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Analysis of Rolling Resistance & Wear Resistance

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A B S T R A C T

Tyres are an essential part of the any vehicle which is the oldest component of any vehicle used for transportation. The main component is the rubber materials (natural and synthetic rubber) use for the tyre compound. In this research paper, we have been trying to analyse rolling resistance, wear resistance, and wet grip index to enhance tyre performance and durability. However, in this paper, we have analysed the various criteria of tyre, and discovered that three responsible parameters (rolling resistance, wear resistance, and wet grip index) are interrelated. All of the variables are affected by the tyre's material qualities, normal load, tyre pressure, roughness, frictional force, and forward velocity.

Keywords: Rolling resistance, wear resistance, and wet grip index

INTRODUCTION

Tyres are an important aspect of the any vehicle which is the oldest component of any vehicle used for transportation. The main component is the rubber materials (natural and synthetic rubber) use for the tyre compound. In this research paper, we have been going to analyze rolling resistance, wear resistance, and wet grip index to enhance tyre performance and life. However, in this paper, we have examined the various criteria of tyre, and discovered that three responsible parameters (rolling resistance, wear resistance, and wet grip index) are interrelated. All of the variables are affected by the tyre's material features, normal load, tyre pressure, roughness, frictional force, and forward velocity.

a) Cross-ply tyres have a higher rolling resistance than radial ply tyres. Because of greater hysteresis, thickness increases rolling resistance.

b) Natural rubber tyres have lower rolling resistance than synthetic rubber tyres.

c) Less rolling resistance on a firm, smooth, dry surface the rolling loss as a result of the existence of a few factors:

- The friction between the tyres and the contact surface (Smooth, and rough surface)
- Tyre velocity reduction due to wind age
- Tyre material hysteretic losses as a result of cyclic stressing

Wear is the unwanted removal of material from one or both of the operating solid surfaces in relative motion such as sliding, rolling, and collision. Wear may also be described as surface deterioration caused by material depletion that results in no discernible change in volume or weight. It might happen as a natural result, but it usually happens as a result of surface contact at asperities. The operating conditions and material qualities have a considerable influence on wear [4]. Wet surface performance has long been an essential aspect of tyres and a key component in performance testing. As a result, the impact of tread depth on wet accident data is undeniable. Even if the vehicle has additional electronic safety systems such as traction control, stability control, and an anti-braking system, the ability to drain water from the car is still useful.

The contact patch between the tyres and the road surface will remain crucial The following factors influence a tyre's capacity to grip the road during braking:

- Vehicle speed,
- Degree of tyre wear,
- Type of the road surface.

The friction between a rubber tyre tread and the road surface is greatest when the vehicle is moving slowly or creeping. A tyre braking reaction on a smooth wet road while driving at a high speed

OBJECTIVE

- The main goal is to learn about tyre wear as well as its associated impacts, as well as to create a mathematical Analysis of rolling Resistance to simulate tyre wear and investigate how different factors are effect to tyre working

ANALYTICAL METHOD

The resistance to rolling defined as a resistance force opposing forward motion, the magnitude of which is generated by the product of the rolling resistance coefficient fr" and vertical load.

$$F_r = f_r N = \frac{W}{R} N$$

Where

Fr = Rolling Resistance Coefficient

fr = Rolling Resistance Force

N = Normal Force W = Load of wheel

R = Radius of wheel

Kevin Cooper has proposed the following empirical formula for calculating losses through resistance due to the rolling of the tyres. The formula takes inflation pressure and forward velocity into account:

$$Fr = 0.0085 + \frac{0.018}{p} + \frac{1.59}{p}(10\text{-}6)\ V^2$$

for velocities below 165 km/h

$$Fr = \frac{0.018}{p} + \frac{1.59}{p}(10\text{-}6)\ V^2$$

for velocities above 165 km/h

For velocities above 165 km/h

Where:Fr=RollingResistanceCoefficient

V=Velocityin kilometer/hour

p = Tyre pressure in bar (1 bar ≅ 1 atm)

Calculate the losses due to the rolling resistance at different-different velocities and tyre pressure at 1 atm

S.No	Tyre Pressure in bar	Tyre Velocities in km/h	Rolling Resistance Coefficient
1	1.0 bar	60	0.03224
2	1.0 bar	80	0.03667
3	1.0 bar	95	0.04084
4	1.0 bar	105	0.04402
5	1.0 bar	125	0.05134
6	1.0 bar	140	0.05766
7	1.0 bar	165	0.06978

S.No	Tyre Pressure in bar	Tyre Velocities in km/h	Rolling Resistance Coefficient
1	1.0 bar	165	0.6128
2	1.0 bar	185	0.0724
3	1.0 bar	205	0.0848
4	1.0 bar	215	0.0914
5	1.0 bar	235	0.0984
6	1.0 bar	245	0.1058
7	1.0 bar	265	0.1296

