.07.025
[8]. J. Marais , G. Venter (2018), Numerical modelling of the temperature distribution in the cross-section of an earthmover tyre https://doi.org/10.1016/j.apm.2018.01.018
[9]. Nasersinha, Sayyadnasiri, VahidKarkhanech,(2015), Effects of resistive loads and tyre inflation pressure on tyre power losses and co2 emmision in real world conditions, http://dx.doi.org/10.1016/j.apenergy.2015.04.010
[10]. Scott David Naranjo, CorinaSandu, Saied Taheri, Shahyar Taheri (2014), Experimental testing of an off road instrumented tire on soft soil, http://dx.doi.org/10.1016/j.jterra.2014.09.003
[11]. Thomas D.Gillespie – SAE Fundamentals of Vehicle Dynamics, pg. 21-42, pg335-371
[12]. GisbertLechnerHaraldNaunheimer(1999), Automotive Transmissions, Fundamental, selection, Design and Application, pg 58-65.
[13]. Martin Meywerk (2015), Vehicle Dynamics , ISBN: 9781118971352
[14]. Design and Development of Measurement system for Automotive tyre parameters by Nilesh P. Mohokar Page 56
[15]. Different types of tyres, its application and performance, Wikipedia, Online open Access.
[16]. The Tire Society, http://www.tiresociety.org/tire/
[17]. N.K. Giri, Automobile Mechanics, Khanna Publication.
[18]. Institute for TyresResearch,Center for Tires Research, http://www.hasetri.com/accreditions.html

A. P. Thakare, et.al. "Design and Development of Measurement System for Automotive Tyre Parameters".*IOSR Journal of Engineering (IOSRJEN)*, 10(1), 2020, pp. 13-21.