Study & Analysis of Tire Wear Characteristics of TATA LPO 1618.

Gaurav Gohane1, Anmol Indurkar1, Palash Chimurkar1, Sandip Patle1, Suraj Kumar Nagina1, Swapnil Tirpude1 and Ujwal Bawane1

1 Mechanical Engineering Department, JD College of Engineering and Management, Nagpur, India.

Email: gmgidcoe@gmail.com

Abstract. The tires are a key sub-system of vehicles that have a big responsibility in comfort, fuel consumption and traffic safety. As we know that current tires are just passive rubber elements which do not contribute actively to improve the driving experience or the vehicle safety. During the driving of vehicle, we get few and unsatisfied information from tires. Therefore, this is the main reason to develop an intelligent tire, which could provide useful information to other systems and become an active safety system. In the Tata (LPO 1618) Vehicle an experimental tire strain-based system is used to measure tire tread deformation by means of various aids. Tests under different working conditions such as vertical load or slip angle considering a certain camber angle have been carried out using an indoor tire test (Slightly). By this project and research work, we are trying to introduce an automated tire monitoring and inflation system, which can ensure adequate tire pressure to better accommodate handling requirements. In this paper the numerical method for introducing the prediction tire where account has been introduced to reduce break down time.

1. Introduction

For our Live Project, we have chosen An Automobile Sector, for the same purpose we had reported certain Bus Maintenance and Repairing Centre at which maintenance of Shiv-Shahi (Public Transport Vehicle under MSRTC) Bus is carried out. In the Maintenance Centre there are buses of Ashok Leyland & Tata. But there are majorities of Tata Buses of Tata LPO 1618, which is commercial vehicle used for public transport by MSRTC (Maharashtra State Road Transport Corporation). Tata LPO 1618 comes fitted with 5883 cc Cummins 6BT 5.9-180-30 – BS4 Water cooled, Turbocharged Diesel Engine. A max power of 131 Kw at 2500 rpm and max torque of 700 Nm at 1400 rpm gives enough strength to the bus to carry load full to its capacity. Like other Tata trucks in this range, thus bus also has a 400 Liters of fuel tank capacity. The tires for this vehicle are available in two options - 10.00 x 20 -16 PR Diagonal Ply - 10R20-16PR and 10.00 x 20 -16 PR Diagonal Ply - 11R22.5-16PR. This vehicle has a GVW of 16200 kg and a max speed of 110 Km/h. It is quite a dependable bus for long distance commutation with those numbers.

While Consulting and Observing the vehicle and its performance experienced by the drivers and people working in the center, we came to know various problems arising in the TATA LPO 1618 Vehicle such as Chassis Issue, Front Axle Issue, Tire Wear Issue, Abnormal Body Length, Impact of Retarder Weight, Misalignment of Kingpin due to sudden high Impact of Shock offered by wheel, Increment offered in temperature of Tire, Tire tread due to surface heating of road due to friction. Due to over sizing of front body, tires wear increases.

While consulting with the employees working in the center, we came to know that their huge amount of investment is spent on the tire and its maintenance. So, to reduce their Investment and tire wear we had focused light on this major arising issue in the maintenance center.

Tire wear is a complex and important part of each and every vehicle that is affected by tire materials, structures, vehicle dynamics, and road conditions. In this paper we basically focused on the tire wear of...
vehicle, because tire is very important part for driving any vehicle and everyone wants that tire of their vehicle should execute less damage and in result it will become more durable. So, basically, we had observed five major and main types of wearing of tire and they are as follow- Camber wear (one-sided wear), Feathered Directional Wear, Cupped Wear (Cupping Wear), Centre wear, Shoulder wear etc. The paper discusses various theoretical models for tire wear in various commercial and non-commercial vehicles and factors affecting the tire wear. A brief review of tire wear characteristics is shown in this paper. Theoretical models for analysis of tire wears are helpful in understanding numerical results with physical mechanisms which are responsible for the generation of tire wear and their behaviour at different values of tire parameters.

