

Testing of Raw materials, Compounds and finished Products in Solid Tire Manufacturing Process.

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To assess the quality and to maintain uniformity in quality of the products regular testing of the raw material, compounds and vulcanized are needed. The manufacturer has to assure himself that the product that he has made, meets the limits imposed by the specifications and customer requirement. In order to meet this specifications, it is essential to establish document implement and maintain a quality management system such as ISO 9001.

Solid tire manufacturers in Sri Lanka, ensuring their product is high-quality and functioning to its fullest potential is extremely important to maintain their market share in the world market. Quality has a lot of weightage, especially in products that play a critical role in high end applications, like tires.

From raw material testing to testing the finished product tests are crucial for manufacturers. Hence Testing in solid tire industry can be divided in to three categories, namely

- Raw material testing,
- In processes material testing and
- Finished product testing.

Raw materials such as Rubber (Natural and Synthetic) ,recycled rubber, carbon black, mineral fillers, various types processing aids, antioxidants, antiozonants,

waxes, vulcanizing agents and accelerators are used to make compounds. Such raw materials are analyzed by using physical and chemical methods.

Determination of the melting point, moisture content, dry mass volume, ash content, volatile matters in dry materials and determination of viscosity, effective substance volume, refractive index, acid value and heavy metals in liquids are the main parameters tested for liquids. These test can be performed as raw material quality control tests in Solid tire industries.

The quality of the finished products depends not only on the quality of the starting materials but also on the correct operation of the various processing steps. Processing errors committed during the manufacture can seriously affect the properties of the final product. For example, too much milling of the rubber in the mixing mill or in the internal mixer can give a product of low strength.

Testing of rubber compounds and vulcanizates during processing are done to control of quality of semi products and component during manufacturing. These testing gives an idea about process ability, indication of quality of final product and serviceability of products. More attention has to be given on this area in the manufacturing process.

Under testing of rubber compounds, testing of rheological properties of the compounds, testing of vulcanizates and Dynamic Mechanical thermal

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analysis of vulcanizates can be done.

Testing of final products are done in Final inspection area under defined test procedures. Static measurements as well as Dynamic measurements can be taken. Specially performed ultrasonic test to find out porosity in solid Tyres layers which leads to service failure.

A test method is a method for a tests in manufacturing industry, such as a physical test, chemical test and specialized testing. Physical content of raw materials are directly give an idea of purity of the used raw materials while Chemical tests give an idea of vulcanizates. Complex testing methods and instruments are being used to chemical analysis. Specialized testing can be performed to measure and identify defects in finished products.

In order to ensure accurate and relevant test results, a test method should be “explicit and experimentally feasible.” as well as effective and reproducible.

A test can be considered an observation or experiment that determines one or more characteristics of a given sample, product, process, or service. The purpose of testing involves a prior determination of expected observation and a comparison of that expectation to what one actually observes. The results of testing can be qualitative (yes/no), quantitative (a measured value), or categorical and can be derived from personal observation or the output of a precision measuring instrument.

Using a standardized test method, perhaps published by a respected standards organization, is a good place to start. Sometimes it is more useful to modify an existing test method or to develop a new one, though such home-grown test methods should be validated and, in certain cases, demonstrate technical equivalency to primary, standardized methods.

However, even more important is choosing a method of measuring the correct property or characteristic.

- Test results of a raw material should connect with tests of a component made from that material. Evaluation of the physical properties of rubber materials can be used to predict the durability and performance for use in a multitude of final product applications.
- test results of a component should connect with performance testing of a complete item
- results of laboratory performance testing should connect with field performance

Raw Material Testing

Standard test methods are used to evaluate quality of Raw materials

Melting Point: (ASTM D 1519)

The melting point can be used to identify a substance and as an indication of its purity. At the melting point the solid and liquid phase exist in equilibrium. Impure solids melt at lower temperatures and may also melt over a wider temperature range, known as melting point depression. The melting point range for pure solids is narrow, usually only 1 to 2 °C, and known as a sharp melting point. Impurities cause structural defects that make the intermolecular interactions between the molecules easier to overcome. Melting point is determined at Accelerators, antioxidants and others.

Softening or Dropping Point: (ASTM D 36/D36 M-14e1)

Softening point is the temperature at which a substance begins to flow under given test conditions.

In particular for polymers, raw polymers, waxes, polyolefins, paraffins, lubricant greases, organic powders, petroleum resin and oils and related substances, the dropping point is used for characterization and quality control.

Volatile matters: (ASTM D 3175-18)

Volatile matter is an unstable material or compounds that are released from a sample. Most of the cases it is water or volatile organic compounds. The weight loss is equivalent to the volatile matter content. Volatile matter is determined at Carbon black, silica, accelerators, antioxidants etc.

Ash Content test: (ASTM D 4574)

An Ash content test is used to determine if a material is filled. The test will identify the total filler content. It cannot identify individual percentages in multi-filled materials without additional test procedures being performed. This is defined for Carbon black, organic chemicals, fillers and rubber additives. The ash content of petroleum products is generally low.

