Investigation of "HD-HS Silica" Embraces Tyre Material and Analysis of Rolling Resistance and Wear Resistance Performance of Tyre

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Abstract— Tyre is one of the extremely old parts of any vehicle to transport anything. The major constituent is natural or synthetic rubber compound used for the tread on the tyre. In this research paper, to investigate the HD-HS Silica used in tyre, As per the research number of verity of silica used in tyre for improving the tyre performance, but in this paper, used advance silica that is known as Highly Dispersible and High surface area (HD-HS) Silica. Due to this advance material also affect the property of the tyre material like wet grip, wear resistance and rolling resistance. In this paper, basically focus on rolling resistance and wear resistance of the tyre; it has a significant influence on fuel economy during constant speed drive.

Key words: HD-HS Silica, Tyre Materials, Rolling Resistance, Wear Resistance

I. Introduction

From the invention of tyre in 1880s by John Boyd Dunlop, the performance optimization of the tyres was always considered. Latest major tyre research development fixates on the reduction of fuel consumption of the conveyances and an enhanced tyre mileage. A component of the kinetic energy generated by a conveyance has to be absorbed by the suspension system, the brakes and the tyres corning and braking [1].

The invention of the wheel is considered to be one of the most consequential ever. The first solid wheels where superseded by voiced wheels which sanctioned for lighter conveyances; their rudimentary design, however, has not been transmuted for ages. The exordium of pneumatic tyres in the tardy nineteenth century led to a leap forward in providing comfort by enveloping microscopic hitches on the road. Since then, pneumatic tyres have been amended in construction and geometry. These tyres are referred to as inequitableness-ply or diagonal tyre, radial tyre has become more popular, in which the plies are laid at alternate angles of less than 90°. Since the 1960s, radial tyres have become more popular, in which the ply layers are laid at 90° with veneration to the center line of the tread. These layers are referred to as carcass. On top of the radial carcass diagonal belts are placed at angles between 20 and 30° for more rigidity and better presentation. Meanwhile, tubeless tyres which do not require a separate butyl rubber inner tube were introduced and have ameliorated safety. Nowadays, the aspect ratio of the tyre – the height of the sidewalls to the tyre width – inclines to decrement. This change is driven by an incremented conveyance power and the increasing paramountcy of design. It additionally provides better handling on dry roads. The consequentiality of tyre design in the consumer market is reflected in tread pattern types as well. The tread pattern was very simple at the exordium of the pneumatic tyre. Nowadays, intricate tread patterns are available for different applications, from which the summer, winter and all-season tyres are the most prominent. These tyres differ not only in tread pattern, but withal in rubber compound. For instance, winter tyres consist of a tread rubber complex which is softer than summer tyres, even at low temperatures. Moreover, special tyres have been established for trucks, trailers and agricultural transportations. The main objectives of the tyre are: (i) to carry the mass of the conveyance, (ii) to conduct acceleration braking services from tyre towards road and (iii) to provide luxury and weaken unwanted shakings. These tyre characteristics result in different requisites which are considered supreme for the evaluation of tyre quality [2].

A. *Tyre Functions*

- Vehicle to road interfacing
- Support vehicle load
- Road surface friction
- Absorb road irregularities

There is important parameter of tyres [3].

B. *Tyre Material*

- Carbon black
- Silica
- HD (Highly Dispersible) Silica
- HD-HS (Highly Dispersible and Highly Surface) Silica

C. *Rolling Resistance*

Interest in fuel conservation and the national goal of more energy efficient vehicle generated considerable interest in the phenomenon of the rolling resistance of tyres. It is generally recognized that the tyre represent one of the major loss mechanisms for the engine output of vehicle. The quantitative influence of tyre rolling resistance on fuel consumption driving cycle.

The rolling loss of a tyre is made up of three parts:

- Friction between tyre and roadway
- Wind age loss of the tyre
- Hysteretic losses of the tire material due to cyclic stressing [4].

D. *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 [5].

II. Materials and Methodology

Natural and synthetic rubber does not have sufficient for long life of tyre. So achieve high performance in tyre efficiency, used some filler materials in tyre material like carbon black, silica, HD silica and HD-HS silica etc. It has been seen many change in tyre properties.

