Thermo-Mechanical Defect on Commercial Vehicles Tyres

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Abstract— A numbers of patents on tyre Life Span have been reviewed with a focus on those which can be applied to Commercials Vehicles Tyres for the Automobile Industry. This patent is separated into different functional solutions and reviews are made based on practicality and potential for most significant use. The life of tyres depends on the frequency of usage, tyre pressure level, weather and friction level between tyre and road surface. Heat and friction will increase the wear and tear of the tyre during long distance travel. Consequently, the life of the tyre is reduced. Finally, the mechanism of heat transfer within the tyre carcass is introduced as well as the basic tyre structure and effects of overheating on tyre operation. These methods are related to current research paper which aim to develop a fresh mind set and extend the working life of Commercials vehicles tyres.

Key words: Alignment, Commercial Vehicles, Thermo-Mechanical Defect, Wear-Out, Heat Transfer, Tyre Life Span, Tyre Cooling

I. Introduction

A. *Significance to Industry*

The cause of Thermo-Mechanical Defects within Commercial Vehicle Tyres plays an important part in the operation of many automobile companies. The control of tyre wear has traditionally occurred through management of fleet owner. Tyre manufacturers have played an important part in developing new compounds which are more heat resistant in nature. Despite the management of tyre wear, efficient maintenance, monitoring strategies and developments in tyre technology, sites continue to suffer from premature failures. Implementing an efficient wear out strategy will result in reducing the thermal stresses to the tyre and extending the tyre life. Tyre wear management has been a constant issue for fleet owner and consumers for decades. Hence, there is a definite need for an effective and active method to reduce Thermo-Mechanical Defects in Commercial Vehicles tyres.

B. *Tyre Structure*

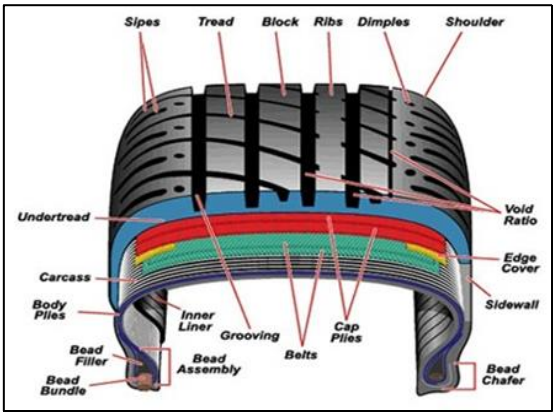

Fig. 1: Structure of tyre

Commercial vehicle tyres have a number of structural layers within the carcass. These are included primarily for strength and wear resistance purposes. Fig. (1) Illustrates some of the major commercials vehicles tyre sections and components, sourced from a Bridgestone safety manual [1]. Although the tyre carcass can withstand high loads and has reasonable wear properties, it has very low thermal conductivity and therefore cannot effectively dissipate the heat to the surrounding atmosphere. Before moving to elaborate on the details, it is important to briefly introduce the mechanisms and nature of the heat generation within the carcass.

C. *Heat Generation*

To estimate the exact heat generation rate in tyres, it is required to fully understand the structure and rolling and flexing mechanisms of tyres. The fundamental phenomenon behind the heat generation in tyres is the friction between molecules when the rubber in the structure of the tyre is under a kinematic deformation by a continuous compression-tension or torsion [2]. This kinematic deformation is known as the hysteresis effect. In fact, as the tyre rolls and flexes, a portion of the motive power transmitted to the tyre is absorbed due to the tyre hysteresis and thus converted into heat and consequently the tyre temperature increases [3, 4]. This effect is worse by increased load and speed as well as tyre under-inflation, road undulations and excessive cornering. Tyre operating temperature is shown to have a significant impact on tyre life in Fig. (3) [17]. If the tyre carcass is maintained at low temperatures then its life can be considerably extended.

