A review of the filler materials being used in rubber processing industry

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Abstract

Going by the definition, in view of rubber industry fillers are those materials that are added to the latex (natural rubber) or synthetic rubber in order to get desired properties out of the given rubber to meet the industrial applications and also to lower the consumption of the binder material to curb the economics of the production cost. Carbon black and Calcium Carbonate is by far the leading filler material being used in the industry. But other materials like sulfates, silicates like mica, feldspar, nepheline syenite, talc, clay, wollastonite etc. along with hydroxides like ATH, MDH and nano-fillers are also cover a broad spectrum of filler material being used these days. This review covers effect and rubber-filler interaction of above mentioned filler materials along with their industrial applications.

Keywords: latex, (carbonate, hydroxides, silicate)-filler, rubber-filler interactions

Introduction

Of the ingredients used to modify the properties of rubber and plastic products, the filler often plays a significant role. The term “filler” is misleading, implying a material intended primarily to occupy space and act as a cheap diluent of the more costly elastomer. Most of the fillers used today offer some functional benefit that contributes to the process ability or utility of the rubber or plastic product[1].Fillers are used to modify the physical properties of plastics, such as flexural modulus and heat distortion temperature, or to impart some special function, for example, flame retardancy or magnetic properties. High filler loadings, however, may adversely affect process ability, ductility and strength of the compound [2]. The characteristics which determine the properties that a filler will impart to a composite are particle shape, particle size, surface area and particle-matrix compatibility. Particle-matrix compatibility relates to the ability of the polymer to coat and adhere to the filler.[1].The shape of most mineral filler particles can be approximated as a sphere, cube, block, plate, needle or fiber. Some filler contain a mixture of shapes. Mineral particles resembling plates, needles and fibers are further characterized by their aspect ratio [1]. For elastomers, if the size of the filler particle greatly exceeds the polymer inter chain distance, it introduces an area of localized stress. This can contribute to elastomer chain rupture on flexing or stretching. Fillers with particle size greater than 10,000 nm (10 μm) are therefore generally avoided because they can reduce performance rather than extend or reinforce. Fillers with particle sizes between

1,000 and 10,000 nm (1 to 10 μm) are used primarily as diluents and usually have no significant affect, positive or negative, on rubber properties. Semi-reinforcing fillers range from 100 to 1000 nm (0.1 to 1μm). The truly reinforcing fillers, which range from about 10 nm to 100 nm (0.01 to 01 μm) significantly, improve rubber properties [1]. The equipment used for particle size analysis, whether based on principles of x-ray sedimentation, light scattering, light extinction or electrical resistance/volume displacement, match the behavior of a particle, regardless of shape, to that of an ideal sphere of specific diameter. Particle size is therefore conventionally reported as diameter, but the values reported are actually in terms of **e**quivalent **s**pherical **d**iameter (**esd**) [1]. Fillers are often sold according to "nominal" mesh size. This can mean anything from 95% to 99+% through the indicated mesh. Mesh size indicates nothing about the size distribution of the oversize particles or the undersize particles [1].
Now lets us consider different filler materials employed in the rubber processing industry and glimpse their characteristics and effects on the rubber material being produced.

WORK DESCRIPTION

CALCIUM CARBONATE
One of the most important phenomena in material science is the reinforcement of rubber by rigid entities, such as carbon black, clays, silicates, and calcium carbonate. Thus, these fillers, or reinforcement aids are added to rubber formulations to optimize properties that meet a given service application or sets of performance parameters . Although the original purpose is to lower the cost of the molding compounds, prime importance is now attached to the selective active fillers and its quantity that produce specific improvements in rubber physical properties. CaCO3 particles are generally supplied as agglomerates and during processing they are broken and dispersed into primary particles. Large particle-particle interactions result in inhomogeneous distribution of the filler, processing problems, poor appearance, and inferior properties. This fact may emphasize the importance of homogeneity where the increasing amount of aggregates leads to a decrease of tensile properties of the rubber composites. It is well known that the overall performance of composites is achieved by the addition of a low molecular weight organic compound, such as stearic acid, resulting in a better dispersion of the particles in the rubber matrix. Finally, aging behavior is taken as deterioration due to the prolonged action of high-energy radiation, where several changes in the chemical network structure can occur. Evaluation of aging behavior isn't only estimated from the changes in tensile properties but also to include liquid absorption measurements. This article deals with the effect of CaCO3 addition to natural rubber (NR) or nitrile rubber (NBR) on the cure characteristics and physicomechanical Properties

Cure Characteristics:-

The cure characteristics of CaCO3 loaded the rubber matrix (NR or NBR) is shown in Table 1.

Table (1) : Technical Specifications of Calcium Carbonate (CaCO3)

Specific gravity (g/cm^3)	2.65
Oil absorption	35
Particle size (μm)	3.25
Surface area (m^2/g)	3.6

The results seemed to be dependent mainly on the rubber matrix. Values of the cure time, t_{90}, are decreased with increasing CaCO3 content for both rubber compounds. The NBR matrix exhibits longer

T_{C90} than those of NR compounds. This result can be related to the fact that CaCO3 particles are isotropic in nature, have small nucleation effect and interact strongly with rubber especially with a polar rubber such as NBR. Cure rate index (CRI), which is a measure of the rate of the cure reaction, is given by:

$$CRI=100/(T_{c\,90}-T_{S2}) \qquad (1)$$

It is seen that CRI increases with CaCO3 addition and it supports the activation of the cure reaction up to 20 phr and 40 phr for NR and NBR respectively. At higher loading, a deactivation of the cure process was observed due to the increase of the optimum cure time, t_{C90} values, resulting in a poor interfacial interaction between rubber and CaCO3, which confirmed the tendency of the filled compounds to form filler agglomerates. Therefore, to evaluate the activity of CaCO3 for reinforcement potential, the following expression was employed

$$\alpha=(D_{max}-\mathring{D}_{max})/\mathring{D}_{max} \qquad (2)$$

Where D_{max} and $\mathring{D}_{max}$ are the maximum torque of filled matrix and gum vulcanizates, and α is the relative increase of the maximum torque that should increase when CaCO3 is incorporated into a rubber matrix in rheometer torque data during vulcanization as shown below table 2.

TABLE 2

Matrix	Filler, phr	Torque, dNm		α x10^{-2}	(T_{S2})[a], min	(T_{C90})[b], Min	CRI[c], min^{-1}
		D_{min}	D_{max}				
NR	0	5	46	---	2	14	8.33
	10	3.5	49	6.52	3	13	10.0
	20	3	52	13.04	3	12	11.11
	40	2	50	8.70	2.5	13	9.53
	60	2.5	48	4.35	2.5	14	8.70
NBR	0	5	76	---	8	23	6.67
	10	8	82	7.89	8	20	8.33
	20	9	84	10.53	7	19	8.33
	40	8	88	15.79	6	17	9.09
	60	8	86	13.16	6	20	7.14

[a] Scorch time.
[b] Cure time.
[c] Cure Rate Index [=100/ (t_{C90}-t_{S2})].

In Fig. (1a), the linear relationship between Δ torque, (D_{max} − D_{min}), and CaCO3 loading exhibits higher values for NBR matrix than those obtained for NR, which result in the formation of filler agglomeration especially at higher loading. The ratio between the torque increase of the filled compound and that of the gum was found to be directly proportional to filler loading as shown in Figure (1b).

$$\frac{Dmax-Dmin}{\mathring{D}max-\mathring{D}min}-1=a_f\frac{m_f}{m_r} \qquad (3)$$

where D_{max} - D_{min} is the maximum change in torque during vulcanization for filled rubber, D^o_{max}-D^o_{min} is the maximum change in torque during vulcanization for gum, m_r is the mass of rubber in the compound, m_f is the mass of filler in the compound, and α_f is a filler specific constant that is independent of the cure system and closely related to the morphology of the filler. The relative torque shows an increasing value as a function of the continuous incorporation of CaCO3 up to 20 phr and 40 phr for NR and NBR respectively. These compositions could be considered as the optimum concentrations, i.e. a good dispersion of filler up to the estimated optimum values for NR and NBR compounds are achieved, resulting in better interfacial interaction between rubber and filler.