Viscosity: (ASTM D 5478-13)

The viscosity of a fluid is a measure of its resistance to deformation at a given rate. By increasing the temperature the viscosity of a fluid decreases due to increase in molecular motion. Pressure doesn't have very much effect but slightly effect when high pressure is applied.

Ford cup and Brookfield viscometer can be used.

Acid No: (ASTM D 664-18e2)

Also it is define as the mass of Potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance. Acid value is called as neutralization no or acid no or acidity

The acidity of oil is due to hydrolysis or oxidation of oil by atmospheric moisture leading to the formation of fatty acids. Lubricants oil with acid values greater than 0.1 corrode metals, form gum and sludge during operation.

Saponification value: (ASTM D 5558-95)

This value represents the number of milligrams of potassium hydroxide required to saponify 1g of fat under the conditions specified. It is a measure of the average molecular weight (or chain length) of all the fatty acids present.

Iodine Value: (ASTM D 5554-15)

Iodine numbers are often used to determine the amount of unsaturation in fatty acids. This unsaturation is in the form of double bonds, which react with iodine compounds. The higher the iodine number, the more C=C bonds are present in the fat.

Testing For Carbon Black

Carbon Black used as filler in compounds in order to optimize mechanical properties in the compounds. Rubber/Polymer and carbon interaction is very important and it depends on three factors.

Intensive factor (surface activity)

Geometric factor (structure of carbon black)

Extensive factor (surface area of carbon black).

Testing for carbon black is typically performed during formula investigations and reconstructions or as a quality control. Determination of pH of carbon black ,determination of volatile substance ,ash content, Sieve residue analysis, oil absorption number, iodine adsorption number ,tint strength, pallets hardness pour density ,Powder density and surface area can be conducted for carbon black. Therefore performing above tests very much help full to control quality of semi products and final products.

The following standards are used in testing of Carbon black.

Pelleted Fines and Attrition ASTM D1508

Iodine Adsorption Number ASTM D1510

Sieve Residue ASTM D1514

Oil Absorption Number (OAN) ASTM D2414

Total and External Surface Area by Nitrogen Adsorption ASTM D6556

Plasticity Retention Index: (ASTM D3194-17)

Plasticity Retention Index (PRI) is used to analysis of heavy metals in rubbers. At the increase of temperature heavy metals dropping down molecular weight of polymer and its effect to physical mechanical properties. PRI is low when sample is having low amount of heavy metals.

Thermo Gravimetric Analysis: (ASTM e1131 ,ISO11358)

This is a method of monitoring of sample volume changes in depending on its temperature Composition of the rubber compound and vulcanizes can be analyzed. Percentage volatile materials, rubber , carbon black and ash in the sample can also be determined. Ashes can be from polymer, minerals such as Clay, CaCo₃, ZnO or filler.

Incoming Testing of Reclaim rubber, crump rubber and Devlucanised rubber can be performed by using this test method.

Testing of Semi products and vulcanizes in solid tire manufacturing process.

Test results of Raw materials connect with compounds/ components made from it. Errors can be occurred at chemical weighing, mixing and operations (temperatures) as lot of people involved and raw material pass lot steps in between Raw material to mixing.

Testing of Rubber Compounds

Mooney Viscosity: (ASTM D 1646 / DIN 53 523/ ISO 289)

Determination of Mooney viscosity is the widely use method in process. It is based on torque measurement of shearing disc and the temperatures of the chamber. Small as well as large rotors are available. Viscosity gives an idea of mechanical processing ability.

Rheometer Test: (ASTM D 6204-19)

Rheometer is mainly used to determine vulcanization

behavior of rubber compounds. In other words, the rehometer test allow us to determine cure characteristics of rubber compounds. The cure or vulcanization curve is called the rheograph. From the graph, rubber compound characteristics such as TS2 (Scorch time), TC90 (optimum cure), M0 (Initial torque), ML (minimum torque) and MH (maximum torque) can be obtained.

Testing Of Rubber Vulcanized

Physical testing of the rubber vulcanized is required to find out the short falls in processing methods, to control and maintain the quality of the products. Even though it is true that the basic polymer properties have a profound influence on the actual service life of a product, it also depends on processes involved in the fabrication of the product. In certain products like tires, the design of the product also equally affects the final performance. The important basic tests done on vulcanized are the Stress strain tests, ageing tests, hardness tests, specific gravity test, tear test, resilience test, etc. The tests which are related to the performance tests are abrasion tests, flexing tests, compression tests etc.

Tensile Test: (ASTM D 412)

Tensile strength is defined as the force per unit area of original cross section of the sample, required to stretch the rubber test piece to its breaking point. Modulus is the tensile stress required to stretch a rubber test piece to a predetermined elongation. Elongation at break is the maximum elongation, expressed as the percentage of the original length, prior to the rupture of the sample.