2. Literature review

2.1. Measurement and analysis using a tire sensing approach

When we drive the vehicle, various forces and moments are applied on the tire which leads to rolling deformation of tire by application of braking, cornering and accelerating. Due to this rolling resistance is decreased which tends to increase in fuel consumption and carbon emission. Tire tread plays the main role for improving the rolling resistance of tire. Therefore, we have to focus on measuring this. To measure this, there is provision for optical laser sensors which measure the deformation such as inner profile, loaded radius, Sidewall and tread deformations of heavy vehicle. It is a 2D laser profilometer with an ultra-high-speed sampling rate. It consists of Two triangular laser sensors for measuring the rolling deformation of tire: Laser sensor 1 (Keyence LJ-V7300) and Laser sensor 2 (Keyence LK-H150). In this, sensor module is embedded into the sensing house and mounted on a steel rim by means of tread attachment. To measure the angular position of 2D laser profilometer, an optical encoder (2048 counts/revolution) with in a slip ring nut (Michigan Scientific SR 20AW/T1024) is used. It is used for new and remolded tire too. Laser1 provide the direct measurement of inner profile of tire rolling deformation due to which unreasonably many high and low values is occurred. To eliminate this, filter is used for showing the clear peaks, when tire is being actually deformed. The actual arrangement is somewhat like that the sensor equipped tire is used in the truck and data acquisition system I.e. hardware is placed on the fuel tanker of the vehicle and the software I.e. the display system is on the driving board. The measurement signals which we are getting from the Laser Sensor 2 include both periodic errors and random noise. The main reason for the periodic errors is mainly the eccentric alignment between the rotating axes of the tire and slip ring. To reduce such type of error, a pattern recognition procedure is applied to minimize this type of error. Now for the random noise, the main reason behind this error is road roughness (texture less than 1 mm) which can be smoothed by a Butterworth low-pass fitter. Fully integrated miniature module:

- Size: 4.9x2.5x1.56 mm.
- Emitter: 940 nm invisible laser (Class1).
- SPAD (single photon avalanche diode) receiving array with integrated lens.
- Low-power microcontroller running advanced digital firmware.
Figure 1. (a) Methodology for the tire sensor system; (b) prototype for the tire sensor system

There is also presence of Pin-to-pin compatible with the VL53L0X Flight Sense™ ranging sensor Fast and accurate long distance ranging up to 400cm distance measurement up to 50Hz ranging frequency Typical full field-of-view (FoV): 27° Programmable region-of-interest (ROI) size on the receiving array, allowing the sensor FoV to be reduced Programmable ROI position on the receiving array, providing multimode operation control from the host.

2.2. Numerical optimization of wear performance – Utilizing a metal model based friction law
In the present contribution, Aleksandra Serafinska, Nermeen Hassoun and Michael Kaliske had developed a finite element wear analysis methodology, which aspires to fulfill several requirements on a realistic modeling of this phenomenon. Pronounced and uneven wear lead to significant durability and service life reduction of tire and its surface structures. Thus, the development of methods for the enhancement of wear performance is of prime importance. Since the reduction of wear is a significant goal also for the pneumatic tire design, several tire optimization approaches can be found in the literature.

To reduce the future tire wear and uneven characteristic tire wear we can use the predicted technique of search, analyze and run technique in which we have to pre-analyses the path on which we have to drive the vehicle. By doing this, we are able to predict the tire wear based on the experiment results that we will carry out in further experiment or we can choose alternate way of path to drive the vehicle.

In this brief and as per our review, a finite element wear analysis is developed in the research paper, which aspires to fulfill several requirements on a realistic modeling of this phenomenon. First, the ability to perform an iterative adaption of the geometrical configuration due to material removal, based on a wear rate calculation within a constitutive wear equation is given. Second, the friction-wear interaction is considered within the FE (Finite Element) wear analysis, since wear and friction phenomena exhibit a strong correlation. Third, the influence of local frictional phenomena on wear is taken into account in friction-wear interaction since local stress concentrations are identified as the origin of wear. The initial pioneering work in this field is done by “Reye”, who discovered that the depth of the worn material is proportional to the tangential stress and therefore, to the contact pressure. Furthermore, he concluded, that the volume of the worn material V is linearly dependent on the work W done by the tangential force. The above theory will be going to consider in further analysis and experiment that will be going to carry out.

2.3. Abrasive wear amount estimates for 3D pattern tire utilizing frictional dynamic rolling analysis.
In this paper the numerical method for introducing the prediction tire where account has been introduced in this paper to reduce break down time. The frictional energy dissipation through the tire footprint containing with the abrasive ground was computed by fictional dynamic simulation off the 3D pattern tire model. As a result this paper introduced the fictional energy rate was correlated with the thread wear
read by a power function wear rate model that was derived on an experimental basis as illustrated through numerical experiments threadbare amount can be estimated and also this numerical method can be useful to determine the rubber compound the tread pattern and the material and structure composition in the design of the tire model which satisfy the preset rear performance.

