Lecture No. (7)
Rubber Fillers

Introduction of Rubber Fillers

Rubbers in general are rarely used only because of they are too weak to fulfill practical requirements for many applications such as lack of hardness, strength properties and wear resistance, but when addition of particulate fillers the strength could be increased by 10 times. Therefore, the elastomer can be modified when using the additives such as fillers, pigments, stabilizers, plasticizers, etc.

The fillers are used with other components to form the rubber compounding called compounding ingredients, that contains about (5 %) or less than of filler per (100 %) of elastomer materials.

The use of fillers in rubber products is nearly as old as the use of rubber itself, because of most rubber applications is modified when incorporation the rubber with particulate fillers, increase the viscosity of the rubber product, improve the processability, performance, properties and life of the final rubber product about (10 to 15) times, reduce cost of rubber product, and impart its color.

The selection any type of fillers that used in rubber is depended on the required property and cheapens the final rubber product. The first used of fillers in early of 20th century, prior World War I, which was used for color of rubber.

Sources of Rubber Fillers

The major particulate fillers are used in the rubber industry can be classified as (black) and (non-black), depending on their original, which are mostly produced from petroleum and mineral sources.

1- Non-Black (Whitening) Fillers

A wide range of non-black fillers are used with rubber, such as alumina, clays, cellulose, magnesium carbonates and calcium carbonate, in the past the rubber reinforcement with different types of clay minerals as fillers.

2- Black Fillers.

The most important particulate fillers have been used in rubber industry are carbon black and silica as conventional fillers to enhance the mechanical properties of various rubbers. In general, the carbon black would be used as black filler

reinforce of rubber to enhance tensile strength and higher modulus of elasticity than silica reinforced only. While the silica including the highly dispersible in the rubber. The carbon black is the most widely used as reinforcing filler in elastomers, due to the physical, chemical or mechanical characteristics and performances it gives to original rubbers, about 5 million tons of carbon black is globally consumed each year, while only 250,000 tons of silica are used each year.

Types of Rubber Reinforcement Fillers

1- Non-reinforcing or degrading fillers.

2- Semi-reinforcing or extending fillers.

3- Reinforcing fillers.

The term (reinforcement) refers to an improvement in the performance and properties of rubber compounding when it is using. Reinforcing filler is a particulate material that is able to increase the tensile strength, tear resistance and abrasion resistance of natural or synthetic rubber. Semi-reinforcing filler is a particulate material that is able to moderately improve the tensile strength and tear strength, but does not improve the abrasion resistance. Non reinforcing filler is unable to provide any increase on these properties and it function only as a diluent.

Carbon Black Fillers

Carbon black (CB) is the general term is used to describe a commercial powder form of carbon. Carbon black is a fluffy powder has extreme fineness, chemical stability and high surface area. When the carbon black incorporation with rubber gives improved tensile strength, modulus of elasticity, fatigue resistance and abrasion resistance, but due to its polluting nature, black color of the rubber compounding and dependence on oil feedstock for the synthesis caused to look at for white reinforcing materials.

Carbon black is prepared and manufactured by many methods includes: incomplete combustion or by thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions, and prepared by incomplete burning of

natural gas on the carbon surface. Also can be produce by thermal decomposition of solid hydrocarbons in the absence of oxygen.

The carbon black is composed essentially from three particles morphological that existing in rubber compounding includes (primary particle, aggregate, and agglomerate) as shown in Figure (1). The sizes of these morphological forms order (particle < aggregate < agglomerate). Single carbon black particles typically have particle size ranges (15 to 300) nm, they are the fewest using in rubber industry. While, the aggregates do not break during rubber compounding and have particle size ranges (85 to 500) nm, the carbon black particles are most widely used as aggregate. While agglomerate consists of group of aggregates and have particle size ranges (1-100) µm. Which it require large amount of energy to break down during rubber compounding due to high cohesive forces among carbon black particles, the carbon black are commonly used in rubber compounding as agglomerate.

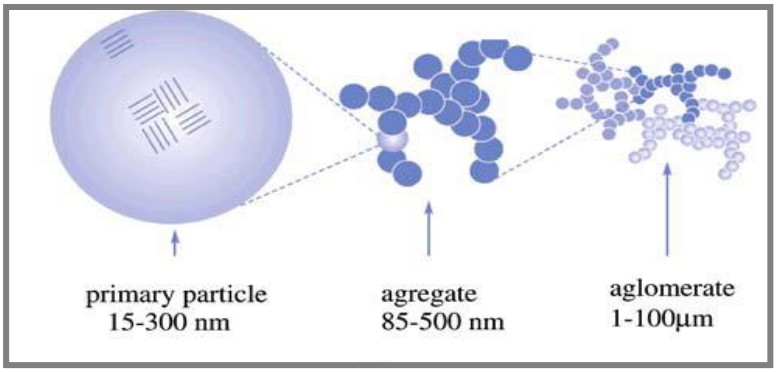

Figure (1): Morphological of Crbon Black Particles.