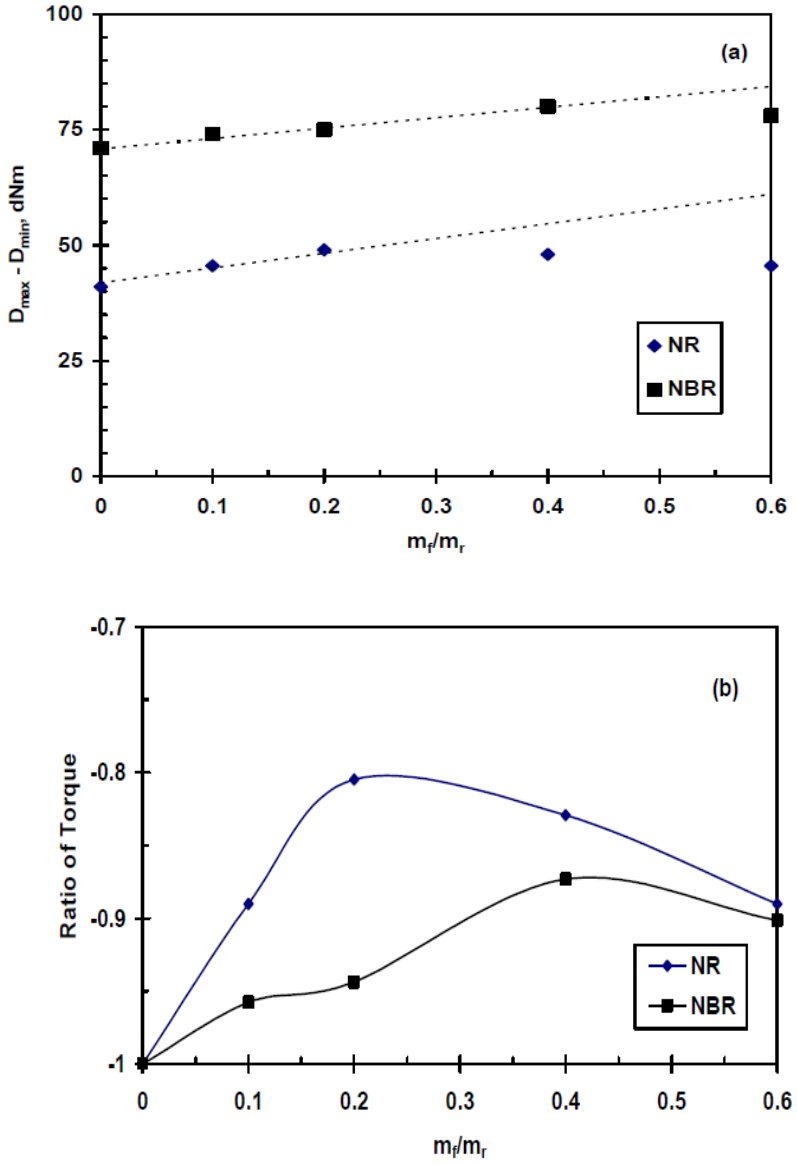


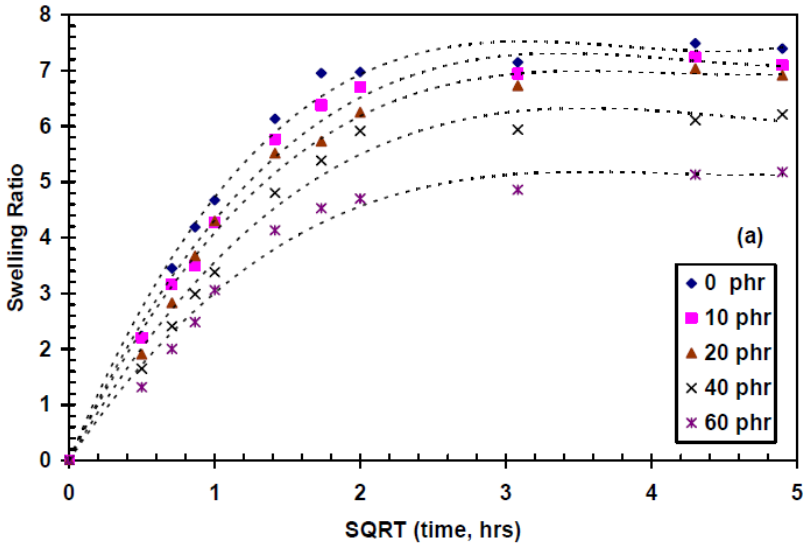
Fig. (1): Variation of (a) Δ Torque (D_{max} – D_{min}); eqn. 6, and (b) Ratio of Torque; eqn. 7, as a function of $CaCO_3$ loading at different rubber compounds.

3.2. Swelling Properties

The influence of CaCO3 addition to the swelling ratio values of the proposed rubber specimens in toluene is plotted against square root of time ($t^{1/2}$) at room temperature as shown in Figure (2 a, b). Initially, swelling curves exhibit a linear portion followed by a plateau region at longer time. Again, the results seemed to be nearly dependent on the rubber matrix due to the filler matrix effects during vulcanization where NBR matrix shows lower values than NR. Fig. (3) Shows the variation of the maximum values of swelling ratios as a function of the CaCO3 content, these values give a direct measure of the crosslinking density, ν_e, where as the swelling ratio decreases the degree of crosslinking increases. The rubber-filler interaction values are estimated from the data of the swelling experiment and according to Kraus equation [4,5,6]:

$$\frac{\Phi_o}{\Phi_r} = 1 - \frac{m\,C}{1 - C} \qquad (4)$$

where Φ_r and Φ_o are the volume fractions of the filled rubber and pure gum vulcanizates respectively, and m is the rubber-filler interaction parameter that is easily obtained from the slope. The obtained m-values were 0.585 and 0.175 for NR and NBR respectively and suggested NR-filler interaction which is better than that of NBR. In both rubbers, values of Φ_o/Φ_r decrease with increasing filler loading above the estimated optimum values due to their agglomeration.



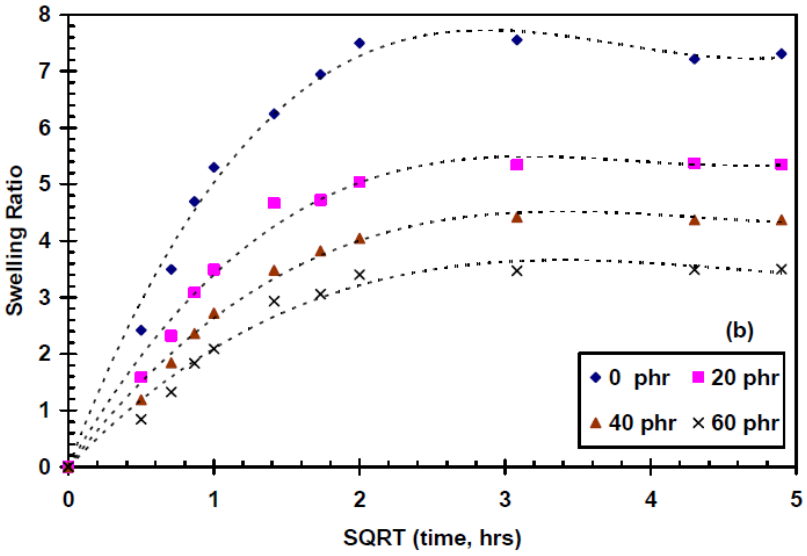


Fig. (2): Swelling ratio of $CaCO_3$ filled (a) NR and (b) NBR.

