THE EFFECT OF CARBON BLACK LOADING ON THE TENSILE STRENGTH OF RUBBER COMPOUND

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ABSTRACT

The purpose of this study is the effect of carbon black loading on mechanical properties of rubber compound. There are several studies about tensile strength of rubber compound and the results are positive. Rubber blends are used for many reasons such as lowering the compound cost, for ease of fabrication and to improve the performance of the rubber industrial. Study the effect of tensile strength on rubber compound based on filler loading has played important role in contributing the fundamental to formulate the rubber compound and investigate the mechanical effect. The aim of this study is the effect carbon black loading on tensile strength of rubber compound. The previous study was show that the different filler and loading give the different effect reinforcing to rubber compound. The objective in this study is to study the effect of filler loading on the tensile strength of rubber compound. We are using two roll mills in high temperature and at medium speed this is to ensure the rubber mix well with other ingredients. The filler use is carbon black N220 and be tested in three experiment based on filler loading at 10phr, 30phr and 50phr. The mechanical properties – such as tensile strength properties of the present industrial rubber – were studied. The study also indicated that filler materials affect on the mechanical properties of the blends.

ABSTRAK

Tujuan kajian ini adalah mengenai kesan campuran karbon hitam pada cirri-ciri makanikal getah. Sudah banyak kajian megenai “tensile strength” getah dan keputusannya adalah positif. Campuran getah digunakan atas banyak sebab seperti merendah harga sebatian, untuk pembuatan dan meningkatkan kualiti dalam industri getah. Kajian kesan “tensile strength” pada getah adalah berdasarkan pada campuran karbon hitam yang telah memainkan banyak perana dalam meyumbangkan kepada asas pembentukan formula getah dan mengkaji kesan mekanikal. Kajian lepas ada menunujukkan perbezaan campuran carbon black akan menghasilkan kekuatan yang berbeza. Objektif kajian ini adalah untuk mengkaji kesan campuran karbon hitam pada “tensile strength” sebatian getah. Kami mengunakan Two Roll Mill mesin pada suhu yang tinggi dan halaju yang sederhana ini untuk memastikan getah bercampur dengan bahan-bahan yang lain. Karbon hitam yang digunakan adalah N220 dan ia dijalankan dengan 3 ujian berdasarkan bahagian campuran karbon hitam 10phr, 30phr dan 50phr. Cirri-ciri mekanikal – seperti cirri-ciri “tensile strength” getah industri sekarang – telah dikaji. Kajian juga membincangkan kesan “filler material” pada cirri-ciri mekanikal campuran getah.

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LIST OF ABBREVIATIONS

PHR (phr)	-	part per hundred
CBS	-	N-(1, 3-dimethylbuthyl)-N-Phenyl-P-Phenyllenediamine
CB	-	Carbon Black
SMR	-	Natural Rubber
IPPD	-	Iso Propyl-N-P- Phenyllenediamine

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The present day about three quarter of rubber in production is a synthetic product made from crude oil. There are about 20 grades of synthetic rubber and the intended end use determines selection. In general, to make synthetic rubber, byproducts of petroleum refining called butadiene and styrene are combined in a reactor containing soaps suds. Close to 21million tons of rubber produced in 2005 of which around 42% as natural. Today the main sources of natural rubber are Indonesia, Malaysia and Thailand together account around 72% of all natural rubber production.

The natural rubber is an elastomer that was originally derived from milky latex, found in sap of some plant. The purified form of rubber is the chemical polyisoprene, which can also be produced synthetically. Natural rubber is used extensively in many applications and products as in synthetic rubber. Natural rubber is an elastomer and a thermoplastic. But we should note that as the rubber is vulcanized into a thermoset. Most rubber in everyday use is vulcanized to a point where it shares properties of both. If it is heated and cooled, it is degraded but not destroyed.

At a particular shear rate, shear viscosity increases with blend ratio. The dependence of flow behavior on extrusion velocity indicates a surface effect. The extrudate die swell and maximum recoverable deformation are related by a linear relationship, which is independent of sulfur or accelerator ratio, extrusion temperature and shear rates blend ratio. The principal normal stress difference increases nonlinearly with shear stress. Although natural rubber (NR) is known to exhibit numerous outstanding properties, reinforcing fillers are necessarily added into NR in most cases in order to gain the appropriate properties for specific applications. A wide variety of particulate fillers are used in the rubber industry for various purposes, of which the most important are reinforcement, reduction in material costs and improvements in processing. Reinforcement is primarily the enhancement of strength and strength-related properties, abrasion resistance, hardness and modulus. In most applications, carbon black (CB) and silica have been used as the main reinforcing fillers that increase the usefulness of rubbers. When CB is compounded with rubbers, tensile strength, tear strength, modulus and abrasion resistance are increased. For this reason, CB has been extensively exploited in numerous rubber engineering products. In general, a CB-reinforced rubber has a higher modulus than a silica-reinforced one.

