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"Case studies of tyre defects and cpkm of commercial vehicles"

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ABSTRACT: The transportation is a service oriented business. In this business, tyres are the more expensive part of the vehicles. So that what type of tyres are used should be defect free. Some processes or methods are cause of generation of defects in the tyres which causes the life of tyres are decreased and increased the cpkm. The causes are to be identified and to be rectified. The rectification should be done timely. To enhancing the tyre life and decreasing the cpkm is the aim of project.

The defects are due to manufacturing or non-manufacturing, should be reduced by TQM tools. Through the project work used the TQM tools are used to eliminating or decreasing the defects and the decreasing the cpkm of tyres. Some of the benefits of this project includes increased tyre life/mileage, lower the cpkm, lower the defects caused by improper work, reduce the mechanical breakdown, reduced the total expenses of the vehicles. The overall efficiency of the vehicles are the increased and firm will be beneficiary.

I. INTRODUCTION :

The project objectives are :**(1).** To know how firm had implemented the TQM practices in its enterprise to achieve the reduction in defects**(2).** To know the different types of tyre defects**(3).** To know what are TQM practices it had gained to overcome the defects **(4).** To know how efficiently defects can be overcome by using TQM Tools and its practices**(5).** By applying the different TQM tools as - data collection, regression analysis, root cause analysis, histogram and plotting the different graphs with comparisons the tyres defects can be decreased **(6).** To know the cpkm analysis between defective tyres and healthy tyres. The analysis of cpkm steps to be followed as -

• Select data of tyres a single route vehicles
• Comparisons to be conducted of tyres with pattern and NSD

1.2 Tyredefects :

There are various types of defects and causes which affect the tyre life and the tyre'scpkm. The lessercpkm is beneficial to a firm. If cpkm is increasing then it is necessary to know the causes. Because of higher cpkm indicates the some potential problems are existed which are to be identified and to be rectified. The causes or defects can be grouped in two major sections which are as under -

(A). Non-manufacturing defects: It covers defects due to improper inflation, defects due to mechanical problems/issues, defects due to wrong fitment.
(B). Manufacturing and retreading defects : It covers OEMs defects and retreading defects.

1.2.1 Defects due to improper inflation :

The proper inflation plays a vital role to lower the cpkm of the tyres. By proper inflation can get higher mileage of the tyres. If proper inflation are not maintained then causes premature failure of the tyres, tubes, flaps, rim or disc. Because of tyres are designed to inflated on specified level so it should be maintained. There two main defects cause of improper inflation which are as under –
(1)-Both shoulder wear
(2)-Centre wear

(1)-Both shoulder wear
● Shoulder wear is result of the lower or under inflation.
● When inflation is lower from specified level then shoulder wearing is occurred.
● Under inflation causes rapid wearing occurred of tyres specially at both shoulder.
● In under inflation excessive heat is generated causes tyre rubbers will be soften and get wearing faster.● Due to under inflation premature failure of tyres occurred.

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Fig01 Both shoulder wear

(2)-Centre wear● When inflation is made above mentioned level is called the over inflation.
● Over inflation may result to serious damage of tyres.
● Due to over inflation impacts or shocks are generated during driving cannot be absorbed by the tyres.
● Due to over inflation major wear is occurred at the centre. Such wearing or defects is called the centre wear of tyres.

Fig 02 Centre wear

1.2.2 Defects due to mechanical problems :
The mechanical parts are also play a massive role in faster and uneven wearing of tyres. The main defects are created by mechanical parts are as -
(1) - One side wear
(2) - Flat wear
(3) - Spotty wear
(4) - Diagonal wear
(5) – Wavy wear etc.

(1)-One side wear : These defects are results of mechanical parts wearing and tearing caused positions and functions are changed. Every mechanical parts have the definite life. So that after longer use wearing and tearing started. The relative motions between the parts generated to heat that is main cause of wearing. The proper lubrication are required to reduce the heat and wearing.

