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Comparative Study of Tyre Rubber and V-Belt Rubber: Composition and Mechanical Properties

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Abstract: *Natural rubber is used for manufacturing of tyres, seats, seatbelts, floor mats of automobile, foot-rest of bikes, etc. Natural rubber also finds its application in belts industries where different types of belts are manufactured viz. flat belt, V-belt, and multi-groove belt. As natural rubber is sticky in nature, it is generally used after curing. Cured natural rubber is used for manufacturing of treads of tyres, vehicle mats, and conveyor belts in manufacturing companies related to automobile. Curing is done by the process of vulcanization. Sulphur is commonly used vulcanizing agent. Along with sulphur, various additives and accelerators are added to boost its properties according to the final product application. Each product made of rubber is different in its composition as well as its physical and mechanical properties. In actual, physical as well as mechanical properties of each product made up of natural rubber depends mostly on its composition. This paper appraises the study of two distinguish materials made of rubber i.e. simple tyre rubber and vee-belt rubber in terms of their composition and its mechanical properties.*

Keywords: *Natural rubber, Curing, Vulcanization, Tyre rubber, V-belt rubber*

I. Introduction

Natural rubber is an elastomer whose structure is being transformed by chemical crosslinking, the process known as curing. Far from the past, natural rubber is in excessive usage in the form of various products. Natural rubber is used in many manufacturing industries. There are various manufacturing companies as well as factories which are using rubber in large extent for their production of products. Whether it's related to automobile industries, medical companies or defense sector, rubber finds its application by one way or other. Rubber is used by many manufacturing companies for the production and manufacturing of various products. The first use of rubber is eraser. Natural rubber is used as by-product in manufacturing of different products. Uncured rubber is used for insulating blankets and footwear as well as friction tapes. Uncured rubber is also used for adhesives and cements. Cured natural rubber is used for manufacturing of treads of tyres, vehicle mats, and conveyor belts in manufacturing companies related to automobile. Similarly, it is used in manufacturing of raincoats and sponges, toys, paints, bowling balls, electrical insulation, balls, rafts etc. Hand gloves used by doctors and chemical and medicinal tubing finds its application in medical industries. Nowadays, rubber bullets have been made as ammunition for defence sector. So natural rubber finds its application in almost every section. In mechanical engineering, natural rubber is associated in large extent. Natural rubber is used for manufacturing of tyres, seats, seatbelts, floor mats of automobile, foot-rest of bikes, etc. Natural rubber also finds its application in belts industries where different types of belts are manufactured.

The Natural rubber is in the form of latex is sticky, soft, and thermoplastic. It has low tensile strength and low elasticity. It is a mixture of polymeric chains with varying lengths [1]. Most importantly, there is no cross linking. Some goods become brittle in cold weather and some gum together under the sun As a result, the material did not find any significant application. However, these properties are changed by a process known as vulcanization. Vulcanization is a chemical process in which natural rubber or related polymers are converted into more durable materials via the addition of accelerators (generally sulphur) [2]. These additives modify the polymer by forming cross-links between individual polymer chains. Vulcanized rubber is elastic & less sticky not alike raw rubber, doesn't harden or soften much with cold weather except at very high temperatures. In addition, it is highly resistant to abrasion [3]. The cross linking improves its tensile strength. Vulcanized rubber is ten times stronger as well as more rigid than natural rubber. As natural rubber is sticky in nature, it is generally used after curing [4]. Each product made of rubber is different in its composition as well as its physical and mechanical properties. In actual, physical as well as mechanical properties of each product made up of natural rubber depends mostly upon its composition.