1.2 Problem Statement

The rubber prize is randomly high and low this crisis happens because of the decreasing rubber supply and the sources are unevenly spread. Rubber price is increasing and decreasing dramatically every year and it will burden people. Producing rubber compound randomly will increase the quantity and low quality. Also many rubber compounds are wasted.

Rubber is durable and safe. The tire industry is the biggest user of rubber, synthetic or natural. But, rubber cannot be destroyed easily and cannot be burned due to toxic gases it emits while burning. Rubber recycle is the only solution to the problem. Most of this recycled rubber goes into the production of rubber granules which can be used as mulch for a wide range of operation.

1.3 Objectives

i. To study the effect filler loading on rheological properties of rubber compound.

1.4 Scope of Study

To achieve the objectives, scopes have been indentified in this research. The scopes of this research are listed as below:-

i. Carbon black fillers are used in the rubber compound formulations.
ii. Loading of fillers will be varied from 10phr, 30phr and 50phr.
iii. The effect on mechanical properties of black-filled compounds will be determined.

1.5 Rationale and Significance

This study has potential in minimizing economical losses by study the tensile strength and properties of rubber, aiding analysis on proposed change in filler or carbon black loading by predicting the results. The data and result we gained from this study approximate will decrease the rubber blend cost and increases the optimum value of tensile strength.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a body of text that aims to review the critical point of current knowledge and or methodological approaches on a particular topic. Literature reviews are secondary sources, and as such, do not report any new or original experimental work. Most often associated with academic-oriented literature review usually precedes a research proposal and result section. Its ultimate goal is to bring the reader up to date with current literature review on topic and forms the basis for another goal, such as future research that may needed in the area. A well-structured review is characterized by a logical flow of idea and relevant references with consistent, appropriate referencing style proper use terminology and an unbiased and comprehensive view of the previous research on the topic.

Tensile strength is indicated by the maxima of a stress-strain curve and, in general, indicates when necking will occur. As it is an intensive property, its value does not depend on the size of the test specimen. It is, however, dependent on the preparation of the specimen and the temperature of the test environment and material. Tensile strength, along with elastic modulus and corrosion resistance, is an important parameter of engineering materials used in structures and mechanical devices. It is specified for materials such as alloys, composite materials, ceramics, plastics and wood.

Reinforcement concerns finished rubber part that means vulcanized material; it is quite remarkable that properties of rubber compounds begin to significantly differ from those of unfilled material when the filler has reinforcing capabilities. In addition to usual hydrodynamics effects, reinforcing filler impart indeed other modification in flow properties whose origin is assigned to strong interaction arising between and the filler particle. The natural rubber or elastomers would be impossible without the reinforcing of certain filler, such as carbon black. Reinforcement is usually defined as the “improvement in abrasion, tear, cutting and rupture resistance, in stiffness and hardness of vulcanized compounds through the incorporation of finely divided particle.

Table 3.1: Generalized rubber formula

Material	Part per Weight	Function
Raw rubber	100	The main component in rubber compounding
Filler	50	To modified the mechanical properties and reduced cost
Softener	5	To ease the processing, to modify the specific properties.
Anti oxidant	1	To protect the rubber from aging(an

		irreversible change in material properties after expose to environment
Accelerator	1	To increase vulcanization process and reduce the time of vulcanization
Zinc oxide	5	As activator to increase the accelerator efficiency
Stearic acid	1	As activator to increase the accelerator efficiency
Sulphur	2	To produced a cross linking

Each ingredient has a specific function, either in processing, vulcanization or end use of the product. The various ingredients may be classified according to their specifics function in the following groups: Filler (carbon black, whiting and china clay filler), plasticizer or softeners (extenders, processing aid, special plasticizer), age resistors or antidegradants (antioxidants, antiozonants, special age resistors, protective waxes), vulcanizing or curing ingredients (vulcanizing agents, accelerator, activators), special-purpose ingredients (coloring pigments, blowing agents, flame retardants, odorants, antistatic agent, retarders, peptizers).