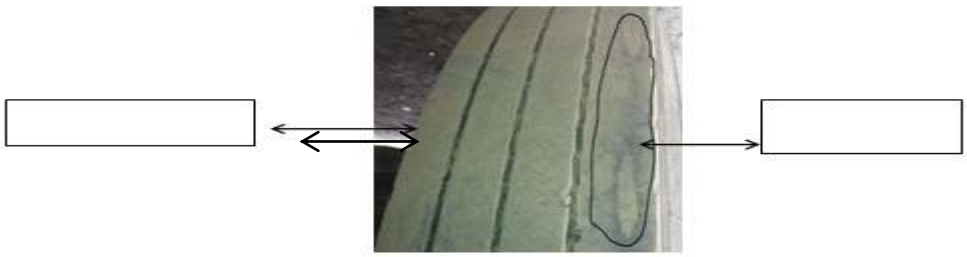

Fig 03 One side shoulder wear

(2)-Flat wearing : Flat wearing is occurred in tyres due to many mechanical irregularities or parts wearing and tearing, which are listed below :

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Table 01 List of mechanical problems/parts wearing and tearing

Sl No.	Issues/mechanical problems
i.	Centre bolt cut
ii.	Leaf spring plate cut
iii.	Bush of leaf plate eye rubbed
iv.	Shackle pin of leaf spring wear out
v.	Sub axle wear
vi.	King pin wear
vii.	U-bolt bent, loose, cut
viii.	Bell crank wear out
ix.	Equalizer & hanger wear out
x.	Tyre rotation work
xi.	Wheel alignment

The above failures can be seen in below tyre**Fig 04**, in the form flat wearing. This defect is results of parts failure or wearing and tearing so that misaligned is occurred. After investigation the rectifications are to be done.

Fig 04 Flat wearing

(3)-Spotty wearing : Due to improper braking system caused the spotty wearing occurred in the tyres.Brake lining rubbed and exposed the rivets. Brake boosters or actuators poor functions cause the spotty wear. Brake shose return springs loose. Slack adjuster's functions are poor. Bearings are broken etc.

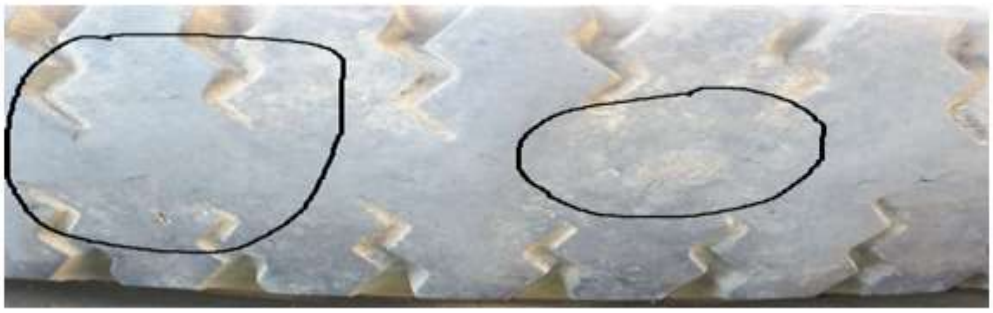

Fig 05 Spotty wear

(4)-Diagonal wear : Diagonal shaped wearing occurred at tread area one shoulder to opposite shoulder.Generally such wearing occurring at whole due to tyre loose wheel bearings and check nut. Bearings arebroken. Inflation differenceis more than 10 psi.

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Fig 06 Diagonal wear

(5)-Wavy wear :A cupped shape wearing occurred at the tread area. It is occurred due to hub play.

Fig 07 Wavy wear

1.2.3 Defects due to wrong fitment :
These defects are results of wrong fitment of tyres . Due to wrong fitment faster wearing occurred in the tyres. These defects can be minimized by proper implementation of tyres fitment rules. Reducing the wrong fitment result the lower the cpkm. Some wrong fitment or defects are as

(1) - Improper dual due to height
(2) - Ribs tyres fitted in trolley axles
(3) - Block tyres fitted in steering axles
(4) - Dual /pairing of radial and nylon
(5) - In steering axle has one side nylon and other side has radial etc.