II. Literature Survey

H. Bechir et al. (2005) revealed that theoretical and experimental techniques are considered for the mechanical behaviour of vulcanized natural rubber which is incompressible & isotropic and for the mechanical behaviour of vulcanized natural rubber which is filled with carbon black and is quasi incompressible. Strain energy density function (W) was derived by generalizing the neo-Hooken model. He identified the strain energy density function (W) by taking simple tests and determined the 2-dimensional field of homogeneous displacements by using image analysis cross correlation technique developed at home. His technique is a success as the results obtained numerically and experimentally are same and can be used for characterizing the behaviour of natural rubber. [5]

Ch S S R Kumar et al. (2007) published an article informing the techniques to alter molecular structure and how to influence the physical properties of vulcanised rubber. According to him, rubber obtained from the trees in the form of latex is very soft, thermoplastic and sticky with low elasticity and low tensile strength and without the crosslinking. It was Charles Goodyear who accidentally discovered the process of vulcanisation in 1839. He advised the use of various accelerators like sulphonamides etc. to influence the physical properties and additives to alter the molecular structure in order to find the application of rubber in various fields such as automobile tyre, balls, eraser, v-belts etc. he revealed that the process of vulcanisation should be controlled at each and every level. He concluded that many MRC's are utilized in industries to improve the qualities of rubber for wide range of applications.

Al. Pusca et al. (2008) overviewed various studies on reuse of scrap tyres for production of various other rubber products. He also go through various studies carried out on mechanical properties of tyre rubber. He concluded various factors affecting the properties of blended polymers such as size, filler content, shape of particle, and structure. Stiffness, strength and various other mechanical properties also makes an impact on properties of blended polymers. Type of moulding methods and compounding methods as well as type of coupling agent and dispersion aid used also affect its properties. When minerals were added to polymers, their properties are not the same as that of brittle polymers.

S. Shylin H. Jose et al. (2015) reviewed mechanical properties of rubber composites as well as fillers used to increase various mechanical properties. Commonly used fillers in rubber composites are starch, carbon black, silica, bentonite, polystyrene, and nano clay and palm ash. Increasing starch will boost the mechanical properties. He also reviewed the increase of tensile strength upto 40 phr (parts per hundred) with addition of fillers in natural rubber. Adding palm oil in natural rubber will increase tensile modulus, tear strength and tensile strength. He also studied the decrease of tensile strength due to increase in ratio of ethylene propylene diene monomer (EPDM) in the blends of natural rubber/EPDM filled with carbon black. V-belts are manufactured and produced from fibre reinforced rubber composites. He concluded that fillers are added for the improvement of mechanical properties in rubber composites and ultimately to reduce the cost of the product. He also included in his conclusion that adding fillers upto some extent will increase its mechanical properties and beyond that further addition will decrease the mechanical properties.

Mohd bijarimi et al. (2010) studied the effect of carbon black grades when added to different tyre tread compounds. He choose N339/N375 and N550/N660 grades of carbon black. He found no or minimal effect of carbon black grades of N339/N375 on tear strength, tensile strength, hardness and resilience of tyre tread. But N550 should be substituted indirectly with N660 otherwise it will affect the mechanical properties of the tread compound.

Tae keun lee et al. (2007) analyzed vibration analysis of automobile tyre, when passed through a cleat or bump. He also analyzed the change in design factor of proposed tyre due to bump impact as freedom system of automobile tyre is assumed to be 7-degree. He also assumed three rigid bodies of tyre of which it consists are tread ring, tread block, and sidewall. Stiffness and damping of each body depends upon tyre design factor and vertical spring rate. Experimental method and numerical analysis were used for the verification of model of automobile tyre. Numerical analysis was done by using the root mean square method. Harshness test was done experimentally. He concluded that stiffness and hardness in tread rubber will decrease on reduction of vibration energy which produced when an automobile tyre passes the road dump or cleat. He also concluded that side part can also play an important role in reducing vibration energy as vibration from bump to rim transmits through it. Other notable conclusions were increase in mass of tread block as well as tread ring, decrease in belt angle and increase in width of belt, apex length, and decrease in apex hardness. [6]