![Figure 2](image)

**Figure 2.** A simulation tire model: (a) FEM mesh and (b) specification of loading and driving condition.

2.4. **Tire wears particle hotspots: A review of influencing factor.**
From this research paper we understood that, Author found the major influencing parameter on the amount of tire wear. First is the rolling resistance offered by road it is mainly depends upon the surface of road with varying density, it is found that low density roads cause higher amount of wear rate and it also occurs the highly rolling resistance which leads to tire wear and the other is due to the uneven and occasional seasonal change. It is found that wear rates in summer increases by 1 to 4 % per degree Celsius which reduces the lifespan of tire by 9% for commercial vehicles other parameter also causes the tire wear of the commercial vehicle like tire pressure, tire geometry, tire age and the balancing of wheels-Imbalance causes wear.

![Figure 3](image)

**Figure 3.** Graphical representation of (a) Traction coefficient (b) mean values for wear rates of vehicles as a function of the maximum admissible weight.
2.5. Study and analysis of passenger bus tie rod.

**Figure 4.** (a) Worn out tie rod; (b) Tie rod of TATA LPO 1618

Prashant Vithalkar, R. R. Gawande – the authors of the research paper of above research area, the main objective of this paper on study of buckling load on tie rod of steering system because of the external factors like road conditions, vibrations, sudden jerks are having great impact on the tie rod. The tie rod generally buckles under the action of the compressive forces when it becomes worn out the steering became difficult and hard to steer, which ultimately leads to the tire wear. From the observation, they have taken readings and measurements of the tie rod of the passenger bus and by that reading they have prepared the 3D CAD model of the tie rod using the software Pro-E.

2.6. ECU controlled intelligent lift axle dropping and lifting system for heavy trucks

In India, heavy transportation using trucks are used for transferring the goods to their final destination. It is an expensive mode of transportation. While transporting through heavy vehicles, over loading of these vehicles are one of the main reasons of pavement damage and tire wear due to the excessive pressure on the road at the tire road interface. Restoring the wear damage caused by overweight trucks requires huge capital investments and also reduces the capacity of traffic flow due to construction. In this paper I studied about an automatic lift axle dropping and lifting system to help improve the tire life and to adhere to the legal per axle weight and weight distribution limits. The main aim of an automatic lift axle dropping system is to drop the appropriate axles automatically based on the loading condition, instead of being manually controlled and lifted by the driver. We know about the conventional axle lifting system. In manual controls and usages, solenoid valves are controlled by switches mounted in the instrument panel in the truck cabin. In order to lift/drop the axle, the driver pushes the corresponding switch and the axle is actuated directly, regardless of the vehicle condition. But it has some disadvantages, because it is sometimes ignored by the driver and leads to damage the tire particles and pavement too. The purpose of an automatic lift axle lifting and dropping system is to automate the dropping action. It aims to lower damages to the truck, as well as damages to vehicle parts and road pavement due to loading conditions.

The main requirement for the Auto-Drop system is the measurement of axle loads. The system must drop the required axles automatically based on the loading condition. If the second axle is lifted and if the rear axle group load exceeds 18.0 tons, the system will drop the nearest axle, which is second axle, for sharing overload and maintain axle loads under permissible limits and does not allow driver to lift axle again. In this paper, The Auto-Drop system algorithm developed for the 8×2S test truck runs in a PI INNOVO M250 ECU module using MATLAB/Simulink as the software development platform. ECU parameter calibration and embedded program variable monitoring is provided with ATI VISION based on CCP (CAN Calibration Protocol). Automatic tag axle dropping system has been developed for mechanical suspended vehicles for the first time to reduce tire pressure by preventing to get damaged and worn out. Measurement of integrated axle weight via electronic sensors has been developed in mechanical suspended vehicles with tag axle lifting feature for the first time. The axle load approximate error per axle was decreased to 0.4 tons from 2 tons as compared to conventional methods. By ensuring
that axle loads remain within permissible limits, service maintenance costs are reduced. We found that here the system allowed the transmission of vehicle weight data to Electronic Brake System (EBS) with higher accuracy. Tag axle Lift/Drop Function is connected to Parking Brake in order to activate parking brake actuators located at tag axle. First time implemented in Turkey 2020 by using the EU Directive 1230/2012 EEC Mass and Dimensions Policy.