The tensile test results can be used to evaluate the strength of the vulcanized and the degree of cure of the vulcanized. This gives an idea of mixing quality of rubber mixes.

Tear Test: (ASTM D 624)

Tear strength is defined as the force per unit thickness required to cause a nick out in a rubber when it is stretched, under constant rate, in a direction substantially perpendicular to the plane. Tear tests give an indication of the behavior of the vulcanized in tear initiation and tear propagation. The tear test can be performed using the tensile testing machine.

Hardness Test: (ASTM D 2240-15e1)

Hardness test involves the measurement of the depth of penetration of an indenter of specified dimensions under the application of a load either by a dead weight or by a spring. The indentation hardness is a measure of the elastic modulus of the material under conditions of

small strain. Hardness is an important property to the compounded since its specification imposes limits upon the type and quantity of certain compounding ingredients like fillers, plasticizers and also gives an idea of curative dispersion etc. in a particular compound.

This test can be used as a quality control test in the production process, here rubber compound sample can be vulcanized at elevated temperature within short period of time and measure hardness before product move one to another work station. A Portion of Same sample can be used to measure density/Specific gravity of the particular compound.

Specific Gravity Test: (ASTM D 792)

Specific gravity is the ratio of the density of a substance to density of reference substance. (Specific gravity is the ratio of the weight of a volume an equal volume of the reference substance.

Rebound Resilience Test: (ASTM D 7121-05)

Rebound resilient refers to compound ability to regain its original size and shape after temporary deformation. Rebound resilient defined as the ratio of energy given up in recovery to the energy required to produce the deformation. It gives an idea of heat buildup.

Accelerate Ageing Tests: (ASTM D572 -04 /ASTM D573-04)

The natural deterioration of the Vulcanized under the action of heat, UV light, oxygen, ozone etc. is termed as 'ageing'. Accelerated ageing tests magnify the influence of one or more of the above agents which affect the service life of the products. The fall in properties from the initial value or the change in appearance gives an indication of the resistance of the rubber vulcanized to that particular factor.

Compression Set: (ASTM D395-18)

Compression set in rubber may be defined as the amount (percent) by which a standard test piece fails to return to its original thickness after being subjected to a standard compressive load or for a specified period of time. Compounds specially use as inner heel and heel need to be tested. The set value should be very low. Usually high loading of reinforcing fillers and under curing of the compound give high set values.

Abrasion Test: (ASTM D 5963)

Abrasion resistance defined as the resistance of the rubber vulcanized to wearing away by rubbing or impact during service. The loss due to this rubbing is then

calculated and expressed as loss in weight. Abrasion test gives an indication of the resistance of the compounds to abrasive wearing on tread compounds.

Dynamic Tests

Tyres are dynamically loaded during service and material detrition occurs under dynamic condition. Due to this reason, dynamic properties of side wall and middle compounds to be evaluated. Flex resistance test can be performed to evaluate dynamic properties.

Flex Resistance: (ASTM D 4482-11)

Products like tires, are subjected to repeat flexing during service. This repeated flexing may gradually lead to failure of the product. This is because, repeated flexing of a rubber vulcanized causes cracks to develop in that part of the surface where tension stress is set up during flexing or if that part contains a crack or cut. Causes the crack to extend in the direction perpendicular to the stress. This test is used for evaluation of tire tread and side wall compounds.

Resistance to flex cracking is composed of two parts

- (1) Resistance to crack initiation and
- (2) Resistance to crack growth.

Peeling Test (Compound to compound and compound to metal): (ASTM D 429)

Tire is a composite material which is composed from different compounds and materials. Life of the tire depend on their mutual adhesiveness is between layers as well as self-adhesion and it can be evaluated by performing adhesion test for compounds and compound to metal.

Dynamical Mechanical Thermal Analysis: (ASTM D4065, D4440, D5279)

Dynamical Mechanical Thermal Analysis (DMTA) Test is also used to analyze Dynamic properties of rubber vulcanizates. DMTA is the application of the oscillation fore on sample and analysis of the material response.

Testing Of Finished Products.

Basically two type of finished products types available namely resilient and press on tyres. Outer surfaces of tires undergo a visual attribute inspection to ensure the surfaces of the rubber parts are acceptable. Inspectors review the parts for surface defects like knit lines, cuts, de molding damages, Short molds, flash open and foreign material etc.

After the finished rubber products are tested for visual defects, tires are tested for dimensions and weight... Part qualification/Defective tires are crucial for manufacturers and should be taken very seriously to ensure each product is of the highest quality and is free of defects. Implementing a qualification system into your facility will reduce the risk of customers receiving low-quality products that don't meet their standards.

Hardness test perform for all tire categories while ultra-sonic test is done for resilient tires but can be extent to Press on tire inspection too. Test like Caliper test, and bad bond tests are performed for Press on tires. In the case of assemblies, rim /wheel dimensions are very critical and procedures to developed to inspect.

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