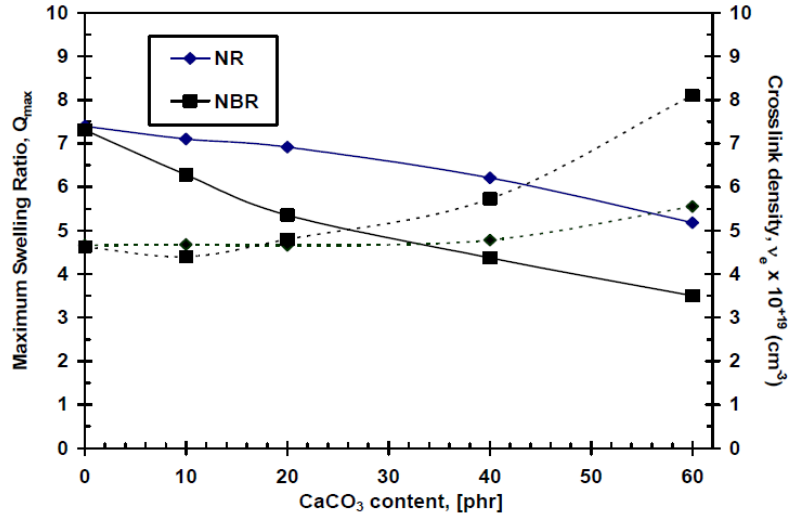


Fig. (3): Variation of both the maximum swelling ratio, Q_{max}, and the crosslinking density, v_e, as a function of the $CaCO_3$ content of the rubber compounds.

3.3. Mechanical Properties

3.3.1. Tensile Strength

The effect of $CaCO_3$ addition on tensile strength for NR or NBR compounds is presented in Table (3). As a general feature, the tensile strength values are mainly dependent on the host matrix and a more significant increase at 20 phr and 40 phr are exhibited for NR and NBR respectively. Unfortunately, a more significant reinforcing effect is expected with the optimum Concentrations of $CaCO_3$ for each rubber compounds separately. While at higher filler content, the tensile strength is decreased, resulting in a poor dispersion of the filler on the rubber matrix. This behavior can be related to the probable tendency to form filler agglomerates.

Table (3) : Mechanical properties of $CaCO_3$ filler rubber vulcanizates

Matrix	Filler		[Tb]a, MPa	Reinforcement Index	Eb, %
	%	phr			
NR	0	0	7.58	---	750
	8.13	10	8.3	13.47	770
	15.04	20	13.37	11.73	825
	26.14	40	9.17	4.63	780
	34.68	60	8.98	3.42	780
NBR	0	0	5.87	---	500
	8.13	10	7.4	15.51	520
	15.04	20	9.3	10.54	540
	26.14	40	11.4	7.43	570
	34.68	60	10.4	5.11	550

[a] Tensile strength

[b] Elongation at break, %

The reinforcing index (RI) shown in Table (3) is an empirical parameter representing reinforcement effect on a mechanical property , and defined as:

$$RI = \left(\frac{N}{N_o}\right)\left(\frac{CaCO_3 \text{ Content } \%}{100}\right) \quad (5)$$

where N and N_o are nominal values obtained by mechanical measurements of the specimen with and without CaCO3 respectively

3.3.2. Elongation at Break, Eb%

Table (3) exhibits also the influence of $CaCO_3$ on the elongation at break, E_b%, of the NR or NBR matrices. It is obvious that for the prepared rubber compounds, E_b% increases steadily, while it decreases gradually with increase in the filler loading. $CaCO_3$ shows an extra extension due to the increase of the dilution effect that imparted at higher loading. For NBR matrix, E_b% exhibit lower values with $CaCO_3$ increase, in comparison with NR matrix that are explained by the mutual reinforcement of the strain-induced crystallizable rubbers, which hinders the mobility of rubber chain molecules. On the other hand, the NBR matrix allows more rheological flow due to nearly good filler-rubber interaction and hence greater E_b% is obtained in this matrix, i.e. good toughening material.

From above discussion it is clear that the cure characteristics and the physicomechanical properties of $CaCO_3$ reinforcement NR or NBR compounds depend mainly on both the filler concentration and the type of the used rubber and The use of $CaCO_3$ as reinforcement filler improves the physicomechanical properties of the aging resistance to γ-irradiation. While at higher concentrations for each, a degradation process of rubber chains is more predominant than crosslinking [3].

CARBON BLACK

Carbon blacks are classified into furnace blacks, channel blacks, thermal blacks, lamp black and acetylene black, etc. based on their method of manufacture. Among these, the furnace type blacks account for a lions share of the total black consumed by the rubber industry. The main reason for the predominant use of furnace type carbon blacks, in elastomers, is the reinforcement they impart to the vulcanisates, Incorporation of carbon blacks into rubber gives enhanced modulus, improved fatigue and abrasion resistance and better overall performance. A simple classification of rubber grade furnace type carbon black is based on surface area and aggregate morphology measured by dibutyl phthalate absorption (table 4) [7]. The highest volume use of carbon black is as reinforcing filler in rubber products, especially tires. While a pure gum vulcanizate of styrene-butadiene has a tensile strength of no more than 2.5 MPa, and almost nonexistent abrasion resistance, compounding it with 50% of its weight of carbon black improves its tensile strength and wear resistance as shown in the below table. It is used often in the Aerospace industry in elastomers for aircraft vibration control components such as engine mounts.

TABLE 4

Types of carbon black used in tires

Name	Abbrev.	ASTM Desig.	Particle Size nm	Tensile Strength MPa	Relative Laboratory Abrasion	Relative Roadwear Abrasion
Super Abrasion Furnace	SAF	N110	20–25	25.2	1.35	1.25
Intermediate SAF	ISAF	N220	24–33	23.1	1.25	1.15
High Abrasion Furnace	HAF	N330	28–36	22.4	1.00	1.00
Easy Processing Channel	EPC	N300	30–35	21.7	0.80	0.90
Fast Extruding Furnace	FEF	N550	39–55	18.2	0.64	0.72
High Modulus Furnace	HMF	N683	49–73	16.1	0.56	0.66
Semi-Reinforcing Furnace	SRF	N770	70–96	14.7	0.48	0.60
Fine Thermal	FT	N880	180–200	12.6	0.22	--
Medium Thermal	MT	N990	250–350	9.8	0.18	--

Practically all rubber products where tensile and abrasion wear properties are crucial use carbon black, so they are black in color [8].

Carbon black particles with pores and cracks have surface area greater than blacks of similar size without such features. This leads to an increased number of particles per unit weight. Thus porous black gives decreased resilience and increased electrical conductivity when compared with equal weight loadings of non-porous blacks [7]. Structure of carbon black aggregates is important in understanding the role of carbon blacks in reinforcement and its influence on properties such as modulus, viscosity and die swell which are known to be shape dependent. Aggregate shape or structure increases with greater aggregate complexity and larger number of particles per aggregate. Highly structured aggregates typically have branches that form voids between them, where polymer can be occluded, which results in higher effective loading of the carbon black in an elastomeric compound. Skeletonisation method has been used for the first quantitative and direct measurement of branching in carbon black aggregates**.** Carbon black

aggregates are classified into four different shape categories that included (a) spheroidal, (b) ellipsoidal, (c) linear, and (d) branched**.** Non-spherical particles have a volume packing which is less dense than that of spheres, leaving a greater volume of voids between the particles. Filler aggregates in elastomer matrix have a tendency to form agglomerates, especially at high loadings leading to chain-like filler structures or clusters. These are generally termed secondary structure or filler network, even though they are not comparable to the continuous polymer network. Such a structure has a significant effect on the properties of filled rubber. Filler networking is determined by the attractive potential 'S_f' between aggregates in rubber as well as by their distance. Wang [9] studied the role of the distance between filler aggregates in the dynamic properties of filled vulcanisates, using fillers with different attractive potential values. This study demonstrated that, at the same interaggregate distance, lower S_f of the filler leads to weaker filler network which is readily broken down and
Re-constituted. The most common method of determining the 'structure' of carbon black is based on the measurement of the combined intra and inter-aggregate void volume by oil absorption (DBPA, ASTM D-2414). The internal void volume may also be measured by the compressibility of the carbon black at high pressures. High structured carbon blacks have high oil absorption and lower compressibility for a given weight of carbon black. Work has been done extensively for carbon black morphological characterization. Table (5) shows in detail the effects of decreasing particle size. [7]

Table 5. Effect of particle size and structure on vulcanisate properties

Vulcanisate properties	**Decreasing particle size**	**Increasing structure**
Rate of cure	Decreases	Little
Tensile strength	Increases	Decreases
Modulus	Increases to maximum and then decreases	Increases
Hardness	Increases	〃
Elongation	Decreases to minimum and then increases	Decreases
Abrasion resistance	Increases	Increases
Tear resistance	〃	Little
Cut growth resistance	〃	Decreases
Flex resistance	〃	〃
Resilience	Decreases	Little
Heat build up	Increases	Increases slightly