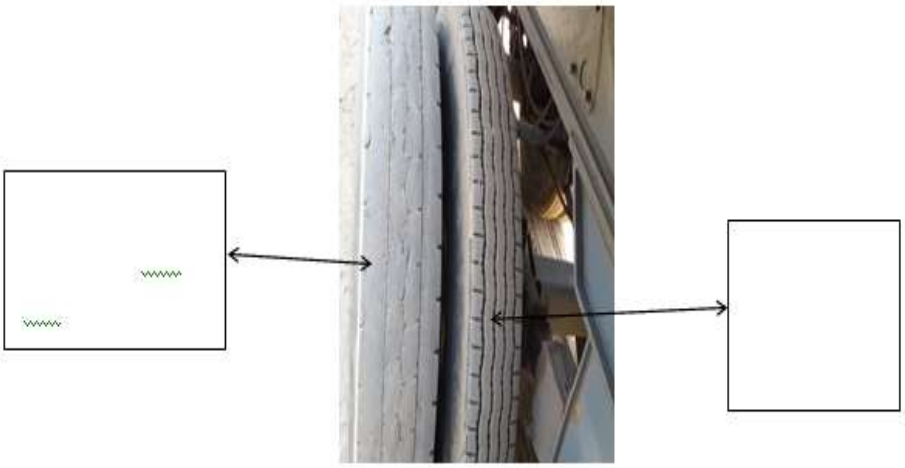

Fig 08 Mismatch tyres

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1.2.4 Defects due to manufacturing and retreading :

These defects are results of improper functions of manufacturing processes or activities. Some defects found under supervision are bead failure, belt separation, buttress crack, chafer Separation, lug base crack, rib tearing, side wall separation, shoulder separation etc. These defects are found in original brand tyres and in retread tyres both.

Fig 09 Shoulder separation

1.3 CPKM Analysis :

CPKM stands for cost per kilometer generally calculated in paise. It is varied on route, road condition, driving style, load applications, patterns of tyres, positions of tyres, maintenance etc.

CPKM = average cost of tyre/average mileage of tyre.

1.4 Scope of the project work :

The research briefly introduces about the tyres consumption of commercial vehicles of transportation firm. The consumptions are increased due to defects of tyres they may be manufacturing based or non-manufacturing based. Mechanical problems have potentially increased the tyres consumptions. If tyre consumption is increased then cpkm is also increased. If cpkm will be increased then total expense of vehicle will be increased and benefits will be reduced.

II. LITERATURE SURVEY

The sources on which basis a roadmap is ready, are the research papers. The study of research papers as objectives, applied methods, collection of data, analysis of data, conclusions etc. are too essential to make a project report. It is necessary to know different vital factors which affects the tyres life which may be inflation, mechanical related issues, wrong fitment, manufacturing defects, retreading defects etc. Some experts outputs in the form of research papers and the service manuals of authorize service centres, firm's own service system etc. related totyres defects are summarized as following -

2.1 Inflation related sources

Vikram Kumar Malviyaet al(1) have studied the tyre life span of commercial vehicles which are useful to automobile industries and transportation sectors. His research is related to different functional solutions which are made on practically. According to report tyres life are potentially depends on tyre inflation level, frequency of usages of tyres, friction is generated between tyres and road, weather etc. The two factors heat and friction potentially increasing the wear and tear of tyres. When long distance travelling is done then wearing and tearing of tyres are occurred more. Concluded that cause of wearing and tearing the tyre life is reduced.

GradimirDanon et al (2) have studied the important role of inflation in the tyres and how it is monitored because of improper inflation is increasing in defects as centre wearing and both side shoulder wearing of tyres. Due to wearing of tyres by improper inflation decreases the tyres life and consequently increases the cpkm. His research is devoted to the proactive approach to the tyre maintenance of commercial vehicles and the uses of tyre pressure monitor system. The result of research have confirmed the tyre pressure monitor systems are much more beneficial by technically and economically. The proper TPMS is increased in traffic safety and in comfort of passengers. TPMS decreases the operating cost and increases the profits.