- Due to carbon black presence in tyre material, improve the tyre tear and wear rate increase. When it is heated to a molting state carbon complete the bond with tyre material and provide hard and tough property. In tyre material present oil extension its provide the uniform dispersion and get shape easily [6]. Silica is a filler material used for improving the rolling resistance.
- HD Silica, it is tyre filler material. For improve the rolling resistance of tyre, silica added in tyre material. Due to presence of carbon black in tyre material increase the rolling resistance so reduce the rolling resistance HD silica added in tyre material. The standard HD silica used in passenger car tyre tends to agglomerate, which limits the reinforcing properties and it is not compatible with emulsion-based polymers such as natural rubber.
- HD-HS silica is another filler material. It is new generation advance tyre filler material. From the this material can achieve better dispersion and can be used for this more demanding requirement profiles, it can result in better wear resistance without scarifying rolling resistance and wet grip.

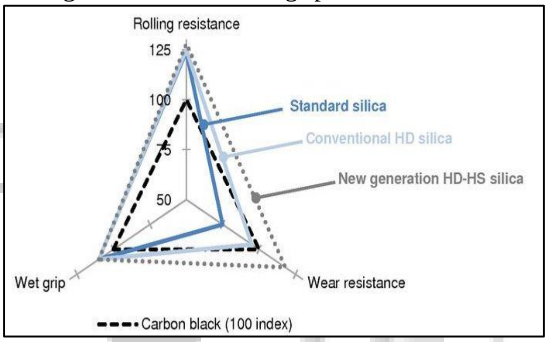

Fig. 1: Performance improvement achieved using new generation of HD-HS silica

Silica Type	Surface area (m^2/g)		
	90-130	130-180	180-220
Conventional	Type casings	Tyre casings Tyre treads	Tyre treads
Semi-high dispersion	Type casings	Tyre casings	Tyre treads
High dispersion	Type casings Tyre treads	Tyre treads	——
Highly dispersible high surface area	——	——	High-performance tyre treads

Table 1 : Classification of silica groups used in rubber tyres

Physical Property	Unit	Conventional Silica	HD silica	HD-HS silica
CTAB surface area	m^2/g	110	160	200
BET surface area	m^2/g	115	165	215
Diameter of elementary particles	m^2/g	25	20	10
Mean Diameter of aggregates	m^2/g	95	60	55-60

Table 2: Characteristic properties of conventional, high dispersion and highly dispersible high surface area silica

A. *Rolling Resistance*

The resistance to rolling expressed via a resistance force that oppose the forward motion, and whose value is given by the product of the rolling resistance coefficient f_w and vertical load.

$$F_w = f_w \, N = \frac{d}{R} N$$

Where
F_w = Rolling Resistance Coefficient
f_w = Rolling Resistance Force
N = Normal Force

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:

For velocities below 165 km/h

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

For velocities above 165 km/h

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

Where
F_w = Rolling Resistance Coefficient
V – Velocity in kilometer per hour
p – Tyre pressure in bar (1 bar ≅ 1 atm)

S. No	Tyre Pressure in bar	Tyre Velocities in km/h	Rolling Resistance Coefficient
1	1.0 bar	50	0.03047
2	1.5 bar	70	0.02569
3	2.0 bar	90	0.032439
4	2.5 bar	110	0.02339
5	3.0 bar	130	0.02345
6	3.5 bar	150	0.02386
7	4.0 bar	165	0.02382

Table 3: rolling resistance at different-different velocities and tyre pressure

S. No	Tyre Pressure in bar	Tyre Velocities in km/h	Rolling Resistance Coefficient
1	1.0 bar	165	0.06128
2	1.5 bar	185	0.04827
3	2.0 bar	205	0.04240
4	2.5 bar	215	0.03659
5	3.0 bar	235	0.03526
6	3.5 bar	245	0.03241
7	4.0 bar	265	0.02836