P. kindt et al. (2008) measured and analyzed vibrations of rolling tyre due to railroad crossings, cobbled road and bumps. A noise radiation below 500Hz frequency occurs due to tyre vibration. Measurement of tyre vibrations were performed with laser Doppler vibrometer. The whole setup was based on tyre-on-tyre principle in which impact excitations can be controlled and repeated as many times under various conditions. Both the tyres were identical. One of them was driven by 3-phase induction motor at 7.5 KW power while multi-axial wheel hub dynamometer was implemented to mount the other tyre on it. He also discussed impact on alignment errors, random noise velocity, and sensitivity. The dynamic behaviour of rolling tyre was characterised by applying an operational model analysis technique. He compared model parameters of rolling tyre and non-rolling tyre and assess the changes in dynamic behaviour of rolling tyre. He concluded that to analyse vibrations of smooth but rolling tyre, the laser Doppler vibrometer is very useful. Resonance frequencies of rolling tyre decreases and change in design of rolling tyre strongly depends on speed of rolling of tyre. [7]

H. Huynh et al. (1997) exposed the shredded rubber to highly alkaline environment to simulate the durability of shredded rubber in concrete. After exposing and placing rubber to concrete matrix for long time, Rubber should have minimum reduction in its strength and degradation. The degradation emerges due to changes in tensile strength, mass, microstructure, and swelling. He resulted small changes in shredded rubber after 4 months of exposure to highly alkaline medium and suggested that no effect on durability of concrete due to addition of rubber. He performed the tests at same time intervals and used fibres in alkaline solution of pH 10 to 12. His conclusions include: small changes in rubber fibres when placed in alkaline medium for long interval of about 4 months, fibres retain their tensile strength after 4 months of immersion in alkaline solution, and examined no change in texture of the rubber fibres. [8]

N. Oikonomou et al. (2009) studied mechanical properties as well as physical properties of mixture of worn automobile tyre rubber and cement mortars. He examined laboratory researches for partial incorporation of worn tyre rubber and replacement of sand in cement mortars. He also measured resistance to chloride ion penetration. He resulted decline in mechanical properties but shows positives in chloride ion penetration and water absorption by immersion. Chloride ion penetration resistance increases but mechanical properties decreases. Effect on Chloride ion penetration reduces the possibility of corrosion. He concluded that concrete products and cement mortars in which worn tyre rubber granules are used can be applicable to the situations where there is demand of high chloride ion penetration resistance and where mechanical properties are not much considered.

J. George et al. (1999) evaluated the various effects of crosslinking on mechanical properties, and rheological properties of high density acrylonitrile butadiene rubber and polyethylene. Electron microscope was used to study the morphology. From the microscopy and dynamic mechanical analysis he indicated that the blends are immiscible. He suggested to employ dynamic vulcanization as a combatibilisation technique to obtain finer plus stable morphology with improved mechanical properties. The rheological data informs to process dynamically vulcanised rubber as thermoplastics. Dicumyl peroxide was used for vulcanisation. If Dicumyl peroxide increases the density of crosslink also increases. Tensile strength and tear strength, after vulcanisation get boosted due to presence of crosslinking of rubber particles.

C. Nakason et al. (2006) studied thermal, rheological, and morphological properties of maleated rubber and its reactive blending with methyl methacrylate. Maleated natural rubber or MNR were prepared at 135°C by blending maleic anhydride with natural rubber for 10 minutes. Chemical crosslinks and chemical interaction between maleated natural rubber molecules might increase levels of maleic anhydride which are responsible for increasing shear viscosity and Mooney viscosity. Increasing maleic anhydride will increase the glass transition as well as decomposition temperature of maleated natural rubber. Shear viscosity and shear stress increases upto some extent and then starts decreasing with further increase in reactive blends of maleated natural rubber [9]. He concluded maleated natural rubber blends as compatible blends on the basis of log-additive log. He also analyses SEM graphs.