2.2 Natural Rubber

The natural rubber Natural rubber is an elastomer (an elastic hydrocarbon polymer) that was originally derived from a milky colloidal suspension, or latex, found in the sap of some plants. The purified form of natural rubber is the chemical polyisoprene, which can also be produced synthetically. Natural rubber is used extensively in many applications and products, as is synthetic rubber. Rubber exhibits unique physical and chemical properties. Rubber's stress-strain behavior exhibits the Mullins effect, the Payne effect, and is often modeled as hyperelastic. Rubber strain crystallizes. Owing to the presence of a double bond in each repeat unit, natural rubber is sensitive to ozone cracking. Latex is a natural polymer of isoprene (most often cis-1,4-polyisoprene) - with a molecular weight of 100,000 to 1,000,000. Typically, a small percent (up to 5% of dry mass) of other materials, such as proteins, fatty acids, resins and inorganic materials (salts) are found in natural rubber. Polyisoprene is also created synthetically, producing what is sometimes referred to as "synthetic natural rubber". Some natural rubber sources called gutta percha are composed of trans-1,4-polyisoprene, a structural isomer which has similar, but not identical, properties. Natural rubber is an elastomer and a thermoplastic. However, it should be noted that as the rubber is vulcanized, it will turn into a thermoset. Most rubber in everyday use is vulcanized to a point where it shares properties of both; i.e., if it is heated and cooled, it is degraded but not destroyed. The use of rubber is widespread, ranging from household to industrial products, entering the production stream at the intermediate stage or as final products. Tires and tubes are the largest consumers of rubber. The remaining 44% are taken up by the general rubber goods (GRG) sector, which includes all products except tires and tubes (Hobhouse, 2005).

2.3 Fillers

Filler are compounding ingredients, usually in powder form, added to crude rubber in relatively large proportions (typically 50 phr). They include two major groups, carbon blacks and non-carbon black filler. Carbon black consists mainly of finely divided carbon manufactured by incomplete combustion of natural gas or petroleum using different process. The non-black filler include whiting and china clay. Clay is also used as a semi-reinforcing agent for rubber, and about 900 million pounds is used per year in the U.S. Most is hard clay mined in Georgia and South Carolina. It is used in tire carcasses, sidewalls, and bead insulation. Clay offers some reinforcement to the rubber compound but less than reinforcing grades of carbon black. Ground and precipitated calcium carbonate is used in rubber compounds. The ground products are added as extender fillers, while the precipitated types offer some reinforcement due to their small particle size. It is reported that over one billion pounds of calcium carbonate is used in rubber compounds in the U.S. per year filler are added for economic or technical purpose. Some are incorporated primarily to extend and therefore make the final product less expensive and others mainly to reinforce it. By reinforcement is meant enhancement of properties such as tensile strength, tear, and abrasion resistance. Consequently, filler may be classified into two broad groups: reinforcing and non-reinforcing, or active and inactive. However, the distinction between the two groups is not clear-cut because many fillers exhibit intermediate properties. A rubber compound contains, on average, less than 5 lbs of chemical additives per 100 lbs of elastomer. Filler loading is typically 10 to 15 times higher. Of the ingredients used to modify the properties of rubber products, the filler plays a dominant role. The term ‘filler’ is misleading, implying, as it does, a material intended primarily to occupy space and act as a cheap diluents of more costly elastomer. Most of the rubber filler used today offer some functional benefit that contributes to the process ability or utility of rubber product. Styrene-butadiene rubber, for example, currently the highest volume elastomer, has virtually no commercial use as an unfilled compound (Meyer, 1991).

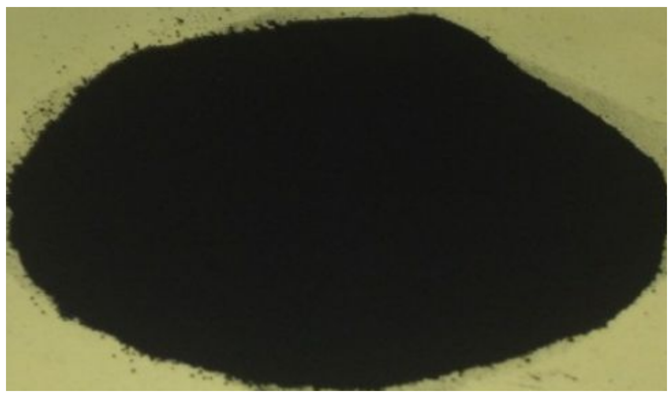

Figure 2.3.1 Filler-carbon black N220

2.3.1 Filler Properties

The characteristics which determine the properties filler will impact to a rubber compound are particle size, surface, structure, and surface activity. For many industrial applications, like anti-vibrating structures, natural rubber is reinforced by carbon black. This leads to an increase of the mechanical properties, i.e. elastic modulus and tensile Strength, as well as a sharp increase of the hysteresis (Chayanoot Sangwichien, 2008). This reinforcement effect comes from the filler–

