Lecture No. (8)
Characteristics of Rubber Fillers

Rubber Fillers Characteristics

The primary characteristics of fillers that influence on the effectiveness and strength of rubbers reinforcement, also represented the basic properties of fillers that have large effect on rubber compounding properties include: particle size, particle dispersion, particle shape, structure, surface area, surface activity, surface chemistry, porosity, filler dispersion and interactions between fillers and rubbers.

1- Adhesion between Filler and Rubber

Chemical compatibility between fillers and rubber is playing important role for dispersion of fillers in rubber and in the strong adhesion bonding between the fillers and rubber. The adhesion between the rubber and filler may be induced by using coupling agent such as silane coupling agents that use for silica fillers, clays fillers, cellulosic fibers, mineral fillers, calcium silicate, and carbon blacks fillers. The differential type's fillers and rubbers require different coupling agents. There are two silane coupling agents commonly used with non-black fillers in vulcanized rubber, include mercaptosilane and tetra sulfide silane, as shown in Figure (1).

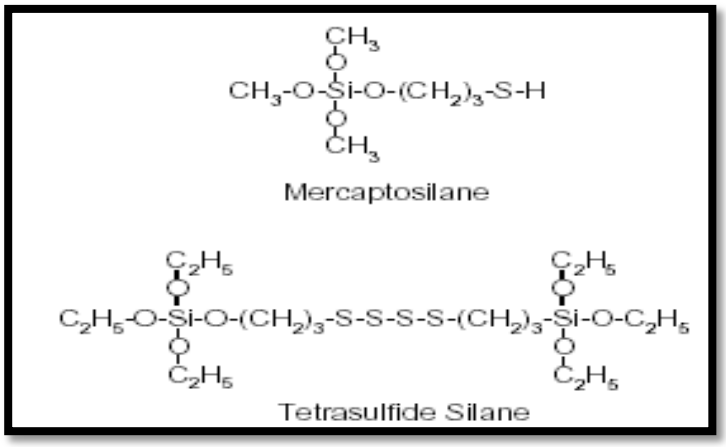

Figure (1): Silane Coupling Agents used with Sulfur Cure.

The silane coupling bond when use these materials is shown in Figure (2), silane coupling agent is most important to mix and bond the rubber with filler in time about (1 to 2 min), because when adding it's the reaction occur between the filler and silane. If mixing process done at high temperature about (150 to 160 ^{o}C), the silane agent are broken and reduce its bond ability between fillers and rubber.

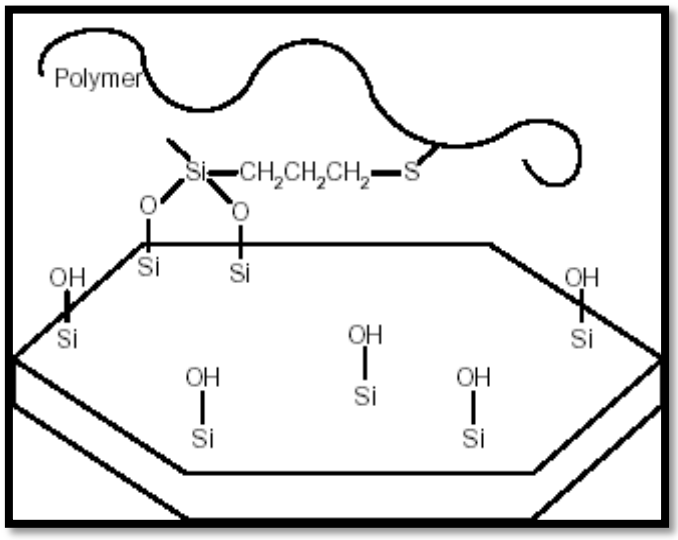

Figure (2): Silane Coupling Bond.

The formation networks interfacial adhesion between fillers and rubber, lead to reduced mobility of elastomer chain and product high tensile modulus of rubber compounds.

2- Particle Size and Particle Size Distribution

Particle size is define the primary particle size of spherical particles, which determines the effective contact area between the fillers and rubber. The improvement of the physical properties, tensile modulus and tensile strength of the rubber is directly related to the particle size of fillers. The fine particle sizes fillers impart greater reinforcement of the rubber and greater influence of rubber-filler interaction and filler surface area, than the coarse fillers. Figure (3) shows classifies of the various fillers by particle size and reinforcement potential.