Miles Mullins et al (3) have studied the tyre inflation, because of maximum persons are

ignoring to maintaining the proper inflation in their day to day life. Due to poor or improper inflation or not maintain the correct tyre inflation may result in increase in horsepower requirement to overcome the drag force. The drag force is a resistant force between tyre and road. In his research made the 21 test trials on tyre inflation and speed. In his test results found lower/under tyre inflation increased horsepower necessary to propel the vehicles.

Elfasakhany et al (4) have studied about improper/incorrect inflation and its impacts on tyre performance and cpkm. An incorrect inflation reduces the vehicle performance, braking effectiveness, vehicle control and riding comfort.During research made the a framework which is tyre pressure checking framework (TPCF). Tyrepressure checking framework is applied for proper inflation of tyres. He categorized two method of TPCF as direct and indirect. Concluded that at low/under inflation or over inflation the operating of tyres may results in severe damage and high risk of accidents.

Stefano d'Ambrosio et al (5) have studied the active tyre pressure by using the an automatic, electro-pneumatic and central tyre inflation. By tyre inflation pressure management applied on the passenger vehicles got the fuel consumption lowered, safety improved and got comfort drivability.

Joney Eckert et al (6) have studied the influence of tyres inflation. The poorly inflated tyres get the new shape and size when come in contact with the road. The poorly inflated tyres (over inflation and lower inflation) are reached the TWI position soon. The rolling resistances are changed because of improper/poorly inflating of tyres. The research result are devoted to influence of inflation, lower the vehicle power required and reduction in fuel consumption.

2.2 Mechanical work related sources

Nirmal Kumar et al (1) have studied therepair and eliminate tyre wear by wheel alignment of the heavy commercial vehicles. Before wheel alignment the tyres wearing are occurred potentially cause of which tyre reach removed from vehicle before reaching the an average mileage. In research explained about inner side wear of tyre at shoulder and outer side wear of tyre at shoulder. These defects can be eliminated by proper wheel alignment conducted on heavy duty vehicles with the help of computerized wheel alignment machine system.In the resultfound that the tyrelife after alignment was significantly improved and lowered the cpkm. Therefore it was confirmed the feasibility of the proposed techniques as a useful repair method to improvedtyre life after wheel alignment.

Firm service schedule system (2) are the system of OEMs service manual. Because of firm is running Bharat Benz, Tata Motors, Ashok Leyland vehicles and they have their own service system and the same for the trailer sections. It is necessary to know about the service of tyre related parts which increase tyre life. Hub greasing schedules are to be done timely otherwise potentially impacts on the tyre life. Some illed service results are as following –

- Brake drum rupture
- Bearings seized
- Sleeve rupture
- Oil seals rubbed grease comes out and lubrication decreased
- Braking parts are rubbed and functioning ill.
- Bell crank parts rubbed occurred
- Leaf spring plates cut, centre bolt and U-bolt cut
- King pin rubbed etc.

Hub greasing should be done on manufacturer schedule service system. During hub greasing if parts are wear out then should be changed. Some parts are have their definite life and after that they decay/decrease their quality and function so that they should be changed. Other works as sub axle, bell crank, leaf plate, braking system etc. are should be checked periodically and to be repaired because their potential impact on the tyre life and performance.

This paper aims to study the influence of the tires pressure. The rolling resistance force is essentially caused by the tires deformation and the adherence phenomenon in the contact, it can be calculated in function of some factors such as: tires structure, tires geometry, tires material, temperature and filling pressure. At low speeds and on hard pavement, rolling resistance is the primary resistance force of the movement. The floor irregularities also cause influence in the rolling resistance, but the tires deformation is the most influential factor. There is a variety of tabulated values to estimate the rolling resistance, however they do not change with the vehicle speed. Based on experimental results, empirical equations were developed to calculate the rolling resistance.