filler and filler–rubber interactions, both chemical and physical, which take place at different length scales due to the specific structure of carbon black. Carbon black particles are strongly bonded to other elementary particles (10 up to 100) to form an aggregate, the size of which is of the order of 100 nm (Chayanoot Sangwichien, 2008). Due to the branched structure of the aggregate, part of the rubber is trapped inside the aggregate and is shielded from macroscopic deformation; the occluded rubber forms with carbon black particles the core of the aggregates and its main contribution is to lead to an effective filler volume fraction. It is commonly accepted that the occluded rubber proportion can be measured from dibutyl-phtalate (DBP) absorption (Chiang Mai Je, 2008). Due to the filler–rubber interactions, polymer chains are strongly linked on carbon black surface and a layer of rubber with modified. Properties, also called bound rubber, surround the filler particles (J. S. Dick, 2002) a new approach has been recently proposed, that takes into account a glass transition gradient around the inorganic particles. This gradient yields a spatial variation of the elastic modulus in the vicinity of the particles which can strongly increase the modulus of the matrix. The aggregates tend to agglomerate, and at high concentrations, can form a percolating three-dimensional network. When the distance between aggregates is low (Jareerat Ruamcharoen, 1990) Carbon black types depend mainly on their specific surface, which is the ratio of the total outer surface of the filler over its mass, their structure and their surface activity and the reinforcement effect is greatly affected by these parameters. The reinforcement effect is classically split into different contributions: the hydrodynamical effect, which corresponds to the reinforcement obtained by inclusions dispersed within a matrix, the strong interactions between the polymer and the filler, leading to the modified rubber layer and the agglomerate structure contribution, above a percolating threshold. Different models have been proposed to predict, mainly from the filler volume fraction, the elastic properties of the composite. Recently, micromechanical model developed within a self-consistent approach have shown a good correlation with experimental results. Rubber without filler has very low physical strength and no practical use (Edwards, 1990). In three successive steps, for a silica reinforced SBR matrix, in order to highlight occluded rubber and bound rubber interactions, then filler interactions with the previous media, leading to an aggregate and finally bulk rubber with the aggregate. Such approaches have also been extended to the non-linear field, in the case of carbon black reinforced natural rubber its ability to enhance the strength of rubber vulcanized (Baker ,1978; Bagghi, 1981). Numerous studies have been found to be carried out on the addition of carbon black in the rubber compounds as its ability to enhance the mechanical properties (Medalia, 1978). However, there were still not much works on the effect of carbon black grades in the tire tread compound apart from the limited number of the works (Patel, 1980).

2.3.1.1 Particle Size

If the size of filler particles 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. Filler with particles size greater than 10,000 nm are therefore generally avoided because they can reduce performance rather than reinforce or extend. Fillers with particles size between 1,000 and 10,000 nm are used primarily as diluent and usually have no significant affect, positive or negative, on rubber properties. Semi-reinforcing filler, which range from 100 to 1,000 nm, improve strength and modulus properties, the truly reinforcing fillers, which range 10 to 100nm significantly, improve rubber properties. Of the approximately 2.1 million tons of filler used in rubber each year, 70% is carbon black, 15% is kaolin clay or china clay, 8% is calcium carbonate or whiting, 4% is the precipitated silicas and silicates and the balance is variety of miscellaneous minerals(D. T. Norman, 1978). Figure 2.2.1.1 classifies the various filler by particles size and consequent reinforcement potential