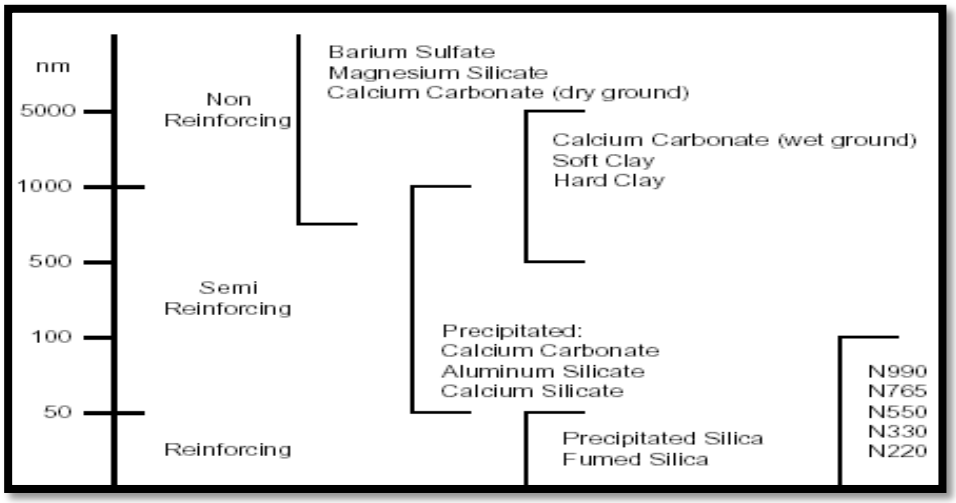

Figure (3): Classification of the Various Fillers.

Different fillers for same particle size may not impart the same reinforcement effect, for examples carbon black and silica fillers.

In addition the average particle size (particle-size distribution) has a significant effect on rubber reinforcement. Particulate fillers with a broad particle-size distribution have better packing in the rubber than that provided by an equal volume of filler with a narrow particle-size distribution. The important problem in reinforcement is the presence of large particles or agglomerates in the rubber, these agglomerates not only reduce the contact area between filler and rubber but also function as failure initiation sites which lead to failure of materials.

3- Particle Shape

The shape of particulate filler is important factor that effects on the performance of rubber compounds. Inorganic and mineral fillers have large differences in particle geometry that is depending on the crystal form. An isometric particle have approximately equal dimension in the three directions. Some an isometric are particles which have one dimension is much smaller than the two others, called platelets. The most an isometric are particles which have two dimensions is much smaller than the third, called rod-shaped.

In rubber compounds that containing filler the tensile strength, tensile modulus and hardness increases with increasing an isometry, due to highly crystal structured of fillers such as structural aggregates of carbon black or silica, which can line up parallel to one another during reinforcing process of rubber. Platelets shapes of filler have higher reinforcement of rubber compounding. The other shapes of particulate fillers may be occurring such as spherical, cubic, prismatic, tubular, or flaky.

4- Surface Activity

The surface activity of the filler lead to increasing mechanical properties of rubber compounding such as tensile strength, tensile modulus, abrasion resistance and tear resistance, because of the surface activity is the control factor of interactions between rubber and fillers that can be done through either chemical bonding or physical absorption. When high ability of fillers to reaction with rubber

by chemical bonding that leads to formation strong interfacial bonds and increasing the strength of rubber compound. While, when absence the strong chemical bonds the physically absorbed occur on the filler surface, that lead to reduce the mobility of the rubber molecules chains near the filler surface.

The bonding between rubber and filler develop through active sites on the filler surface. This bonding is referring to the filler-rubber interactions which can be considered as a measure of the filler surface activity.

5- Surface Area

The surface area of particulate filler plays an important role in its interaction with rubber chains and determines the effective contact area between the filler and rubber, also determines the degree of rubber reinforcement (any increasing in surface area leads to increase of rubber reinforcement), because of the filler surface have active sites as reactive organic groups that cause attraction to rubber.

Spherical particles have a lower limit useful specific surface area about (6 m^2/cm^3), and the upper limit useful specific surface area about (300 to 400 m^2/cm^3) for significant rubber reinforcement. The surface area of particulate fillers is related to its particle size, when decreasing the particle size that lead to increasing the surface are of filler. Most particulate filler are considered as spheres, therefor the surface area of spherical filler calculated from equation ($S= 6/d \rho$), where S: surface area of fillers, d: diameter of filler and ρ: density of filler.

6- Fillers Dispersion

The higher surface area leads to restrictive the dispersion of small particulate fillers into rubber, therefore the particle size of particulate fillers that added to rubber must usually be made as small as to ensure good contact area with the rubber and good dispersion of particulate fillers through the rubber.

7- Surface Chemistry

A mount or composition of various functional groups such as the (hydroxyl groups or carboxyl groups) that found on the fillers surface, called surface chemistry.

8- Structure

The size of particle aggregate or degree of irregularity filler is called structure, the structure of filler plays an essential role in the restrictive motion of elastomer molecules chains near the filler surface under stress applied.

9- Porosity

Porosity is a characteristic property of particulate fillers that can be affecting the properties of the rubber vulcanization and effect on the rubber reinforcement; in most cases the porosity is too small for the polymers and rubbers.

General Effects of Rubber Fillers

The most important characteristics of rubber fillers are particle size, particle shape, surface area and surface activity are interdependent to improving rubber compounding properties and play an important role in interaction between filler and rubber. The general influence of these fillers characteristics on rubber properties can be summarized by follows:

1- Increasing surface area of fillers (by decreasing particle size) gives lower resilience and higher viscosity, higher tensile strength, higher abrasion resistance, and higher tears resistance of rubber compound.

2- Increasing surface activity of fillers (by surface treatment) gives higher abrasion resistance, higher chemical reaction, and higher tensile modulus of rubber compound.

3- Increasing particle size or effective particle shape of fillers (as spherical filler) gives higher viscosity, higher tensile modulus, lower shrinkage, lower tear resistance, lower resilience of rubber compound.