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2.3 Wrong fitment related sources

The wrong fitment results in huge loss of tyres. Tyres consumption will be increased and cpkm will be increased. The wrong fitment of tyres cause heat generation, uneven wearing, premature failure due to burst, puncture etc. The service manuals of firm's related to tyres and its fitment help to analyse the wrong fitment. Some wrong fitment of tyres are pointed out as following -

• Rib type nylon tyres are fitted in trailer axles
• Rib type nylon tyres are fitted in drive axle
• In a dual/pair nylon and radial tyres
• In single axle one side nylon tyres other side radial tyres
• Sometimes in a pair heights of tyres are not levelled

The above factors are decreasing the tyres mileage, efficiency, performance and increasing the cpkm. Such factors should be reduced or eliminated. If cpkmhighers it means losses are increased.

2.4 Manufacturing & retreadingrelated sources

Vankar Bharat et al (1) have studied the recycling of tyres which is generally called the retreading. If a defect free tyre will retread then it will give beneficial results. The research output is to investigate the new/original tyre life and to investigate the retread life. After original use when tyres are removed from the vehicles are healthy then should be retreaded. The retreadtyres are mostly used in the commercial vehicles. The retread tyres life and performance are depended upon the number of retreading and distances covered after each retreading. The research shows that the retreading cost is 28 % and life is 75 % to the new tyres.

Hardik Patel et al (2) have studied tyres recycling of tyres and its defects. The defective and weak tyres will give premature failure causes higher the cpkm. Healthy casings of tyres should be retreaded. Shoulder separation, belt loose, patch comes out are the result of ignorance etc. occurred during casing checking of tyres. Old casing tyres removed from the vehicles and applying the new belt on the casing tyres. The process are retreading as treading, vulcanizing, enveloping, buffing etc. should be done carefully. The defect free retread tyres are beneficial to the firm and reduce the thecpkm.

Cristiano F. et al (3) have studied the factor involved during the manufacturing of the tyres. A tyre is composition of around three hundreds different chemical elements. The elements may be organic and inorganic, natural and synthetic materials. The manufacturing processes involve various activities are as mixing, calendaring, extrusion, moulding, vulcanizing etc. Every activities play vital role to produce a defect free tyre. If the contents of elements are varied from given range then impacts are seen in the form of defects in the tyres. The proper processes are also play important role in defect free tyres. The defects of tyres are as following –

• Shoulder separation
• Side wall separation
• Buttress crack

• Chafer separation
• Rib tearing
• Tread or channel crack
• Bead failure etc.

These defects can decrease the market share of the tyre manufacturer, so required to investigate and eliminate the defective processes and the improper composition of the contents.

III. ANALYSIS AND EVALUATION :

3.1 Benchmark/Assumption :● The rib pattern tyres should be fitted in steering axles which generally bias/nylon tyres. Radial block pattern tyres are used in drive axles. And bias nylon tyres block patterns are used in trailers axles.Route Ballari to Chennai.

● The tyres inflations are maintained 120 psi in bias tyres and 140 psi in radial tyres.

● The timely fitment of tyres and removal of tyres for retread are done for better mileage and lower cpkm.

● All mechanical irregularities are removed and services are done timely.

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3.2Inflation related calculations :
Taken 1380 numbers of tyres as sampels. During observations found inflation in tyres are abnormal. 86 tyres are over inflated and 56 tyres are under inflated.

Table 01 Over Inflation

Sr. No.	Tyres	Inflation found
1.	CEAT mile xl rib pro - recommended 120 psi	125 psi to 150 psi
2.	CEAT hcl super - recommended 120 psi	125 psi to 150 psi
3.	CEAT win super D - recommended 140 psi	145 psi to 180 psi

Table 02 Under inflation

Sr. No.	Tyres	Inflation found
1.	CEAT mile xl rib pro - recommended 120 psi	115 psi to 80 psi
2.	CEAT hcl super - recommended 120 psi	115 psi to 80 psi
3.	CEAT win super D - recommended 140 psi	135 psi to 100 psi

Necessary actions taken &results :● Inflation maintained as per OEM recommendations.
● All parts are checked.