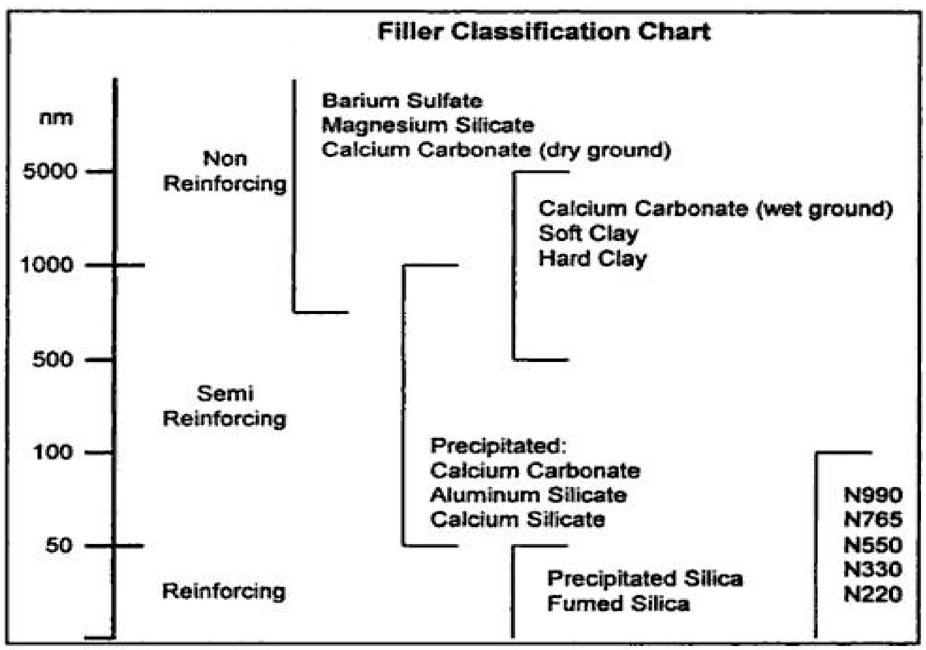

Figure 2.3.1.1.1 Filler Classification Chart

Most tales and dry –ground calcium carbonates are degrading filler because of their large particles size; althouglh the plannar shape of the tale particles contributes some improvement in reinforcement potential. The soft clays would fall into a class of diluents fillers that do not contribute reinforcement, yet are not large that they degrade properties (D. T. Norman, 1978). The hard clays contribute some reinforcement to rubber compounds, primarily because of their smaller particle size and are normally classified as the semi-reinforcing class. The carbon black is available in various particles sizes that range from semi-reinforcing to highly reinforcing. They generally exist as structural agglomerates or aggregates rather than individual spherical particles.

2.3.1.2 Surface Area

Particle size is generally the inverse surface area. Filler must make intimate contact with elastomer chains if it is going to contribute to reinforcement. Filler that have high surface area have more contact area available, and therefore have a higher potential to reinforce the rubber chains. The shape of the particle is also important. Particles with a planar shape have more surfaces available for contacting the rubber than spherical particles with an equivalent average particle diameter. Clays have planar-shaped particles that align with the rubber chains during mixing and processing, and thus contribute more reinforcement than a spherical-shape calcium carbonate particle of similar average particle size (S. J. Chen, 1998). Particles of carbon black or precipitated silica are generally spherical, but their aggregates are anisometric and are considerable smaller that the particles of clay. They thus have more surfaces per unit weight available to make contact with the polymer. Rubber grade carbon black varies from 6 to 259 m^2/g.

2.3.1.3 Structure

The shape of an individual particle of reinforcing filler like carbon black is of less importance than the filler's effective shape once dispersed in elastomer. The black used for reinforcement have generally round primary particles but function as anisometric acicular aggregates. These aggregate properties-shapes, density, size-define their structure. High structure filler has aggregates favoring high particle count, with those particles joined in chain like cluster from which random branching of additional particle may occur. In simplest term, the more an aggregate deviates from solid spherical shape and the larger its size, the higher is its structure. The higher its structure, in turn, the greater it's reinforcing potential (Chayanoot Sangwichien, 2008).

For reinforcing, fillers which exist as aggregates rather than discreet particles, carbon black in particular, a certain amount of structure that existed at manufacture is lost after compounding. The shear forces encountered in rubber milling will break down the weaker aggregates and agglomerates of aggregates (Chayanoot Sangwichien, 2008). The structure that exist in the rubber compound, the persistent structure, is what affects process ability and properties

2.3.2 Filler Effects

The principal characteristics of rubber fillers-particle size, surface area, structure, and surface activity-are interdependent in improving rubber properties. In considering fillers of adequately small particles size reinforcement potential can be qualitatively small particles size, reinforcement potential can be qualitatively considered as the product of surface area, surface activity, and persistent structure or anisometry (planar or acicular nature). The general influence of each of these three filler characteristics above on rubber properties can be summarized as follows:

Increasing surface area or decreasing particle size gives lower resilience and higher Mooney Viscosity, tensile strength, abrasion resistance, tear resistance, and hysteresis. Increasing surface activity including surface treatment gives higher abrasion resistance, chemical adsorption or reaction, modulus (at elongation>300%), and hysteresis.

Increasing persistent structure/anisometry gives higher Mooney Viscosity, modulus (at elongation<300%), and hysteresis, lower extrusion shrinkage, tear resistance, and resilience, and longer incorporation tim