Compression set	Little	Little
Electrical conductivity	Increases	Little

Carbon black pellets

SULFATES

Barium sulfate ($BaSO_4$) is one of the mineral fillers used in polymeric compounds to replace other fillers. Unlike other heavy metal based fillers, it is nontoxic, has good whiteness, and is reasonably priced. The synthesis and characterization of organic–inorganic nanocomposite have been known as a subject of increasing interest in recent years. These systems appear as a new class of materials in which inorganic particles with nanoscale dimension are dispersed in the organic polymer matrix. However, the effects of fillers on the mechanical and other properties of the composites depend not only on filler type, but also strongly on the filler's particle shape and size [10]. Commercial name of barium sulfate is BARTEX and hence it is been commercialized as a rubber filler with the name of BARTEX. All of BARTEX products are suitable depending on requirements in particle size, whiteness, brightness, and cost. Plastic and rubber compounds use barium sulfate as a high density filler, to build weight in the product at low cost. The adhesive industry uses barium sulfate as an inert extender with high specific gravity. End use applications include for plastics: bowling balls,
traffic cones & toys and for rubber: floor mats, foam & carpet backing. Other uses for BARTEX include ceramics, paper casting, and brake linings [11].
Finer particle barium sulfate extenders have higher absorption capacities and will absorb more plasticizer in polyvinyl compounds. They also have a stiffening effect on most plastic compounds, primarily due to higher absorption characteristics. BARTEX used as a filler will increase specific gravity, frictional resistance, chemical resistance, and Xray opaqueness in most systems. Barium Sulfate will promote a faster cure as a filler in polyester resins. It will provide high density in
Polyurethane foams with higher load bearing properties, improved processing, and sound suppression [11].
Another filler is "Barite", it is also a derivative of barium sulfate. Its common attributes include, High brightness, high purity, usually -325 mesh or finer; typically >95% BaSO4, <0.1% Fe2O3, < 0.5% moisture.

Barite

Filler uses for barite generally require high brightness, high purity, and fine particle size, usually 325 mesh or finer. The highest quality filler grades are made by flotation, followed by wet grinding, bleaching with sulfuric acid, washing, drying, and milling.
Barium sulfate is also commercialized as “Blanc fixe”. Blanc fixe is precipitated barium sulfate for uses where higher brightness and purity and finer particle sizes are required than are generally available with barite. To make blanc fixe, crushed barite is first roasted with coke in a rotary kiln at about 1200^{o}C to form barium sulfide. This is quenched in water and countercurrent leached to produce a barium sulfide solution. Blanc fixe is produced by treating this solution with sodium sulfate to precipitate ultrafine barium sulfate [1]

HYDROXIDES

The use of rubber and plastic materials in the manufacture of domestic and industrial products has grown substantially in the last decades. Some applications of these products require the utilization of flame retardants, the halogenated (bromides and chlorides) and phosphorous compounds being the most widely used. Nevertheless, these compounds generate toxic and highly corrosive fumes in fire, which make the damage even higher. Interest in using metal hydroxides as fire retardants has grown, since these compounds do not produce fumes and present low corrosiveness. Metal hydroxides retard combustion by absorbing heat and by cooling the substrate through dehydration reaction [15].
ATH and MDH are the most commonly used hydroxides as filler materials. Here ATH expands as Aluminum trihydrate and MDH as Magnesium dihydroxide. Use of these hydrated fillers, offers the advantage of acting as flame retardant as well as smoke suppressor [12].
Let us take ATH first and discuss its properties and effects as a filler material. Aluminum Trihydrate (ATH) is used as Flame Retardant , Smoke Suppressant , and Filler in Rubber, Thermosetting , Artificial marble , onyx marble , Solid Surface , Adhesive , Fiber Cement , Paint , Plastic such as Cables, Artificial Leather, Wall Covering , and etc. With increased attention being given to smoke & toxic fume emissions [13]. Aluminum trihydrate (ATH) improves arc-track resistance in plastics for electrical applications [14]. ATH is the most widely used as flame retardant additive in volume terms and was selected for this work because it has a very low cost. ATH has a few mechanisms which contribute to the reduction in thermal decomposition, like heat absorption by decomposition, large volume of water liberated during this reaction that promotes heat absorption (for the heating and vaporization), water vapor produced which promotes the gas phase dilution (reducing the O_2 availability) and refractory oxide Al_2O_3 that act like a protecting layer on the substrate surface. Limitations are concerned with the maximum processing temperature which

is about 200^{o}C, with the necessary high loading that can be detrimental to mechanical and electrical properties and with its low stability at high temperature, due to loss of water [12].
ATH has found large volume application in vinyl as a low smoke, non-toxic replacement for antimony and in polyurethane , polyester resin , latex, neoprene foam , Rubber, Wire & Cable insulation, vinyl wall & flooring covering and epoxy. For Unsaturated polyester resins, ATH is generally preferable to calcium carbonate as a filler as it imparts a degree of translucency, not possible with calcium carbonate due to the different indices of refraction and may be flame retarded up to the most rigorous requirements with ammonium polyphosphate or red phosphorous combined with varying amounts of ATH. For Acrylic Resin, ATH acts to give excellent texture as artificial marble, heat resistance, damping property and the like to the resulted molded article. ATH is also used in FRP Epoxy Laminate, SMC (Sheet Molding Compound) and BMC (Bulk Molding Compound) as smoke suppressing as well as being an economical resin extender. Silicon rubber insulation uses ATH as filler content, which acts as an arc quenching agent thereby it maintains local temperature below the degradation level of silicon rubber [13].

Table.6(SPECIFICATIONS)

Index Name	Specification
Appearance	White Power
$Al(OH)_3$	99.7 min
Whiteness (%)	97 min
Oil Absorption (Linseed Oil) (ml/100g)	22 max , 33 max
SiO_2 (%)	0.02 max
Fe_2O_3 (%)	0.01 max
Na_2O (%)	0.2 max
PH	8.5-10
Moisture (%)	0.2 max
Average Particle Size (D50) (micron)	1, 5 , 8 , 10 , 12 , 14 , 20 , 25 , 40 , 50 , 60 , 75 , 90

MDH (magnesium dihydroxide)

The metal hydroxide most commonly used as a fire retardant is aluminum hydroxide. Aluminum hydroxide has been used as a fire retardant in many materials including thermosets, elastomers and thermoplastics. However, its low temperature of decomposition (approximately 180°C) limits its application. Many polymers must be processed at higher temperatures, which hinder the utilization of this compound. It is exactly in these cases that the use of magnesium hydroxide becomes attractive, owing to

its higher temperature of decomposition (approximately 330°C). The main applications of magnesium hydroxide are in polymers such as polypropylene and nylon, which should be processed at high temperatures, and in elastomeric cable coatings, which require high temperatures for rapid processing. Magnesium hydroxide, as well as alumina trihydrate, is commonly used at high concentrations, such as 40% to 70%. Due to cost considerations, magnesium hydroxide does not fully replace aluminum hydroxide. Rather, it broadens the utilization of metal hydroxides as flame retardants in a way that the damages as well as the environmental pollution are minimized.

Magnesium hydroxide-based products are available in the market. These are mainly obtained by precipitation of magnesium hydroxide from brines and sea water. The production of the hydroxide for fire retardant filler application via hydration of magnesium oxide has been hindered by the process economics. Purity requirements for this application result in the need for purification steps, which substantially increase the final cost of the product. Direct hydration becomes a very interesting option where large deposits of pure magnesite (a precursor of magnesium oxide) are available, as in Brazil. Different processes lead to products with different crystallite size, surface area, particle morphology and chemical composition. According to the literature, these properties affect not only the fire retardant performance but also the mechanical properties of the final composite [15].