Wear Resistance

By the archard's wear theory, the contact between tribo- pair involve and breakage of junction. In other way, contact occurs only at roughness surface. The Archard model is demonstrated in figure, where cross section of roughness surface after plastic deformation is assumed to be circular

$$Q = KWL/3H$$

Where: Q = Wear Material Volume

K = Probability of removing a wear particle

W = Normal Load

L = Sliding Distance

S.NO	Probability of removing a wear particle(K)	Norm al load in kN (W)	Hardness of the softer material in *GPa* (H)	Wear Material Volume (Q)
1	1.11×10^{-04}	12	2	2.22×10^{-4}
2	1.11×10^{-04}	18	2	3.33×10^{-4}
3	1.11×10^{-04}	22	2	4.07×10^{-4}
4	1.11×10^{-04}	26	2	4.81×10^{-4}
5	1.11×10^{-04}	35	2	6.47×10^{-4}

Tyre Wet Grip

Interdependence of tyre parameters If the rolling resistance parameter is improved, the wet grip parameter is improved, and the wet grip parameter is improved, the exterior rolling noise is reduced. When the wet grip rises, so does the outward rolling noise. Tyre wet grip is the most crucial element for tyre safety. It consists of several components, including wet braking on moist pavement and hydroplaning on a heavy water layer.

Tyre Grip Index

Wet grip index means the ratio between the performance of the candidate tyre and the performance of the standard reference test tyre.

$$Wet\ Grip\ Index\ (T) = \frac{BFC\ (T)}{BFC\ (R)} \times 125 + a \times (t - t_0) + b \times \left(\frac{BFC(R)}{BFC(R0)} - 1.0\right)$$

T = Wet Grip Index

BFC (T) = Breaking Force Coefficient

BFC (R) = Breaking Force Coefficient t = Temperature during the test

t0 = Reference temperature

BFC (R) = Breaking Force Coefficient for SRTT16

BFC (R0) = Breaking Force Coefficient for SRTT are reference condition a = Temperature Adjustment Factor

b = Surface friction adjustment factor BFC(R0) = 0.68 is the breaking force coefficient for the SRTT16" in the reference conditions a= -0.4232 & b = -8.297 for N33ormal tyres If a road vehicle is braked in the 'straight-ahead' condition, wheel slip increases as the deceleration increase under increased driver effort. This is not a linear relationship, and ultimately a limit to the available braking force is reached,

Where the slip is 100%, which is the condition of the condition of wheel lock and skid. The term 'braking force coefficient' (BFC) can be used to represent the instantaneous ratio between the retrading force and the normal reaction force atthetyre/road interface

Assume the Braking Force on the wheel and Dynamic wheel load

S.No	**Braking Force on the wheel (N)**	**Dynamic wheel load (N)**	**BFC**
1	1.3 kN	1.5 kN	0.86
2	1.5 kN	1.8 kN	0.83
3	1.8 kN	1.9 kN	0.94
4	2.1 kN	2.1 kN	1.0
5	2.3 kN	2.6 kN	0.88

Test Speed	(60 ± 2) km/h
Test Load	(70 ± 5) % of Load Index
Test Inflation Pressure	Standard – load tyre : 180 kPaExtra – load tyre : 220 kPa
Water Depth	(1.0 ± 0.5) mm
Ambient Temperature	7 ~ 38 ℃
Wet Surface Temperature	7 ~ 38 ℃
Wetted Frictional properties	0.7 ± 0.1μpeak.corrected by temp.of SRTT 14"

S.No	**BFC(T)**	**Wet Grip Index**
1	0.86	148.734
2	0.83	143.219
3	0.94	172.684
4	1.00	182.739
5	0.88	153.680

RESULTS

It has been determined that rolling resistance, wear resistance, and wet grip are all linked. If we enhance the frictional resistance, we improve the wet grip index, and we improve the wet grip, we improve the exterior noise. When the forward velocity rose, so did the rolling resistance coefficient. And the wear of tyre substance is entirely dependent on the typical load and material qualities. The wet grip index is similarly affected by the BFC, as seen in the figures below.