Table 3: rolling resistance at different-different velocities and tyre pressure

B. *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.

$$Q = \frac{K\,W\,L}{3\,H}$$

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)	Normal load in kN (W)	Hardness of the softer material in GPa (H)	Wear Material Volume(Q)
1	1.11×10^{-04}	10	2	1.85×10^{-4}
2	1.11×10^{-04}	15	2	2.77×10^{-4}
3	1.11×10^{-04}	20	2	3.7×10^{-4}
4	1.11×10^{-04}	25	2	4.62×10^{-4}
5	1.11×10^{-04}	30	2	5.55×10^{-4}

Table 5: Wear resistance at different-different normal load

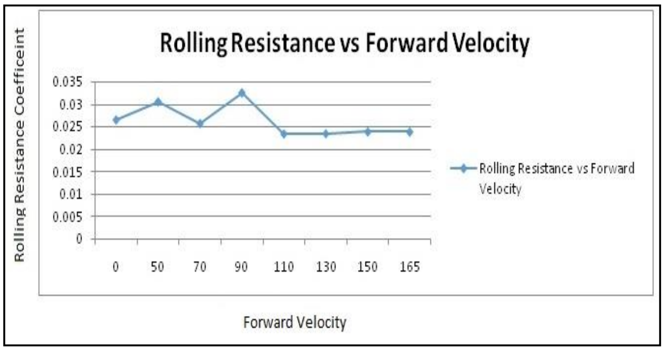

Fig. 2: Rolling resistance vs forward velocity

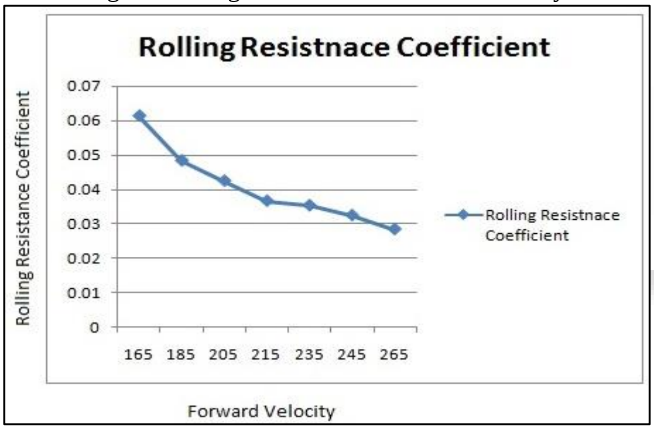

Fig. 3: Rolling resistance coefficient

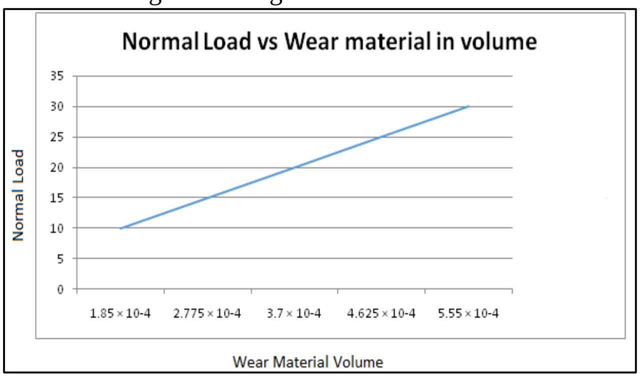

Fig 4: Normal load vs wear material in volume

III. Result

When mixed the carbon black improve the wear and tear property of tyre. It achieves the rolling resistance of tyre, silica added in tyre material. Due to presence of carbon black in tyre material increase the rolling resistance so reduce the rolling resistance HD silica added in tyre material. It achieves better dispersion after using HD-HS silica this applicable high speed and heavy load vehicle. When the silica content increases with decreasing carbon black, the hardness decreases gradually. Compared to carbon black, a higher amount of silica is needed in order to achieve the same hardness level.

IV. Conclusion

After using different types of filler material in tyre material its has been found that using HD- SH silica in tyre material can be achieve long tyre life, high dispersion and reduce the rolling resistance. Rolling resistance force changes at velocity and tyre pressure. Wear resistance depends on normal load and tyre pressure.

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