Table.7 (chemical and physical properties of magnesium hydroxides prepared from hydration (MH-H) and precipitation (MH-P))

Parameter	Content (%)	
	MH-H	MH-P
MgO	68.8	67.8
CaO	0.5	0.7
SiO_2	0.2	0.2
Fe_2O_3	0.2	0.1
Al_2O_3	0.2	0.2
MnO	0.1	—
Loss by ignition (weight %)	30.0	31.0
Specific surface area, BET, (m^2/g)	8.6	18.0
Median particle size[a], µm	5.0	1.2
Specific gravity, (g/cm^3)	2.44	2.43

[a]50% finer as measured by Sedigraph

MDH can be anticipated to be used as

PVC substitute for cable insulation:-

Industrial cables, automobile cables, electrical equipment cables (including those within equipment)

PVC substitute for fire retardant construction materials:-

This can be applied to flooring, wallpaper, and decorative laminates.

PVC substitute for various flame-retardant molded products:-

This can be applied to sheets and films.

(1) General-purpose flame-retardant grade
Special surface treatment was adopted aiming at high dispersion on various polyolefin resins. Mechanical properties of the compound (tensile strength) were improved compared with conventional products (treated with higher fatty acid).
(2) Highly flame-retardant fine grade
Micronization of the primary particles provided higher efficiency of the endothermic reaction on particle surface leading to an improvement in the fire retardancy. In addition, compound-formation with multiple elements provided a high inhibitory effect against char production and oxygen during combustion.
(3) Special grade
Special surface treatment provides high acid resistance for molded resins [16].

CLAY

Clay is a widely used filler for rubber compounds of all types, including components of tires such as fiber adhesive compounds, and the entire range of non-tire rubber applications where good reinforcement, moderate cost and good processability are desired. Clays are usually added to compounds at levels of 20 to 150 phr [17].

Amongst clay contingent kaolin clay is the one used widely in the rubber processing industry as filler. Kaolin Clay is a Platy Alumino Silicate. Its continuous Sheet Structure produces thin Particles which exist in nature as overlapping flakes. These can occur as "Books" which under magnification resembling stacks of paper. Kaolin Crystals are bound via hydrogen bonding of the octahedral layer hydroxyl face of one plate to the tetrahedral layer oxygen face of adjacent plate. Separation into individual clay plates is therefore difficult, but can be accomplished by mechanical means to produce delaminated kaolin.

Application of Kaolin Clays in Rubber:-

Rubber Filler Clays are Classified as Hard or Soft Clays in relation to their particle size and stiffening effect in Rubber.

Hard Clays:-

Particle Size: 0.25 -0.5 Microns

- Very Fine grained
- Provides good Tensile Properties
- Stiffnesss
- Abrasion Resistance
- Improves Properties of Ground Calcium Carbonate Compounds
- Low Cost Substitute for Portion of Carbon Black/PPT Silica

Soft Clays:-

Particle Size: 1 – 2microns

- Larger Flakes
- Low Reinforcing Effect
- Higher Loadings
- Quicker Extrusions

Hard clay will have a median particle size of approximately 0.25 to 0.5microns and will impart High Modulus, High Tensile Strength, Stiffness and good abrasion resistance to the Rubber compounds. Soft Clay has a median particle size of 1 to 2 microns and is used where high loadings (for economy) and faster extrusion rates are more important than Strength.

TABLE.8

	Hard Clay	**Soft Clay**	**GCC**
Median Particle Size (Microns)	0.3	1.3	3.0
BET Surface Area (m2/gms)	23	16	3
Hardness, Shore A	61	62	53
Tensile Strength (Mpa)	12.8	8.8	1.6
M300 (Mpa)	3.2	2.8	1.2
Die A Tear (KN/m)	24.6	20.2	5.3

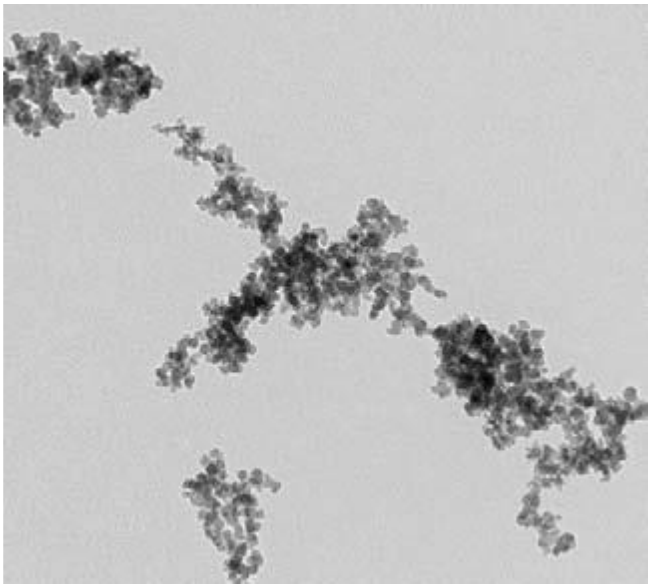
This comparison of Hard Clay, Soft Clay & GCC graphically illustrates the effect of Particle Size, Surface Area & Shape on reinforcement of an SBR Compound.

More hard clay then soft is used in rubber because of its semi –reinforcing effect and its utility as a low cost complement to other fillers. It is used to improve the tensile strength and modulus of GCC compounds and will substitute for a portion of more expensive carbon black/ppt. Silica in certain compounds without sacrificing physical Properties. The Equal filler volume study demonstrates the advantage of hard clay as opposed to GCC (Grounded calcium carbonate) in replacing a portion of Precipitated Silica without compromising compound properties significantly.
Now let us glimpse different clays derivatives of kaolin clay.

Air Float Clay:
It is dry ground kaolin that has been air separated to minimize impurities and control Particle Size Distribution. About 80% of the Kaolin used in Rubber is Air Float Hard Clay.
Calcined Clay:
The Kaolin is heated to partially remove surface hydroxyls. Its used in different industries such as Wire & Cables for excellent Die electric and Water Resistant Properties to Produce calcined clay for Filler uses, the Kaolin is water washed and heated partially to remove surface hydroxyl groups. The Partial or complete removal of surface hydroxyls provides a corresponding decrease in surface activity and thus reinforcement, but calcined clay is commonly used in wire and cable coverings because of excellent Dielectric & water resistance properties [18]

SILICA

There are significant quantities of mineral fillers used in rubber compounds. These include both natural and synthetic fillers. Synthetic silicas offer significant benefits to rubber reinforcement. The surfaces of these fillers possess siloxane and silanol groups. The silanol groups are acidic and interact with the basic accelerators, causing detrimental effects such as unacceptably long cure times and slow cure rates, and also loss of crosslink density in sulphur-cured rubbers. Moreover, because the surfaces of silica are polar and hydrophilic, there is a strong tendency to adsorb moisture, which adversely influences cure and therefore properties of the cured rubbers. The amount of water adsorbed on the surfaces of these fillers affects the ionisation of the silanol groups , and this in turn affects cure. When a large amount of silica is added, the viscosity increases significantly, making processing more difficult, and causing excessive wear and tear on the processing equipment. Increases in viscosity are attributed to the strong interaction between the silica particles. For these reasons, the use of silica in rubber products was hampered until bifunctional organosilanes were available. These materials are primers for treating silica surfaces to make the filler friendly to rubber [21].
The major synthetic filler used is precipitated silica. Precipitated silica is produced by the controlled neutralization of sodium silicate solution by either concentrated sulfuric, hydrochloric or carbonic acids. Reaction conditions are manipulated according to the particle size required. Dilute solutions and controlled acid addition rate are used to minimize the formation of silica gel. This silica is 0.02 micron in average particle size. The reinforcing properties of precipitated silica can usually be related to particle size; 10-30 nm particles are reinforcing, while 30+ nm particles are semi-reinforcing. Because of the difficulty in measuring the size of particles this small, surface area , rather than particle size, is usually used for classifying various grades. For example, silica in the range of 125-250 m2/g is generally reinforcing, while products in the range of 35-100 m2/g are semi-reinforcing. In rubber compounds, which are the primary application for precipitated silica,the silica particles exist mostly as small clustered agglomerates rather than discrete particles.
Precipitated silica is usually sold with about 6% adsorbed free water and a surface essentially saturated with silanol groups, the latter making it very receptive to in situ reaction with organosilane, most often mercaptosilane [1].