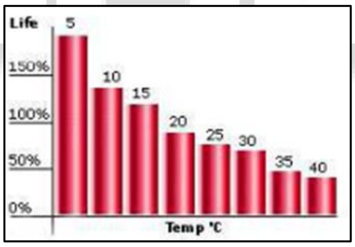

Fig. 2: Tyres used in commercial vehicle

Types of Tyres used in commercial vehicle

According to Construction:

- Cross ply/Bias tube type Tyre (eg-10.00X20)
- Radial tube Tyre (eg- 10.00R20)
- Radial tubeless Tyre (eg- 11R22.5)

According to Tread Design:

- Rib Tyre
- Lug Tyre
- Semi Lug Tyre
- Mines Tyre

II. Types of Tyre Wear

A. *Both Side Shoulder Wear*

Fig. 3: Both Side Shoulder Wear

The tread is not making flat contact with the highway. The outer portions of the tread are carrying most of the load because the tyre is underinflated for the load.

B. Diagonal Wear

The tyre is not tracking straight down the highway. But is bouncing slightly sideways during parts of its rotation. It may be wobbling on the axle or rim.

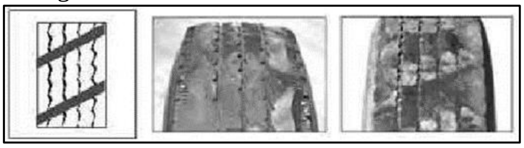

Fig. 4: Diagonal Wear

C. Rib Punch Wear

The worn areas are scrubbing the highway because the tread area is distorting in the footprint.

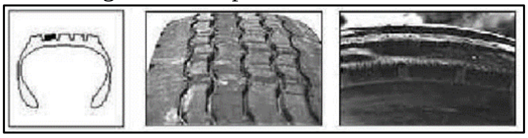

Fig. 5: Rib Punch Wear

D. Shoulder Scrubbing/Scuffing Wear

The tyre is being dragged sideways (lateral scrubbing). This is commonly seen in vehicles operating in spread axle or multiaxle configurations and on trailers subjected to tight turning maneuvers.

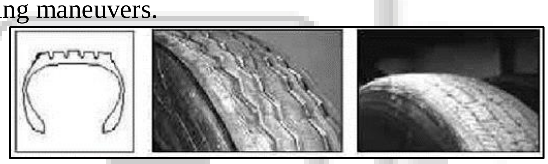

Fig. 6: Shoulder Scrubbing/Scuffing Wear

E. One sided Wear

This tyre is worn from corrective steering due to vehicle thrust (rear axle misalignment), cocked (toe in or out), tilted (camber) or the axle is bending due to overloading.

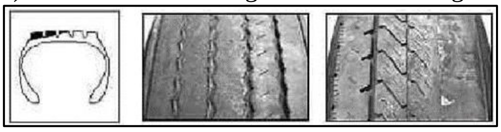

Fig. 7: One sided Wear

F. Feather Edge Wear

The tyre is not tracking straight down the highway, but is cocked slightly to the side.

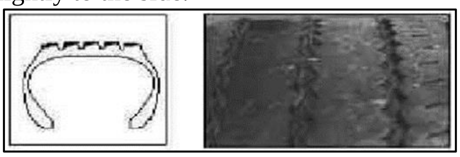

Fig. 8: Feather Edge Wear

G. Spot Wear

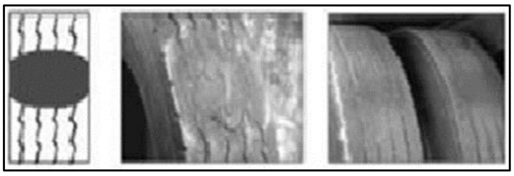

Fig. 9: Spot Wear

The tyre slid across the road surface, scung away the tread in one area. One or more small, localized spots of comparatively rapid tread wear.

H. Heel & Toe Wear

The trailing portions of the lugs are scuffing like a rubber eraser. The lugs are distorting during acceleration or during operation so they are not making flat contact with the highway.

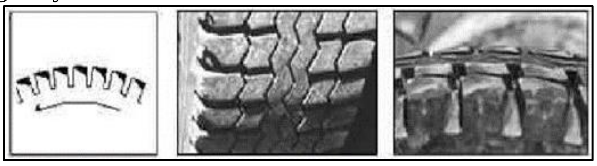

Fig. 10: Heel & Toe Wear

I. Alternate Lug wear

The tyre's lugs are not wearing consistently because they are not making uniform contact with the highway.