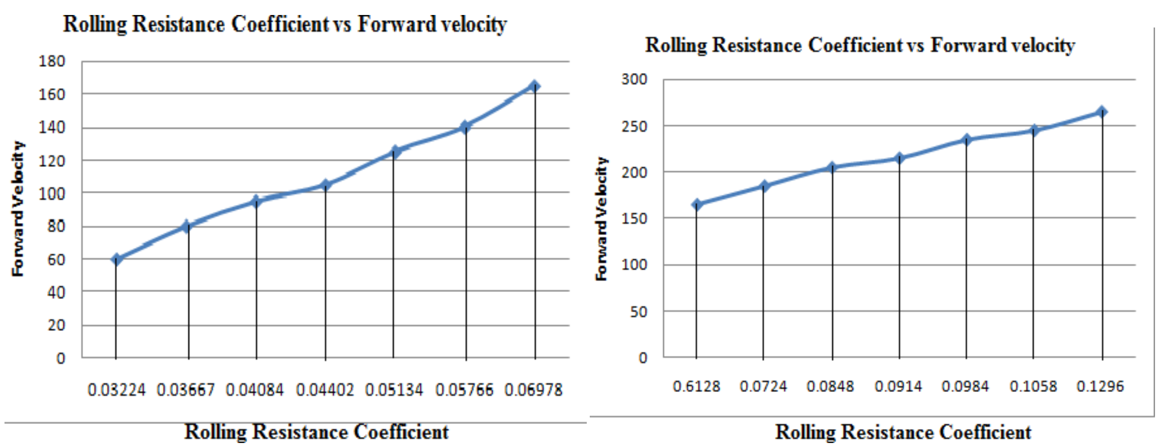

Fig.1 & 2 Rolling resistance vs forward velocity

The graph above shows that as the forward velocity of the wheel grew, so did the rolling resistance coefficient. We calculated the rolling resistance coefficient at various speeds. We estimated rolling resistance coefficients for two velocity ranges: forward velocity of wheel less than 165 km/h and forward velocity of wheel greater than 165 km/h.

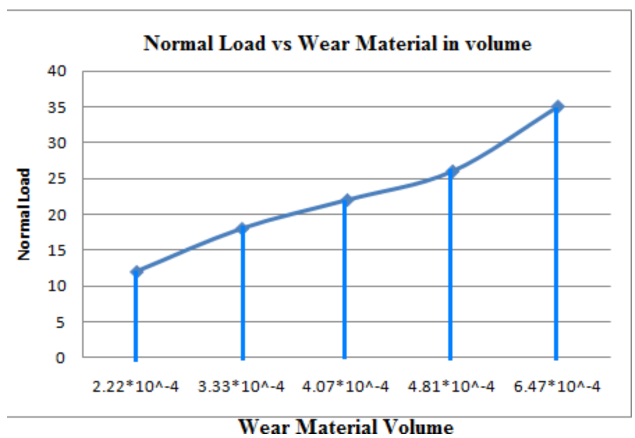

Fig.3 Normal Load vs Wear of Material

Draw a relationship between two factors such as normal load and wear material in volume above the graph. Finally, we arrive to the idea that materials wear is dependent on typical load. It is safe to assume that as the typical load increases, so will the materials wear.

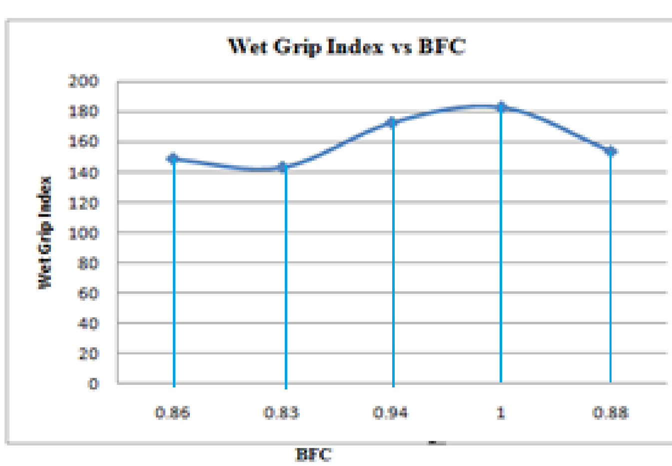

Fig.4 Wet grip index vs BFC

The relationship between the wet grip index and the braking force coefficient is seen in the graph above. According to this graph, as the braking force coefficient grew, so did the wet grip index.

CONCLUSION

The rolling resistance force changes with velocity and tyre pressure. As seen in Figures 1 and 2, the rolling resistance coefficient increased as the forward velocity of the wheel increased. Normal load and tyre pressure have an impact on wear resistance. Using the same tyre pressure at different speeds, the rolling resistance coefficient was calculated, and it was observed that the rolling resistance coefficient varied with forward velocity. Wear resistance was calculated using the same tyre pressure with different normal loads and found to vary with normal load. The material wear rises when the usual load is increased, as seen in fig. 3. The most important component in vehicle safety is wet grip. The wet grip index has an effect on the BFC score as well.When demonstrated in Fig. 4, as the braking force coefficient increased, so did the wet grip index.

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