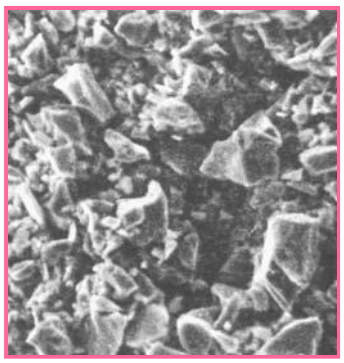


Precipitated Silica

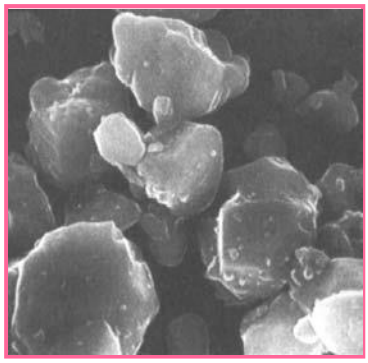
The silica is added to enhance the modulus and tear strength of tire compounds. It is also used as an ingredient in fabric and wire bonding systems. The silica, along with resorcinol and hexamethylene melamine, are used extensively in wire adhesion systems. Typically 10-12 phr of silica is used. In addition, several tire compounds designed for very low rolling resistance have 60 phr of silica coupled with a silane coupling agent to achieve very low tangent delta values in the tread. The silica has an average surface area of 150-175 square meters per gram [19]. The next stage of development came with the universal adoption of radial tires which required the use of even finer particle size fillers, and saw the advent of treatment systems such as silane coupling agents to provide a chemical bond between non-black fillers and the rubber molecule[20]. Fine precipitated silica is the only fully reinforcing alternative to carbon black for general rubber compounding. It is used in compounds designed to be translucent or colored, and in general compounding, to promote abrasion resistance, cut growth resistance, tear strength, elastomer-to-textile adhesion, and resistance to heat aging [13].

Different shapes of ultrafine silica showed insignificant trends in the curing characteristics of ultrafine silica-filled natural rubber vulcanisates, but the irregular ultrafine silica showed higher values of torque as compared to the cubical and elongated shapes. The irregular shape showed the highest tensile strength, E_b, tensile modulus and hardness, followed by the elongated and cubical ultrafine silica. The morphology study confirmed that the better dispersion of irregular-shaped ultrafine silica had improved the adhesion between the ultrafine silica and the natural rubber matrix [21].

Precipitated silica is an amorphous form of silica, now let us consider the crystalline form of the silica. Generally crystalline silica is witnessed in two forms namely Ground Quartz and Novaculite.



Ground Quartz



Novaculite

Ground silica, also known as ground quartz or silica flour, is produced by grinding high-purity quartz to finer than 200 mesh. Air separation is used as required to remove mineral impurities. Ground silica for filler uses offers high brightness, low moisture, chemical inertness, relatively low surface area, and the low liquid absorption that allows high loading levels.
Novaculite is microcrystalline quartz that is milled to low-moisture, high purity, platy particles. Brightness is generally lower than for other forms of ground silica, but novaculite offers higher aspect ratio, lower binder demand, lower abrasivity, and availability in a range of particle size distributions (to as small as 2 micrometers average).[1]

TALC (Hydrated Magnesium Silicate [$3MgO.4SiO_2H_2O$]**)**

Talc is one of the most important industrial minerals and is the most common mineral for daily use as a body and face powder. TALC is also written as $H_2Mg_3(SiO_3)_4$, which corresponds to 4.8% H_2O; 31.7% MgO and 63.5% SiO_2. It is essentially a secondary mineral formed by the hydrothermal actions and regional metamorphism of magnesium rich rocks like dolomite, pyroxenite, amphibolite, seerpentine, dunite and chlorite. It has been found to be excellent filler. It can withstand temperatures upto 1300^oC. It has low electrical and thermal conductivity. Above all it can be easily powdered, cut and sawn into any shape and size. Pulverized talc has wide industrial applications as filler in rubber, textile, plastic, linoleum, asbestos products, polishes and soaps; as a loading agent for paper of all kinds; as a carrier of insecticidal and pesticidal dusts and for coating calcium ammonium fertiliser. In rubber industry talc is used for two purposes, one to prevent rubber moulds from sticking and the other as compunding material in the preparation of certain types of hard rubber. The consumption of talc for the latter use is small. Talc should

be of fine mesh all passing through 200 mesh [22]. Talc reduces the viscosity of rubber compounds, thereby facilitating the processing of moulded parts. It also improves extrudate qualities, increasing production rates and enhancing UV radiation resistance of exterior parts such as automotive profiles. In sealants and gaskets, they provide good compression resistance, while in pharmaceutical stoppers, they create a barrier against liquids. In cables, talc functions as insulators and in tire manufacture it makes excellent processing aids [23].
Talc products are processed using various combinations of dry grinding, air separation and flotation depending upon the quality of the crude ore and the properties required for intended applications. The talc most often used as filler is commonly called platy talc. It is distinctly lamellar characteristically soft talc. Purity is typically >90% and filler grades are 325 mesh and finer [1].

Platy Talc

FELDSPAR

Feldspar is the most common rock-forming mineral. Feldspar is a name for a group of minerals with a general chemical formula of $xAl(Al,Si)_3O_8$, where x can be one or more elements. Feldspar minerals are usually white or very light in color and have a hardness of 6 on the Mohs' Scale of Hardness. Another physical property of the feldspar group is that the mineral has good cleavage in two directions. The cleavage breaks are about 86^o for plagioclase feldspars (albite, oligoclase, andesine, labradorite and anorthite), at 90^o for orthoclase and 89.5^o for microcline. Upon weathering, feldspar minerals break down to form kaolinite, a clay mineral [24]. Feldspars also are used as fillers and extenders in applications such as paints, plastics and rubber. In view of rubber processing industry Beneficial properties of feldspars include good dispersability, high chemical inertness, stable pH, high resistance to abrasion, low viscosity at high filler loading, interesting refractive index and resistance to frosting. The products used in such applications are generally fine-milled grades [24]. Filler grade feldspar is usually produced by flotation and magnetic separation followed by milling [1].

NEPHELINE SYENITE

Nepheline syenite is a rock composed of soda and potash feldspars and nepheline. Nepheline syenite is a natural blend of about 25% nepheline and 75% feldspar [13]. Nepheline has the theoretical chemical composition $NaAlSiO_4$, but potassium invariably substitutes for a portion of the sodium. The amount of potassium in natural nephelines ranges from 3 to12% K_2O by weight. Nepheline is related to the structure of high-trydimite (ahigh-temperature form of silica), with Al^{3+} replacing Si^{4+} in half the tetrahedra. The

charge imbalance is compensated by Na^+ and K^+. Unlike feldspars, the sodium is exchangeable for H^+, making nepheline less acid stable. Nepheline will gelatinize in HCl, while feldspar will not. Nepheline can form only in ageologic environment deficient in silica. Commercial nepheline syenite deposits and the products made therefrom are consequently free of crystalline silica impurities. These deposits are likewise exploited for their high mineral brightness and low level of dark mineral impurities. Commercial products are made by crushing, dry magnetic separation, and milling. Fine particle size grades are produced by air classification. In North America typical nepheline syenite is approximately 25% nepheline, 20% microcline feldspar, and 55% albite feldspar.

TABLE.9 (PROPERTIES OF NEPHELINE, ALBITE AND MICROLINE)

Nepheline Refractive Index: 1.53-1.55 Specific Gravity: 2.57 Mohs Hardness: 5.5-6	$(Na,K)AlSiO_4$
Microcline Refractive Index: 1.52-1.54 Specific Gravity: 2.54-2.57 Mohs Hardness: 6	$KAlSi_3O_8$
Albite Refractive Index: 1.53-1.54 Specific Gravity: 2.62 Mohs Hardness: 6	$NaAlSi_3O_8$

Nepheline syenite is also used as a filler in plastics, rubber, and adhesives because of its low vehicle demand, high dry brightness with low tint strength, nearly lamellar shape, and resistance to abrasion and chemical degradation. It is used as a sand blasting medium due to its absence of crystalline silica [25].