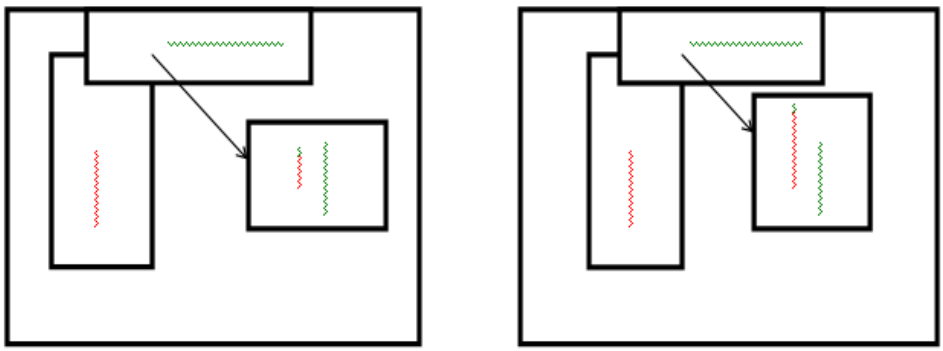

Fig 10 Reduction graph of wearing of centre and both shoulder

Benefits of proper inflation
(i). Achieved uniform tyre wear by reduction in both shoulder wear and centre wear
(ii). Achieved the better tyres mileage as original or retread
(iii). Reduced the heating of tyres
(iv). Reduction in premature removal of tyres from the vehicles

3.2 Mechanical problem related calculations :

Table 03 List of mechanical problems

Sl No.	Issues	Vehicles	Nos. of issues
i.	Centre bolt cut	In 16 vehicles	48
ii.	Leaf spring plate cut	In 08 vehicles	11
iii.	Bush of leaf plate eye rubbed	In 03 vehicles	03
iv.	Shackle pin of leaf spring wear out	In 02 vehicles	02
v.	Sub axle wear	In 01 vehicle	01
vi.	King pin wear	In 03 vehicles	03
vii.	U-bolt bent, loose, cut	In 05 vehicles	11
viii.	Bell crank wear out	In 03 vehicles	03 sets
ix.	Equalizer & hanger wear out	In 09 vehicles	16
x.	Tyre rotation work	In 05 vehicles	05
xi.	Wheel alignment	In 07 vehicles	07
xii.	Bearing seized	In 01vehicle	01
xiii.	Braking system irregular	In 01vehicle	01

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Necessary actions taken & results :
Total problem assigned = 103
Rectification done = 97
Pending = 06
Work completion = 94.17 %

Benefits:
- Premature failure of tyres are reduced.
- Tyre mileage increased and reduced the cpkm.

3.3Wrong fitment related calculations :
Necessary actions taken results
(i).Height levelled done by proper pairing
(ii). Removed the original ribs pattern tyres from trailer section and fitted block pattern tyres
(iii). Removed the block pattern tyre from the steering axle and fitted rib pattern tyre
(iv). Made the correct dual/pair as nylon-nylon, radial-radial
(v). In steering axle fitted the nylon tyres both sides
(vi). In 37 numbers tyres 34 done in correct postion
(vii).03numbers still pending to correct

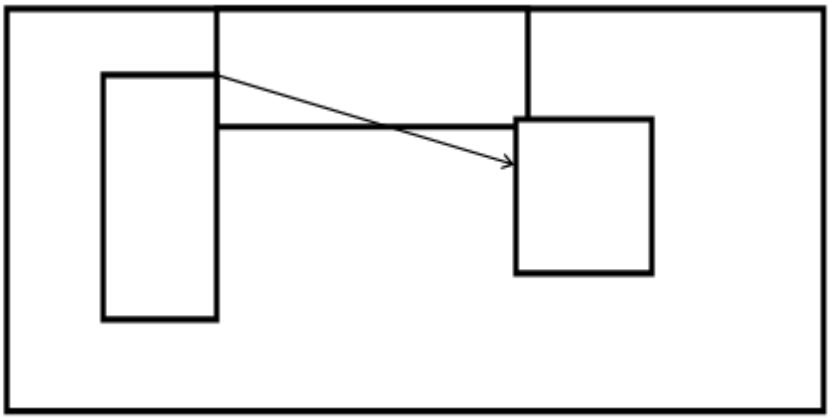

Fig 11 Reduction in wrong fitment

Benefits of reduction in wrong fitment
(i).Reduction in premature failure of tyres
(ii). Reduction in heat generation of tyres
(iii). Tyre mileage increased
(iv). Reduction in puncture of tyres