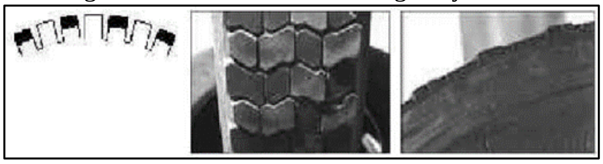

Fig. 11: Alternate Lug wear

J. Flat Spot Wear

The tyre slid across the road surface, scuffing away the tread in one area. This generally happens as a result of brakes locking up due to brake malfunction or the driver aggressively applying the brakes in an emergency situation. Flat spotting can also occur if the tyre sat in oil, fuel or chemicals.

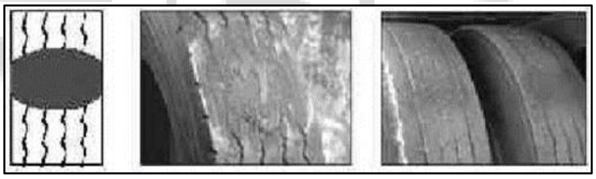

Fig. 12: Flat Spot Wear

K. Cupping/Scallop Wear

The tyre is not tracking straight down the highway, but is bouncing sideways during parts of its rotation. It may be wobbling on the axle or rim. On trailers, the condition is aggravated by running empty. Because of the light load, the trailer begins to bounce, creating more irregular wear, which creates more bouncing, and so forth. The bouncing can create vehicle suspension component wear.

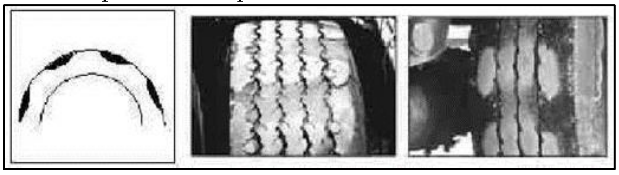

Fig. 13: Cupping/Scallop Wear

III. METHODS TO MAXIMIZE TYRE LIFE

Selection of Tyres/ Tread Depth and Pattern: Commercial tyres are optimized for specific categories of operation, and selecting the right kind of tyre application is a primary consideration. This requires a good working knowledge of the fleet's activities and its drivers' routes. Most tyres wear out prematurely as a result of irregular wear, i.e., the tread wearing unevenly across the face of the tyre. Typically, this results from improper inflation, misalignment, failure to rotate the tyres properly, or out-of-balance tyres. Tread pattern is important because lugs have deeper tread (more rolling resistance) than ribs. If we take a new ribbed tyre as the standard, a new lugged tyre is less fuel efficient by about 6%. A worn tyre is about 7% more fuel efficient than a new tyre. Rib tyres at all wheel positions will provide greatest fuel efficiency. Ribbed tyres on the drive axles provide 2–4% better fuel economy than lugged tyres. Used lug drive tyres can get up to 0.4 mpg better than new lug tyres.

A. Proper Inflation

A critical factor in tyre maintenance is proper inflation, which impacts safety, as well as financial, issues. Overinflation causes premature/irregular wear at the tyre center and, at the extreme, can lead to tyre blowouts. Underinflation, the most common culprit, causes excessive wear on tyre shoulders. Severe underinflation weakens the sidewalls, placing stress on the carcass. It can lead to structural failures, including zipper cuts, sidewall ruptures, or tread separations, posing real driving dangers. Proper inflation pressures critically affect tyre performance. Underinflation can negatively affect tyre performance and durability. Specifically, it:

- Reduces fuel economy
- Increases tyre wear rates
- Creates irregular tread wear
- Reduces casing durability

Every 10 psi of under inflation represents approximately 1% penalty in fuel economy.

Recommendation Inflation Pressure according to tyre type

Radial Tyres (10R20-16 PR): 125-130 psi (Front & Rear Tyres)

Nylon/Cross Ply Tyres (10X20-16 PR): 120-125 psi (Front-Rear Tyres)

B. Proper Rotation

A tyre's wear tendencies are determined, in part, by its position on the vehicle. Front or steer tyres have a tendency to wear on the shoulders, while drive tyres are more prone to wear in the centre. Typically, rear tyres will wear more quickly than the fronts because of their tendency to get scrubbed. While the benefits of proper rotation are obvious, a fleet must consider how to rotate its tyres and determine the optimum rotation times required to keep the tyre healthy without adding unnecessary cost. "The first two rotations are really the most important because that's when the tyre is trying to set up its wear pattern.