Nepheline Syenite(feldspar + nepheline)

NANOFILLERS

Synthesis and control of materials in nanometre dimensions can access to novel functionality and enhanced performances of the materials. At nano scale, materials behave quite differently compared to those at larger scale. Simply, materials, at nano scale, can have different properties which have not shown at larger scale, for example some of nano materials conduct electricity and heat better, some are stronger and stiff and some reflects light better or change the color as the size is reduced to nano scale. The main

feature of the nano scale materials is that they have incredibly high surface area to volume ratio in comparison to micro scale materials, indicating that more surface area is available for interactions with bulk material around them. Therefore, it is crucial to apply the superiority of this novel technology into the rubber industry in view of developing rubber- nano composite materials with unique properties. Three major advantageous of rubber- nano composites over conventional rubber composites are given below.

- Lighter weight due to low loading level of nano particles
- Improved material properties (i.e. mechanical, thermal, electrical) and new functionalities (antimicrobial, barrier, flame retardant)
- Easy processing in comparison to conventional composites

Rubber- nanocomposites

Preparation of rubber-nanocomposites by incorporating nano particles is a novel technology in rubber industry and, as a result, enhanced and new material performances can be achieved in various rubber products. Presently, several potential nano particles have been identified to be used in the rubber industry such as natural and synthetic layered silicates (e.g. montmorillonite, saponite, hectorite), double hydroxide layered silicates (DHL), carbon- nano tubes (single wall and multi-wall) and various metallic nano particles (e.g. alumina, zinc oxide, titanium dioxide, iron). However, amongst all above nano particles, layered silicates (i.e. nano clay) are the most common and widely researched nano particles in the rubber industry.

Carbon black is the most common and important reinforcing filler in the rubber industry today and large quantity of carbon black is globally consumed each year. Nano clays (layered silicates) are promising reinforcing agent because of its surface characteristics and the ability to separate layered silicates into individual layers (platelets) with 1mn thickness. Therefore, layered silicates are potential replacement for the carbon black in the rubber industry. Rubber nano composites based on layered silicates exhibit not only outstanding mechanical properties, but also show good barrier and thermal properties at very low loading levels (i.e. < 10 w/w %) of layered silicates.

As most rubbers are available in solid and latex (solution) forms, incorporation of layered silicates either at the melt state of dry rubber (melt intercalation method) or at the latex stage is considered to be the industrial feasible methods for preparing rubber- nanocomposites. From an industrial point of view, this melt or direct intercalation method is the most direct, cost-effective and environmentally-friendly method to prepare rubber/layered silicate- nanocomposites. However, whatever the technique is used to prepare rubber- nanocomposites based on layered silicates, the key factor is the separation of layered silicates into individual layers (platelets) with 1mn thickness and disperse them homogeneously in rubber matrix. Depending on the dispersion of layered silicates in the rubber matrix, rubber-layered silicate-nanocomposite structures can be categorised into three ideal structures, (a) Micro-composites (b) Intercalated nanocomposites (c) Exfoliated nanocomposites. In addition to rubber nanocomposites based on layered silicates, there are other potential nano particles such as carbon nanotubes, layered double hydroxides and metal oxides can be dispersed in the rubber matrix in order to achieve novel performances/functionalities in rubber compounds for various applications.

Scope:-

Although commercial applications of rubber materials based on nanotechnology are still in their early stages in comparison to thermoplastic nanocomposites, recent studies suggest that rubber nanocomposites and thermoplastic/rubber blends with novel/improved properties are useful for various applications.

Rubber nanocomposites based on layered silicates are the most common material. The main interest in this type of rubber nanocomposite is mainly due to the reinforcement and barrier properties that can be achieved with exfoliated structure of rubber nanocomposites. The major advantages of this nanocomposite are remarkable enhancement in mechanical properties (i.e. stiffness, strength, elongation at break and dimensional stability) at low loading levels (i.e. below 8 w/w %) of layered silicates, resulting in lighter weight compound, and enhanced barrier resistance to small molecules like air and liquids. Potential applications of rubber-layered silicate nanocomposites are tyre treads, inner tubes and latex-based products since it improves the mechanical as well as the barrier properties. Another potential advantage of using layered silicates with rubber is to enhance flame retardant properties of rubber compounds compared to that of conventional flame retardant materials. Rubber nanocomposites based on other nano particles like carbon nano tubes and metal oxides etc. are currently less common in the rubber industry. However, it is now being focussed to prepare functional rubber material using these nano particles. Carbon nanotubes are remarkably high modulus and strength and, therefore, incorporation of these nanotubes into rubber results not only in high strength rubber materials but also it shows thermal and electrical properties. Metallic nano particles such as Al, Fe and Ti can be used to make functional (i.e. electrical, magnetic and oxidative resistant) rubber materials. Moreover, studies are in progress to make nanocomposites by incorporating layered silicates with other nano particles to obtain multifunctional rubber materials with enhanced mechanical properties.

In addition to layered silicates, there are other layered materials that can be used to prepare rubber nanocomposites. Layered double hydroxides (LDH) are gaining attention as potential nano particles since the intercalation capability of several types of material into the layered structure. Tailor made LDH nano particles can be made by intercalating different molecules to the layered structure in order to produce rubber material with different functional properties. LDH are important in preparing flame retardant rubber compounds. The possibility of using synthetic nano-fillers such as nano-sized SiO_2, carbon fibres with rubbers are being investigated recently as reinforcing fillers.

Nano scale zinc oxide will be a strong contender for replacing the conventional micro scale zinc oxide used as a preservative and as a compounding ingredient in the rubber industry (i.e. raw rubber and rubber products industry). High surface area prevailing in nano scale zinc oxide particles in comparison to conventional zinc oxide is responsible for its high efficiency and, as a result, low level of nano zinc oxide would be sufficient for rubber compounds.

Studies have revealed that rubber-toughened thermoplastics/layered silicate nanocomposites are good potential substitute for conventional thermoplastic/rubber blends for automotive applications since a balance of properties of stiffness and toughness can be achieved along with the lighter weight of the blend. Further studies are already underway to modify the layered silicates by intercalating curing agents into the galleries of layered silicates. These modified layered silicates containing curing agents would be efficient and effective in preparing rubber nanocomposite materials. Although tremendous progress has been made

in rubber nanocomposites during the recent past, commercial applications of rubber nanocomposites appear to be moving slowly compared to that of thermoplastic nanocomposites.

Challenges

Nano particles and nanocomposites are the trend in polymer technology today. They show surprisingly enhanced material properties and novel functionalities which cannot be seen in conventional fillers and composites. However, commercial applications of rubber nanocomposites are yet to gain a real momentum, at present, since there are a few unresolved issues needed to be overcome in order to make successful conversion of these novel materials into commercial artefacts.

Most of the rubbers are not compatible with nano particles and, as a result, dispersion of these particles into nano scale within the rubber matrix is a difficult task. Therefore, development of new and effective methods to achieve homogeneous dispersion of nano particles such as layered silicates and carbon nanotubes in rubber matrix is a great challenge faced by scientists since the degree of dispersion is one of the key factors to enhance the material performances. Behaviour of rubber-nano particle interface formed due to the interaction between nano particles and rubber matrix is quite different from either nano particles or bulk rubber matrix. However, relatively little understanding of the behaviour and properties of the rubber-nano particle interface, which is responsible for the most property enhancement, is a huge barrier for further development of this new material. Prediction of mechanical properties such as modulus, tensile strength and elongation at break of conventional composites using mathematical models, is quite common in polymer composite technology. Few mathematical models developed for conventional composites have also been used to predict mechanical properties of nano composites with little success because additional factors, which have not been considered for conventional composites, are needed to be considered in polymeric nano composites. However, presently, researchers are actively involved in developing suitable mathematical models for polymeric nano composites, especially polymer-layered silicate nano composites, considering all aspects of nano particles.

Although rubber nano composites exhibit remarkable improved material properties, cost/performance ratio of some rubber-nano composites is commercially unattractive since some nano particles (e.g. carbon- nano tubes, metallic nano powders) are relatively more expensive. This is one of the major obstacles to commercialise these rubber nano composites. However, it is expected that the high cost of nano particles will come down with the development of new process technology to produce nano particles. In addition to above general challenges, there are specific problems in applying this novel technology for certain rubber products, for example tyres. Replacing carbon black with nano scale layered silicates, which impart remarkable reinforcement at low loading levels, is not economically attractive, at present, in tyre industry. The rubber-nano composites based on layered silicates require large volume of rubber in order to keep the total volume of the final product unchanged. Therefore, scientists and engineers should think differently in order to apply this novel technology in certain applications in the rubber industry.