![Diagram](image)

**Figure 5.** (a) Block diagram & (b) Mechanism of truck Axle lifting mechanisms.

3. **Working Methodology**

For the project on which we are working, we had chosen bus of TATA company having TATA LPO 1618. Tata LPO 1618 comes fitted with 5883 cc Cummins 6BT 5.9-180-30 – BS4 Water cooled, Turbocharged Diesel Engine. Here we know that a maximum power of 131 KW at 2500 rpm and maximum torque of 700 Nm at 1400 rpm gives enough strength to the bus to carry load full to its capacity. Like other Tata trucks in this range, thus bus also has a 400 Liters of fuel tank capacity. The tires for this vehicle are available in two options - 10.00 x 20 -16 PR Diagonal Ply - 10R20-16PR and 10.00 x 20 -16 PR Diagonal Ply - 11R22.5-16PR. This vehicle has a GVW of 16200 kg and a max speed of 110 Km/h. With these numbers, it becomes a dependable bus for long distance commutation. But it consists of major problem that is tire wear due to various parameters like friction, overheating of surface of tire due to heating of road too etc. For the proper analysis of the commercial vehicle (TATA LPO 1618), we had done regular visit to the maintenance center. And while doing regular visits we had found almost five to six major types of tire wear in the tire of the commercial vehicle.

Tire wear is a complex phenomenon that is affected by tire materials, structures, vehicle dynamics, and road conditions. In this paper we basically focused on the tire wear of vehicle, because tire is very important part for driving any vehicle and everyone wants that tire of their vehicle should execute less damage and in result it will become more durable. So, basically, we had observed main types of wearing of tire and they are as follow:

- Camber wear (one-sided wear), Feathered Directional Wear, Cupped wear, Center wear, Shoulder wear etc.

For reviewing and analysis of alignment issue which irrelevantly arises in the vehicle, we had visited MIKHS alignment center, and we got to know some probable solutions on reduction of tire wear causing due to the misalignment in the vehicle arising due to the road conditions, sudden breaks, over friction between the road surface and the surface of the tire etc. And also, we have to do re-alignment of the vehicle in the span of every six months whether the vehicle is in running or in stationary condition in addition with this, we also have to do the re-alignment of the king-pin, so that it will help to execute less wearing of tire while driving. The surface of the road on which the vehicle is going to be run. While doing alignment we have to check proper measures of alignment parameters like “Toe in” & “Toe out”.
Figure 6. (a) Tire Wear Observed in TATA LPO 1618; (b) Alignment procedure of MHKS.

Table 1. Tire wears readings taken by using depth Gauge at Nagpur bus depot.

| Bus No. | Front RHS | Front LHS | Rear RHS out | Rear RHS in | Rear LHS out | Rear LHS in |
|---------|-----------|-----------|--------------|-------------|--------------|-------------|
| 806     | 4mm       | 4mm       | Remould      | Remould     | 2mm          | Reject      |
| 1335    | 5mm       | 6mm       | 3mm          | Remould     | 2mm          | 2mm         |
| 905     | 4mm       | 3mm       | 4mm          | 4mm         | 6mm          | 6mm         |
| 3346    | 6mm       | 7mm       | 7mm          | 7mm         | 7mm          | 7mm         |
| 978     | 2mm       | 3mm       | 4mm          | 4mm         | 3mm          | Reject      |
| 1068    | 6mm       | 6mm       | 6mm          | Remould     | 7mm          | 7mm         |
| 1066    | 7mm       | 7mm       | 4mm          | 6mm         | 5mm          | 5mm         |
| 1018    | 6mm       | 7mm       | 6mm          | 5mm         | 4mm          | 4mm         |
| 903     | 7mm       | 7mm       | 6mm          | 6mm         | 5mm          | 5mm         |

All buses are in the series of **MH 29 BE**
4. Problem Description

4.1. Uneven Tire Wear
Abnormal wear, which is more critical for its safety implications, includes two types: uneven wear and irregular wear. Uneven wear describes non-uniform distribution of wear across tread pattern and irregular wear mainly characterizes circumferential wear vibration. Uneven tire wear is usually caused by improper alignment, over-inflation, under-inflation or a worn-out suspension. Tires are an extremely important component of a Commercial vehicle (Shivshahi Bus). Excess wear on the inner or outer edge of the tire, known as "toe wear" or, in more extreme cases, as "camber wear", suggests something may be wrong with the wheel alignment. Toe or camber wear at one end of the strip indicates wheel alignment problem, center wear in the center indicates over-inflation, edge wear at both ends indicates under-inflation, and patch or cup wear around the edge on one side and a sharp side wear. Setting proper algorithm in FUZZY LOGIC and doing proper maintenance in suitable and preferred time interval to avoid accidental and random tire wear. Using proper monitoring aid or providing tire wear reading meter display on the suitable space area available on the dashboard in front of the driver seat, so that he can decide the proper speed and way of driving on the road surface, to avoid tire wear.