3.4Manufacturing and retreading related calculations :
Observations
(a). The **OEMs defects** are result of improper activities performed during the manufacturing of tyres.
(b). It can be identified on daily basis inspection of the tyres.
(c). Some manufacturing defects are identified during the inspection works are as chafer separation, shoulder separation, tread or channel crack, ribs tearing, buttress crack.
(d). In **retread tyres** are having the belt separation from the casing and patch failure issues.
(e). 11 tyres have OEM defects and 02 tyres have retreading defects.

Necessary actions taken and results
(i). OEMs defective tyres removed from the vehicles and sent for claim settlement.
(ii). Defective retread tyres are removed from the vehicles and sent to retreader for rework on FOC (free of cost) basis.

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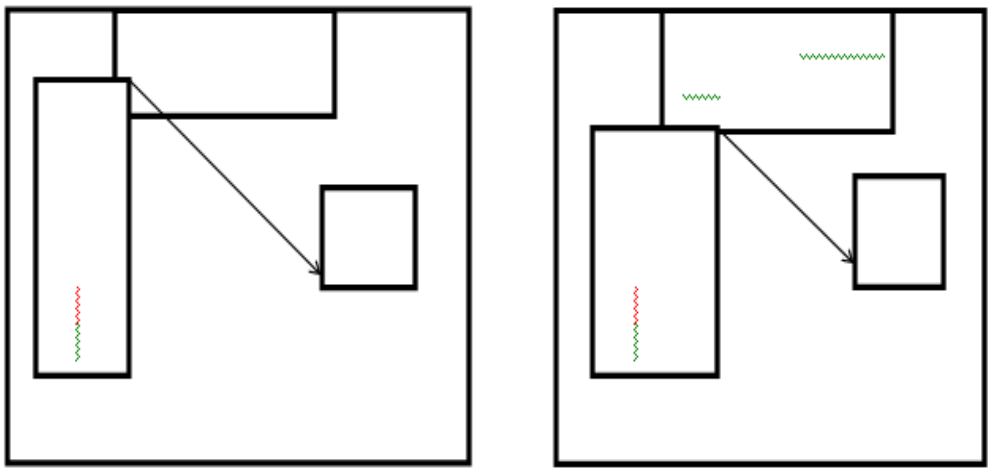

Fig 12 Reduction in OEM and retreading defects

3.5 CPKM calculations :(A) Calculations for rib pattern bias tyres

Table 04 Achieved higher km of rib pattern tyres

Sl. No.	**Sample**	**Av. km-I**(May19,June19, July19)	**Av. km-II**(Aug19,Sep19, Oct19	**Av. km-III**(Nov19,Dec19, Jan20)	**Av. km-IV**(Feb20,Mar20, Apr20)
1.	Original	45078	45176	45375	**48067**
2.	Retread	36104	36256	35983	**38540**

Note : cpkm= av price/av covered km
Av price original = 14425 Rs. (1442500 paise)
Av price retread = 4300 Rs. (430000 paise)

Table 05 Reduction in cpkmof rib pattern tyres

Sl. No.	**Sample**	**Av. cpkm-I**(May19,June19, July19)	**Av. cpkm-II**(Aug19,Sep19, Oct19)	**Av. cpkm-III**(Nov19,Dec19, Jan20)	**Av. cpkm-IV**(Feb20,Mar20, Apr20)
1.	Original	32.05	31.93	31.79	**30.01**
2.	Retread	11.91	11.86	11.95	**11.15**

(B) Calculations for block pattern biastyres

Table 06 Achieved higher km of block pattern nylon tyres

Sl. No.	**Sample**	**Av. km-I**(May19,June19, July19)	**Av. km-II**(Aug19, Sep19, Oct19	**Av. km-III**(Nov19,Dec19, Jan20)	**Av. km-IV**(Feb20,Mar20, Apr20)
1.	Original	60417	59118	59245	**65088**
2.	Retread	40952	39851	40451	**43370**