Despite substantial progress made during the recent past on rubber-nano composites, more research and development work is needed for effective application of this novel technology in the rubber products industry.[26]

Nano materials

MICA

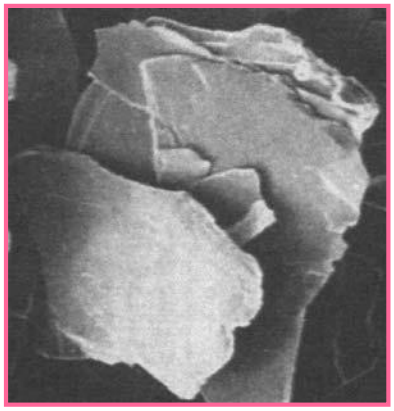
The use of silica brings higher costs, sometimes forbidding its use in some formulations,
which therefore must be compounded with other mineral fillers, like clays, chalks or carbonates, usually leading to inferior technological performance. Recently, mica started to be considered as a filler in the plastics and rubber industry. In rubbers, mica brings a reduced permeability to
gases and liquids, whereas in elastomers exposed to automotive fuels, oils and greases, it provides restricted swelling.

TABLE.10

Physico-chemical characteristics of mica

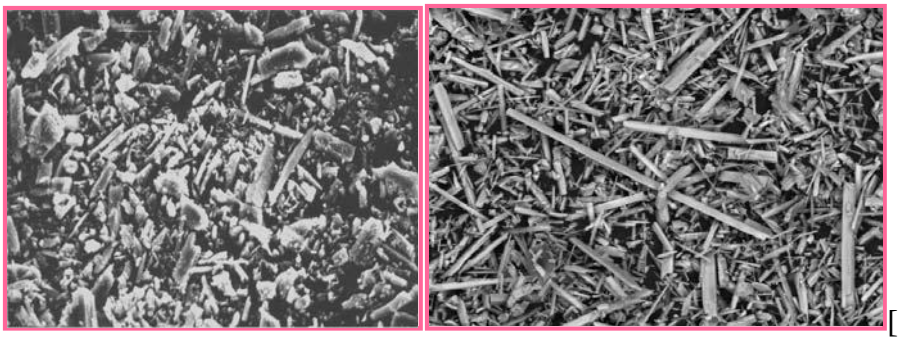
Chemical analysis (%)	
SiO_2	42.70
Al_2O_3	32.50
K_2O	10.40
Fe_2O_3	2.60
Na_2O	0.67
MgO	0.43
H_2O	3.60
Physical properties	
Specific gravity (g/cm^3)	2.00
pH	6.81
Average particle size (μm)	80.00

Mica can be considered for partial replacement of silica in some applications of SBR compositions, leading to a lower formulation cost. Addition of mica to a silica-SBR composition
slightly improves the modulus of the rubber and does not deteriorate properties such as tensile strength, tear strength and elongation at break. However, the fatigue properties of silica-SBR composition are adversely affected by the addition of mica [27]. Mica is considered the most effective mineral for reducing warpage and increasing stiffness and heat deflection temperature [13].



Wet-ground Mica

WOLLASTONITE

 [1]

Powder Grade **Acicular**

Wollastonite is used as a reinforcing filler in plastics because of its low oil and moisture absorption, high brightness and acicularity, and availability with a variety of surface treatments. High aspect ratio wollastonite is a lower cost alternative or complement to short-milled glass fibers for both thermoplastics and thermosets, and is used together with organic and metallic fibers in asbestos-free formulations for friction products such as clutches, brake linings and brake pistons. It is also used as an asbestos substitute in phenolic molding compounds and as a reinforcing filler in nylons, particularly high-impact and platable compounds. Wollastonite is a white reinforcing filler in adhesives and sealants, where it can be used at high loadings. Powder and fine particle sized high aspect ratio grades are used as semi-reinforcing fillers in rubber [13].

CONCLUSION

From the above discussion we concluded that The Effects of Fillers Depend upon Particle Size, Particle Surface Area, Particle Shape, Particle Surface, Activity (Compatability with adhesion to Matrix). Surface Activity relates to the compatabilty of the filler with a specific elastomer and the ability of the elastomer to adhere to filler.Functional Fillers transfer applied stress from the rubber matrix to the strong and stiff mineral. It seems that this stress transfer will be better effected if the mineral particles are smaller because greater surface is thereby exposed for a given mineral concentration. If these particles are needle like, fibrous or Platy in shape , they will better intercept the stress propagation through the matrix. A compound's physical/mechanical properties can be strongly influenced by the surface activity of the filler, which is the ability of the filler's surface to bond with the matrix. For instance, an air gap between a filler particle size and the matrix represents a point of zero strength. If the size of the filler particle greatly exceeds the polymer interchain distance, it introduces an area of localized stress. This can contribute to elastomer chain rupture on flexing or stretching. Fillers with particle size greater than 10,000nm (10mcrons) are therefore generally avoided because they can reduce performance rather than extend or reinforce.

Fillers with Particle Size between 1000 to 10000nm (1 to 10microns) are primarily used as Diluents and usually have no significant effect, positive or negative on Rubber Properties. Semi-reinforcing fillers ranging from 100 to 1000nm (0.1 to 1microns). The Truly reinforcing fillers which range from 10nm to 100nm (0.01 to 1 micron) can significantly improve rubber properties [18]

TABLE.11 (FILLER PROPERTIES)

	Particle Shape	GE Brightness	Oil Absorption	Median P. S., μm	Hegman Fineness	pH 10%	Specific Gravity	Refractive Index	Mohs Hardness	lbs/ solid gal
Alumina Trihydrate	irregular	93-100	32-44	0.25-26	0-7+	7-9.5	2.42	1.57	2.5-3.5	20.2
Barite	irregular	80-95	10-14	1-11	3-6	7-9	4.40	1.64	3-3.5	36.6
Calcium Carbonate										
Ground	irregular	91-95	8-18	1-40	0-7+	9-10	2.71	1.66	3	22.5
Precipitated	irregular	95-98	30-50	0.07-0.7	7+	9-10	2.70	1.66	3	22.5
Feldspar	irregular	89-94	19-28	3-16	0-6.5	8-9	2.62	1.53	6-6.5	21.6
Kaolin Clay										
Airfloat	platy	65-75	30-40	0.3-1.8	4-6	4-5.5	2.58	1.56	2	21.9
Water-washed	platy	80-92	30-45	0.2-4.8	5-6	3.5-8	2.58	1.56	2	21.9
Delaminated	platy	86-92	40-45	0.4-1.0	6-7	6-8	2.58	1.56	2	21.9
Calcined	platy	84-97	50-95	0.8-2.9	4-5.5	5-6	2.50-2.60	1.62	3-4	21.2-22.3
Mica	platy	65-80	40-70	2-40	0-5	7-9	2.82	1.60	2-2.5	23.3
Nepheline Syenite	irregular	88-91	21-30	2-16	0-6.5	10	2.61	1.53	5.5-6	21.7
Silica										
Ground	irregular	80-92	18-42	1.7-21	0-7+	6-8	2.65	1.54	7	22.1
Novaculite	platy	80	17-20	3-15	0-7.5	6-8	2.65	1.55	7	22.1
Precipitated	irregular	90-94	150-250	2-12	7+	6.5-7.5	2.10	1.46	1	17.5
Fumed	irregular	90-94	250-350	-	7+	3.6-4.3	2.20	1.46	1	18.3
Talc	platy	80-90	25-55	1-15	3-6.5	9.5	2.75	1.6	1-1.5	22.6
Wollastonite										
High aspect ratio	acicular	85-93	35-45	2-40	0-5	10	2.90	1.63	5-5.5	24.2
Low aspect ratio	fixed: acicula	85-93	20-30	2-16	0-6.5	10	2.90	1.63	5-5.5	24.2

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