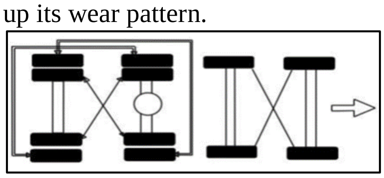

Fig. 14: Rotation

C. Aligning for the Application

It's natural to assume a standard alignment setup works for all conditions, and very often operators are inclined to align the wheels to the centre of the tolerances. However, a standard alignment may not be necessarily accurate. "You need to align the truck to best fit your application," "You want to monitor the tyres for toe-in/ toe-out, even though the necessary corrections may take you to one side of the tolerance." "Most people will check the steer axle (frontend toe-in, and caster and axle alignment), but you don't want to overlook the drive axle alignment. If the drive axle is misaligned, the truck wants to go straight down the road, but you'll end up dog-tracking and wear out the front tyres more quickly." During Axle Alignment Tyres need to point straight ahead in order to roll with the least possible resistance. A tyre that deviates only ¼ degree from straight ahead will try to travel 10 to 15 feet sideways for each mile the vehicle travels forward. Scrubbing the tyres in this fashion is bad for fuel economy and also bad for tyre wear.

Following are the main Alignment parameters:

1) Toe-In Toe-Out Setting

Negative toe, or toe out, is the front of the wheel pointing away from the centerline of the vehicle. Positive toe, or toe in, is the front of the wheel pointing towards the centerline of the vehicle. Toe can be measured in linear units, at the front of the tyre, or as an angular deflection.

Recommended Specification on laden & unladen condition

- B-A = 0~1 mm (laden)
- B-A = 2~3 mm (unladen)

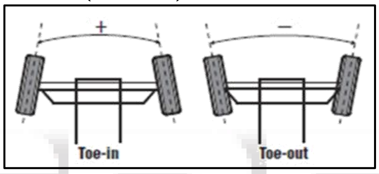

Fig. 15: Toe-In Toe-Out Setting

2) Front Axles Parallelism (SAP)

Recommended Specification for SAP

Alignment Schedule at every 20,000 Kms

- RH Side – All points (ABCD) Touching
- LH Side – All points touching / Gap of max 3mm at E & G

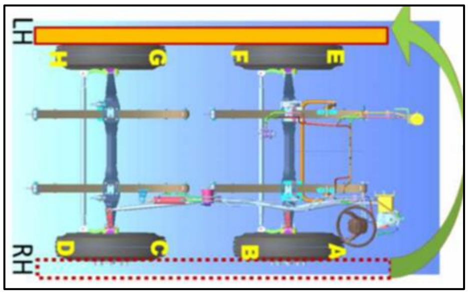

Fig. 16: SAP

3) Thrust Angle/ Wheel Base Difference

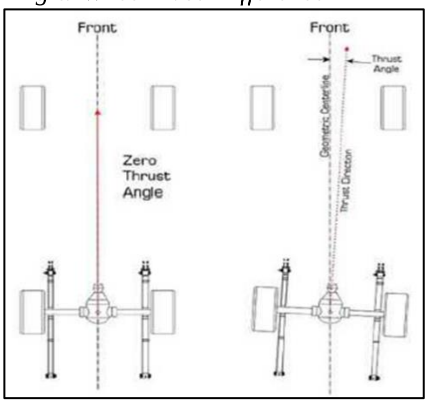

Fig. 17: Thrust Angle/ Wheel Base Difference

Thrust Angle is angle of Drive Axle with Geometric Centre Line. A very important & most neglected parameter due to unawareness. It can be obtained by measuring LH-RH Wheel Base difference.

Specification: Wheel Base RH – Wheel Base LH < ±10mm

4) Scrub Angle/ Rear Axle Skewness

Scrub Angle is angle between thrust line of drive axle & tag axle. It's a major cause of Rear tyre wear. It can be obtained by measuring difference of LH-RH Axle Centre distance.