Note : cpkm= av price/av covered km
Av price original = 16500 Rs. (1650000 paise)
Av price retread = 4300 Rs. (430000 paise)

Table07 Reduction in cpkm of block pattern nylon tyres

Sl. No.	**Sample**	**Av. cpkm-I**(May19,June19, July19)	**Av. cpkm-II**(Aug19,Sep19, Oct19)	**Av. cpkm-III**(Nov19,Dec19, Jan20)	**Av. cpkm-IV**(Feb20,Mar20, Apr20)
1.	Original	27.31	27.91	27.85	**25.35**
2.	Retread	10.50	10.79	10.63	**09.91**

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(C) Calculations for block pattern radial tyres

Table 08 Achieved higher km of radial block pattern

Sl. No.	**Sample**	**Av. km-I**(May19,June19, July19)	**Av. km-II**(Aug19, Sep19, Oct19	**Av. km-III**(Nov19,Dec19, Jan20)	**Av. km-IV**(Feb20,Mar20, Apr20)
1.	Original	89057	86657	87074	**98566**
2.	Retread	41704	41255	44573	**48650**

Note : cpkm = av price/av covered km
Average price original = 19940 Rs. (1994000 paise)
Average price retread = 4600 Rs. (460000 paise)

Table09 Reduction in cpkm of radial block pattern

Sl. No.	**Sample**	**Av. cpkm-I**(May19,June19, July19)	**Av. cpkm-II**(Aug19,Sep19, Oct19)	**Av. cpkm-III**(Nov19,Dec19, Jan20)	**Av. cpkm-IV**(Feb20,Mar20, Apr20)
1.	Original	22.39	23.01	22.90	**20.23**
2.	Retread	11.03	11.15	10.32	**09.45**

IV. APPLICATIONS :

Generally applied in transportation sectors to analyze the performance checkup oftyres. By use of TQM tools to check the defects oftyres and also examine the cpkm oftyres. Defects and cpkm analysis are done commercial vehicles. By cpkm up and down, can know which tyres are beneficial to use to reduce the total expense of a vehicle.

V. ACKNOWLEDGEMENT

We would like to express our appreciation and gratitude to Sri Dr. SP Jagadish(Guide), for his valuable support, advice and guidance during the study of project work and also thanks to all teaching and non-teaching staff. Finally, I thank to almighty God, without blessings of him nothing would be possible.

VI. CONCLUSION:

From the experiments and results with the help of TQM tools found the improvement in tyre life and lowered the cpkm. Through TQM the involvement of the employees increased also. The participation of drivers, assistants of drivers, vehicles technicians, foreman, tyre mechanic, supervisors, engineers, tyresretreaders, tyres manufacturer (OEM), vehicles manufacturers etc. are increased through the TQM. The TQM processes, methods and practices are continuous improvement activities The experimental outputs are showing improvement in results. The following conclusions have been made from the experimental studies -

(I). Tyres mileage or life are increased by maintaining proper inflation, by doing well mechanical works, eliminate the wrong fitment and reducing the manufacturing and retreading defects.

(II). Which type defects are results of which type factors can be solved and can be eliminated or reduced.

(III). By more inspection cum repair works the premature removal or failure of tyres can be minimized.

(IV). The achieved cpkm are lower which show the better performance of tyres. The cpkm which achieved are lower than previous cpkm. The loweredcpkm are as -

Table 10 Gained lower cpkm

Sl No.	**Sample**	**Original/retread**	**Av. cpkm-III**	**Av. cpkm-IV**	**Gain**
1.	Rib pattern bias tyres	Original	31.79	30.01	**1.78**
		Retread	11.95	11.15	**0.80**
2.	Block pattern Bias tyres	Original	27.85	25.35	**2.50**
		Retread	10.63	09.91	**0.72**
3.	Block pattern radial tyres	Original	22.90	20.23	**2.67**
		Retread	10.32	09.45	**0.87**

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