4.2. Tire wear offered due to misalignment
Due to improper alignment of the alignment parameters like TOE IN & TOE OUT, CAMBER AND CASTER, tire wear offered. But in major cases, we have seen the tire wear is more offered due to TOE IN & TOE OUT. This misalignment happens due to the sudden impact of shock offered due to the sudden application of the brakes while running the vehicle on the road surface. In result, the material of the tire also starts removing by its own due to the friction occurs while driving, and gradually the degradation of the quality of the tire initiates.

The industry does not focus on the tire and tire wear until and unless it’s gotten ruptured or worn out, that why it causes critical condition and more investment on the tire maintenance of the vehicle. If we find out any instrument or any proper measuring device that will directly provide the proper measures and reading to the driver during the running of the vehicle on the road. Then, they can easily save the tire to be worn out & send the tire of the vehicle to the industry for remolding and its proper maintenance. In remolding, by adding new tread on the tire surface which will increase the life of the tire and saves the money which is spent on new tire.40 % of money we can save from remolding instead of purchasing new tire.

4.3. Measurement and analysis of the tire wear
To predict the probable and accurate solution of the tire wear, we will be requiring proper readings and data of the tire wear. There is a huge and measure requirement of a proper aid for measuring the accurate data of tire wear in the maintenance center and same in the vehicle itself. So, it will be easier for us to do the analysis of tire wear using various engineering analysis software like ANSYS Workbench, Solid works SW16 or CATIA etc.

For the probable solution of the above-mentioned problem, we have opted measurement technique using sensing approach in which we have to choose 2-D laser profilometer, which can give us ultra-high-speed sampling worn out rate of tire wear. In this device, we can use two types of laser sensor which laser 1 provide the direct measurement of inner profile of tire rolling deformation and laser 2 provides side wall deformation of tire. We can use optical encoder which can display the wearing rate of tire to the driver during the running of the vehicle on the road surface by which we can save the tire to be worn out and send this for remolding.
4.4. Tire Wear due to worn out suspension

This type of wear is majorly occurred in those vehicles whose suspension got worn during driving on irregular and uneven road surface. At the high, when the vehicle experiences sudden impact of speed breaker or even small stops, the padding of the suspension system gets ruptured and in result it gets damaged. And ultimately, the suspension deformed straight and the tensions in the suspension loosen out which results the bending of I-beam. And hence increases the tires wear and the tire wear offered due to this reason is also known as “Scalloped Tire Wear”. To reduce such tire wear, we have to regularly check the width and dimension of the suspension using proper measuring instrument/aid like ‘Depth Gauge’. Using sensors instead of manual measuring method can increase the precision of getting reading of the wearing of suspension directly on the display unit which is mounted on the surface of the dashboard in front of the tire wear.

5. Conclusion

In this paper, we had discussed the tire wear offered in the commercial vehicle that we have chosen (TATA LPO 1618 - SHIVSHASHI), which runs under MSRTC. Abnormal wear, which is more critical for its safety implications, includes two types: uneven wear and irregular wear. Uneven wear describes non-uniform distribution of wear across tread pattern and irregular wear mainly characterizes circumferential wear vibration. While doing survey we also came to know that the tire on the driver side that is the front right side of the commercial vehicle had 1mm of wear after running operation of completing every 12000 Km and correspondingly the tire on the co-driver side that is the front left side of the commercial vehicle had 1mm of wear after running operation of completing every 11000 Km. We can reduce the tire wear using various techniques mentioned in the above section like tire sensing approach, Alignment approach and also using Fuzzy Logic. We can use advanced tire wear measuring aid using advanced sensor which will not only gives tire wear reading but also provide relevant basic solution so that the driver of the vehicle can apply the provided solution in the vehicle, this can be used as a future scope development.

6. Appendices

Appendix A Authors
Prof. Gaurav M. Gohane
Assistant Professor, Mechanical Engineering JD College of Engineering and Management, Nagpur.

Anmol Indurkar, Palash Chimurkar, Sandip Patle, Suraj Kumar Nagina, Swapnil Tirpude, Ujwal Bawane.
(B.tech Under Graduate Students in Mechanical Engineering from J D college of engineering and management, Nagpur)

Appendix B Literature Review

Here all the reviews are written in this section, by which we got an idea about moving forward on this project by doing analysis and comparison between leaf and air suspension of our vehicle which directly related with our tire wear.

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