M. Patel et al. (2000) studied thermal aging of vulcanized polysiloxane rubber at room temperature. In a closed system, aged polysiloxane rubber softens with time but in an open system, it remains rigid. Compression set would be achieved under the identical conditions due to aging of rubber. He assessed various aged sample properties with compression set at different temperatures [10]. He obtained the data relative to Arrhenius treatment. Two degradation processes with different activation energies were found present in the aged samples. He predicted the value of compression set in rubber equal to 25% for a time period of 18.8 years.

III. Tyre Rubber Vs. V-Belt Rubber

Tyres are used in field of automobiles. Each and every automobile vehicle runs on tyre made up of rubber except railway train. Whether it’s a passenger car, motorcycle, scooter, lorry truck, buses, heavy trucks, bicycle etc. Even airplane also have rubber tyres for take-off as well as for landing. These tyres are different to each other in their composition, fillers used, mechanical as well as physical properties but the basic components of each and every tyre are same.

A V-belt is used to transmit power by mechanically linking two or more rotating shafts. There occurs no problem of alignment and slipping in using V-belts, which usually occurs in other type of belts. The cross sectional shape of V-belt is trapezoidal in nature, that’s why it is called as V-belt. The V shape of the belt restricts the slipping of the belt. It is also known as wedge rope. V-belt is mostly used in the factories and workshops, where a great amount of power is to be transmitted, from one pulley to another when the pulleys are very near to each other. The V-belts are made of cords and fabric moulded in rubber and covered with rubber and fabric. These are moulded to trapezoidal shape and are endless.

Comparison Of Chemical Composition Of Tyre Rubber Compound And V-Belt Rubber Base Compound

Table 1: Comparison of composition of Tyre Rubber and V-Belt Rubber

SR. NO.	INGEDIENTS	TYRE RUBBER		V-BELT	
		WT.(IN KG)	PHR	WT.(IN KG)	PHR
1	RENACIT-7	0.020	0.06	0.050	0.178
2	NATURAL RUBBER (RMA)	15.000	50.00	21.000	75
3	SYNTHETIC RUBBER (SBR)	20.000	68.75	6.000	21.42
4	CARBON BLACK (HAF)	24.000	70.00	22.00	78.5
5	ZINC OXIDE	1.750	5.00	3.000	10.71
6	STEARIC ACID	0.700	2.00	0.300	1.071
7	H.S./TQ	0.525	1.50	0.300	1.07
8	4020 NA	0.175	0.50	0.150	0.537
9	WOOD ROSIN	0.700	2.00	0.500	1.78
10	RUBBER PROCESSING OIL (RPO)	3.500	10.00	0.500	1.78
11	P.WAX	0.525	1.50	-	-
12	SULPHUR	0.770	2.20	0.380	1.35
13	CBS	0.525	1.50	0.250	0.89
14	PVI	0.040	0.12	0.030	0.10
15	TMTD	0.070	0.20	-	-
16	MBTS	-	-	0.050	0.17
17	CRUMB/BURA	-	-	2.000	7.14
18	WHITE CARBON (V.L.)	-	-	4.000	14.28
19	C/FLX	-	-	2.000	7.14
	TOTAL	68.800		64.510	

Mechanical properties of tyre rubber compound

The significance of these properties as well as how they are conducted is discussed below:

1. Tensile strength: Tensile strength is a measurement of the force required to break the rubber specimen. It is also known as ultimate tensile strength. It is the maximum amount of force a rubber specimen can withstand without being deformed or fractured when stretched. It provides us the information about the strength of the rubber specimen. Tensile strength is measured with dumbbell shape tensile testing machine [11]. The rubber specimen is placed in between the machine and stretched from both sides. The pointer attached on the side of the testing machine will deflect the value of tensile strength and the amount of force at which the rubber specimen deforms and get fractured. The tensile strength of the tyre rubber compound is 145.5 KG/CM^2 and v-belt rubber compound is 128.5 KG/CM^2.
2. Tear strength: Tear strength or tear resistance is the resistance offered by the rubber specimen against the tension applied to form nick or cut. It is the measure of strength shown by rubber specimen against the effect of tearing [12]. Tear strength is measured with same equipment as that of used for the measurement of tensile strength i.e. tensile testing machine except that the final reading is calculated by dividing the force applied by the thickness of the specimen. The calculated tear strength is 40 KN/M and 37.5 KN/M respectively.
3. Hardness: The measure in which the rubber specimen shows its resistance when the force is applied [13]. It is the resistance to indentation. There are generally two types of hardness tester which are Shore Durometer and International Rubber Hardness Degrees. Shore Durometer are of three types: Type A, Type B, and Type C. Shore Durometer of type A or Shore A is used to measure the hardness of the rubber. The reading is displayed on the screen as it is digital Durometer.
4. Elongation: The rubber is stretched as long as it breaks. The measure of the specimen of how much the rubber stretches before it breaks is known as elongation. It is the increase in the length of the specimen from the original length when stretched by applied force until it breaks [14]. Elongation is measured with extensometer which is attached to the tensile testing machine in which an electronic ruler is attached which measures the extension of the rubber when force is applied [15]. It is generally measured in percentage (%). The elongation at break is 400% and 210% respectively.
5. Modulus: Modulus or Young's Modulus is also known as Elastic Modulus, Modulus of elasticity, and Tensile Modulus. It is the measure of stiffness. Modulus is measured during the tensile strength testing. If we plot a graph between stress and strain for tensile strength, the slope of the curve obtained is the Young's

Modulus. Modulus at 300% means the specimen is stretched 300% and we want to know the value of force required to do so [16].

Table 2: Comparison of Mechanical Properties of Tyre Rubber and V-Belt Rubber

SR. NO.	TEST	UNIT	READING/OBSERVATION	
			TYRE RUBBER	V-BELT RUBBER
1	TENSILE STRENGTH	KG/CM^2	145.5	128.5
2	TEAR STRENGTH	KN/M	40.0	37.5
3	HARDNESS	SHA°	68	85
4	DENSITY OF COMPOUND	G/CC	1.20	1.15
5	ELONGATION AT BREAK	%	400	210
6	MODULAS@300%	KG/CM^2	110	101.5

Both the products, tyre rubber compound and v-belt rubber compound are heated @ 70°c for 72 Hours. The properties of both the products are then again tested and readings are observed. Following are the readings observed and the comparison between tyre rubber and v-belt rubber compounds after accelerated ageing @ 70°c for 72 Hours is done and shown in table. 3

Table 3: Comparison of Mechanical Properties of Tyre Rubber Compound and V-Belt Rubber Compound after Ageing @ 70°c for 72 Hours

SR. NO.	TEST	UNIT	READING/OBSERVATION	
			TYRE RUBBER	V-BELT RUBBER
1	TENSILE STRENGTH	KG/CM^2	125.0	105
2	HARDNESS	SHA°	76.50	90.0
3	MODULUS	KG/CM^2	95	59.5
4	ELONGATION	%	325	140

IV. Conclusion

The different amount of same ingredients and different additives and accelerators used in manufacturing of both the products results in different properties. This study concludes the following:

1. The amount of Natural rubber used in tyre is (15kg) less than v-belt (21kg) but synthetic rubber (20kg) weighs more in tyre compound than v-belt (6kg).
2. A slight difference in amount of carbon black used i.e. 24kg in tyre compound and 22kg in v-belt.
3. Tensile strength as well tear strength of the tyre rubber compound is more than v-belt because of more amount of rubber processing oil, sulphur and antioxidants added in composition.
4. Hardness is more in case of v-belt rubber as that of tyre rubber due to much amount of addition of zinc acid and additives like crumb/bura, white carbon etc.
5. The similar difference is observed between the two rubber products after accelerated ageing of both the products @70°c for 72 hours

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