Carbon blacks are classified into furnace blacks, channel blacks, thermal blacks and lamp black depending up on their manufacturing method. The major types of carbon blacks are manufactured by the furnace process, over 95 % of all carbon black produced today by this process, carbon black is used principally as reinforcement fillers of rubber, black pigment of tires and electrically conductive for other application.

Silica Fillers

Silicon dioxide (SiO_2) is commonly referred to silica, which is formed by strong covalent bonds and four oxygen atoms are arranged at the corners around central of tetrahedron silicon atom, as shown in Figure (2).

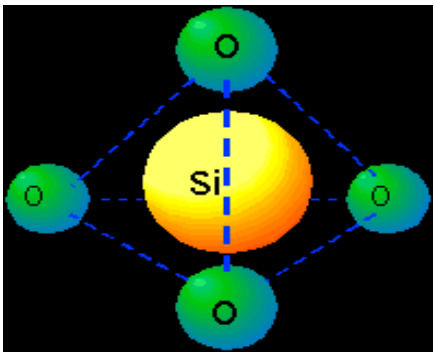

Figure (2): Crystal Structure of Silica Atom.

There are two types of silica are precipitated silica and fumed silica with different manufacturing methods. Precipitated silica is manufactured by acid precipitation from silicate solution, silicate solution product by reactions of sodium silicate with acid or alkaline earth metal salts, it has average particle size (10 to 100) nm and water contains is (10-14%). While fumed silica is produced at high temperature by reaction of silicon tetrachloride with water vapor, it has average particle size (7-15) nm.

Silica is important filler in the rubber industry although of silica is not quite reactive with rubber as carbon black. In the recent years, tires filled with silica to reducing rolling resistance and increasing hardness, therefore the largest application of silica is tire products.

The silica usually exists as aggregates and agglomerates, when exits hydrogen on the silica surface that causes a serious problems in rubber compounding such as poor dispersion of silica. This problem could be solved by adding silane coupling agents into rubber to modification of silica particles surface and increase interaction between silica and rubber. However, the curing time of rubber with silica is longer than with carbon black, thus the production time is long but reduces in productivity.

Alumina Fillers

Aluminum oxide (Al_2O_3) is commonly referred to alumina, which is most widely used as engineering ceramics. It has strong ionic bonding, which gives rising to its desirable characteristics such as high hardness, stiffness, wear resistant, abrasion resistance, compressive strength, thermal conductivity. It also has extreme temperatures resistance, high corrosive and environmental resistance.

The purity of alumina filler ranges (94-99.9%), with excellent size and shape, so that it has a wide range of applications such as seal and any rubber applications, which require abrasion resistance and dimension stability at high temperature.

Cellulose Fillers

Cellulose is the most available natural polymer, which represented the main component for all plants such as cotton and trees, because of it has high mechanical properties. The cellulose structure consists of large linear polymer chains with many hydroxyl groups, which has low amorphous and highly crystalline structures, strong and hydrogen bonding among cellulose chains.

Cellulose can be used in the many applications such as coatings, packing and papers, because of its biodegradability, biocompatibility, available in nature and low cost. Also cellulose fiber use as a reinforcement filler of rubber to give high strength, high stiffness and insoluble in water of rubber products, that use for many applications such as ropes, hose, belt, mats and insulation, but they have not been used for tire applications.

Clay Fillers

Clay is representing the cheap and largest volume of non-black filler that is used in the rubber industry, but it has poor reinforcing capability because of its large particle size and low surface activity. Clay minerals are widely used in rubber compounding to reduce rubber compound cost, give good reinforcing, improving physical properties and processing properties.

The main clay mineral is kaolin and derivative that produced by chemical and heat treatment. Kaolin clay is typically used as rubber filler that classified to

either hard clay or soft clay in relation to their particle size and stiffening that affect in rubber. Hard clay have a median particle size (250 to 500) nm, when it reinforces rubber imparts high tensile modulus, tensile strength, stiffness and abrasion resistance of rubber compounds.

Soft clay has a median particle size (1000 to 2000) nm, when it reinforces rubber impart low physical properties and it is produced rubber compounding where high filling and faster extrusion rates are more important than strength.

Several clays particles can be treated with silane coupling agents before added to rubber, in order to modification of clay particles surface, improve the adhesive bond between clay particles and rubbers, increased tensile modulus, tensile strength and improve the performance of rubber compounding.