Specification: Axle Center Distance RH – Axle Center Distance LH < ±5mm

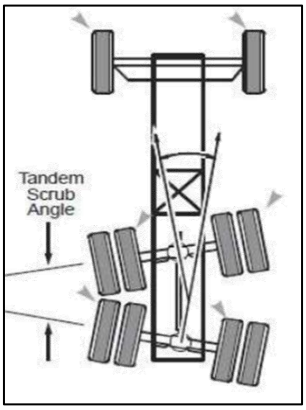

Fig. 18: Scrub Angle

Other Important Parameter are include Caster, Camber, Spring Camber, tightening torque on Suspension U-bolt, Castle nut torque, wheel nut torque, Wear Plate Clearance, Hub Play, Kingpin Play, Play between bush & king pin, Idler Arm Play (8x2), Idler arm play between bush and idler arm, Suspension Bushes & play, Brake drum face & Wheel disc runout, All Greasing point like, Suspension, Brake, Kingpin, Idler arm etc.

D. Weight Impact / Load/GCW/ Proper Balance

Assuming the wheel weights have been properly attached and the tyre properly balanced and mounted, rarely do tyres become out of balance after being mounted on the vehicle. Increased weight causes increased flexing of the tyres. Reducing the weight of components on the truck can result in either better fuel economy, or increased payload for the same amount of fuel consumed.

E. Inside duals often neglected

It is also point out that, when it comes to maintenance, inside tyres on dual assemblies are often neglected because checking inflation is not easy. "You have to be very careful to check for any significant differentiation that may show up in dual tyres.

F. Keeping Tyres Clean

Tyres also frequently pick up chemicals, mud, and debris that cause the rubber to deteriorate. It is recommended washing the tyres while the vehicle is washed. Here again, special care should be taken to include the inside dual tyres, which are commonly ignored.

G. Aggressive Driving costly/ Vehicle Speed

Aggressive driving, including sudden stops and starts, produces excessive wear not only on tyres, but also on other truck components. It shows up on tyres as flat spots and/or locked-up brakes. At the end of the day, such driving behavior can cut into profits in many ways. Attempts to deliver more goods and deliver them faster actually result in a more expensive way to run a business. The most efficient drivers get about 30% better fuel economy & 50% better tyre life than the least efficient drivers.

H. Keeping records on Cost

A good tyre maintenance program should also include calculating tyre cost per- mile, keeping good records, and doing a scrap tyre analysis, if necessary. "Management should have some way of examining every tyre that comes out of service and knowing why it's out of service," "They need to keep records to make sure they're getting their money's worth out of the tyres. If they've bought the wrong tyre for the application or are doing something that shortens tyre life, they need to know what it is,"

I. Introduce Nitrogen filling for Tyre Inflation

Nitrogen Reduced pressure build up thus Uniform tyre wear gives longer tyre life about 25% & Better fuel efficiency. Nitrogen is lighter than compressed air so Wheels role more freely to achieve better mileage also Adds more comforts while driving. Nitrogen expands very less on heating up so Reduces the risk of sudden tyre explosion & increased tyre life. Nitrogen is an Inert gas & dry and clean air which is does not contain moisture thus does not cause any corrosion due to oxidation & Extended Rim life

J. Life span by means of Water-Cooling

Since the relationship between tyre life span and tyre surface temperature is proportional, it can be concluded that, the tyre life span can be increased by the reduction of tyre surface temperature during operation. The experiments have proven that, the tyre surface temperature can be reduced by means of water cooling. In order to reduce the heat on the surface of the moving tyre, a tyre cooling system with water jet spray is designed and tested. The amount of heat dissipated from the tyre is determined based on the reduction of the tyre surface temperature after the water is spayed on the tyre, thus increase the tyre life span.

IV. CONCLUSIONS

This case study contains the main conclusions of this research and recommendations for future projects. The aim of this project is to provide a better tyre life and minimize the tyre wear problem. This work has been performed at the customer hub or authorized dealers of the manufacturer to controlled environment to be able to verify the correlation between the design parameters and the actual work done on the vehicle.

A. Outcomes

- Reduce vehicle breakdown
- Health and Safety
- Saving fuel and time
- Tyre purchasing will reduces.
- Performance of the vehicle will increase in terms of FE.
- Mechanic will be trained and there observation skill will be developed.
- The study`s observation will show the working standard and accuracy of the working practices of the dealer`s mechanic or the owner`s mechanic.

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