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Optimization of calcium carbonate ($CaCO_3$) loading in Natural rubber latex based disposable gloves

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Abstract- Glove manufacturing and exporting industry in Sri Lanka is placed as one of the top manufactures of the world which also contributes more than 5% of global demand. Natural rubber latex is one of the most important polymer materials which is widely used for manufacturing of gloves. Centrifuged latex contains 60% dry rubber content is used for glove manufacturing process. Addition of fillers may have a potential to improve the stiffness like inferior properties of Natural rubber and simultaneously reduces the cost of production by replacing part of rubber by the fillers. Among the types of fillers used with Natural rubber, calcium carbonate ($CaCO_3$) which generally categorizes under non-reinforcing filler is widely used in glove industry due to its availability and the fewer prices. Optimization of calcium carbonate amount in rubber matrices is essential to keep the required limits of specification of physio-mechanical properties in gloves. In this study $CaCO_3$ filled Natural rubber latex disposable glove samples were successfully prepared by varying the $CaCO_3$ loading level from 20 phr to 45 phr at 5 phr intervals. Tensile strength, elongation at break and force at break were investigated as per the physio-mechanical properties of each sample at aged (after aging) and unaged (before aging) conditions. The experiment was conducted in complete randomized design with 3 replicates per each sample. Thirty (30phr) $CaCO_3$ loading level was indicated the best tensile strength of unaged and aged above 17 N/mm^2, elongation at break of aged and unaged samples above 700% and force at break of unaged samples above 9N and aged samples above 6.3N. The results of the statistical analysis indicate that the 30 phr $CaCO_3$ loading level can be considered as the optimum $CaCO_3$ loading level compared to the specifications of the physio-mechanical properties of natural rubber latex disposable gloves.

Index Terms- Centrifuged latex, dispersion, elongation at break, force at break and tensile strength

I. Introduction

Natural rubber (NR) latex is a milky colloidal system consists of cis-1, 4-polyisoprene, proteins, carbohydrates, minerals, fatty acids and large amount of water. Dry rubber content of the latex is approximately 28-40%. Polyisoprene is a polymer of cis-1, 4-butadiene having a broad molecular weight distribution with a high structural regularity. Due to this reason, natural rubber (NR) tends to crystallize spontaneously at low temperatures or when it is stretched (Poompradub S., 2005). Natural rubber has outstanding resilience, flexibility, tear and tensile strength, as well as low heat build-up and resistance to abrasion due to its high molecular weight and chemical nature (De Silva K.G.K., 2003). Before manufacture any latex product, NR latex is concentrated up to 60% dry rubber content by centrifuging and ammonia and soaps are added to stabilize the latex without flocculating.

When consider the largest application by far for NR latex which is gloves, are produced in very large numbers on highly automated production lines. This industry relies on natural rubber latex due to its ability to form smooth and continuous films on formers; the dried and vulcanized films have high strength and outstanding elasticity.

Among the types of gloves, disposable gloves are made by the coagulant dipping process. In this process former is initially dipped in a coagulant bath and then it is dipped in the compounded latex to get a thin film of latex on the former. Several chemical ingredients such as vulcanizing agents, activators, accelerators, antioxidants, stabilizers, dispersion agents and wetting agents are used to compound NR latex in glove manufacturing process (Heijden and Baarle, 2000). Sulphur is used as the primary vulcanizing agent with Zinc oxide as an activator and one or more ultra-fast accelerators.

Fillers represent one of the most important additives used in rubber compounding. Fillers are added to the rubber formulation in order to optimize properties needed for application (Sobby *et al*., 2003). Fillers are generally added to latex compound to modify its physio-mechanical properties and to reduce cost of production by replacing part of the rubber by fillers. The use of fillers in rubber products is nearly as old as the use of rubber itself. As reported by Blackley (1966), filler is a solid material capable of changing the physical and chemical properties of materials by surface interaction. The nature of fillers can be reinforcing or non- reinforcing. Carbon black is prepared from crude oil in different techniques (i.e. channel method) which is highly consumed as reinforcing fillers while silica is also considered as reinforcing filler (Subramanium K., 2002). But in glove manufacturing industry, white mineral fillers such as clays, calcium carbonates and silicates are mostly used. Most of these fillers are non-reinforcing and the use of these fillers can reduce the cost of production as well as it improves the stiffness and other mechanical properties of gloves up to some extent (Gorton Tony, 1994). Other than these fillers, organic fillers which are based on high styrene polymeric resinous materials do not necessarily increase tensile strength as carbon black like reinforcing fillers, but they greatly harden, or stiffen the rubber and improve wearing properties of products (Baarle, 2005).

In the disposable glove manufacturing process, Calcium carbonate is widely used as the major filler material due to its availability and less cost. It is easy to grind or reduce the size of particles to a specific particle size and it is compatible with a wide range of polymeric resins. When the particle size is carefully controlled, calcium carbonate contributes to increase both impact strength and flexural modulus (stiffness) of glove (Anon, 2014). Therefore, there is a possibility of replacing a certain amount of natural rubber in gloves by incorporating filler, while maintaining the expected physio-mechanical properties at unaged (before aging) and aged (after aging) conditions of samples, to achieve that, the optimization of calcium carbonate loading level into NR is beneficial in commercial scale.

II. Materials and Methods

Materials

Centrifuged NR latex, calcium carbonate, other analytical grade laboratory chemicals and laboratory equipment were supplied by Industrial Clothing (Pvt) Ltd, Prime Polymer Division, Avissawella and experiments were conducted during 2015/05/01 to 2015/10/05

Method

Sample Preparation

Each compounded NR latex sample was prepared by compounding 3kg of preserved centrifuged NR latex and calcium carbonate filler as explained in the Table 1 while keeping constant the amounts of other chemical ingredients in standard compounding formulation. Calcium carbonate loading was changed from 20 phr (parts per hundred parts of rubber) to 45 phr at 5 phr intervals (S1-S6). Sample which contains 20 phr of calcium carbonate loading was taken as the control sample (S1) because it was the calcium carbonate loading level widely used in disposable glove manufacturing industry.

Table 1: Calcium Carbonate Filler Loading Level

Sample	Filler Loading (phr)
S 1 (Control)	20
S 2	25
S 3	30
S 4	35
S 5	40
S 6	45

Then a standard former was dipped into each compounded NR latex sample for 1 minute as the dwell time and withdrawn former was rotated to get an evenly thick, thin latex film on the former surface. The former was dried at 80ºC for 10 minutes to remove moisture and cured at 120ºC for 20 minutes in a dried air circulating oven. Then glove samples were stripped, thumblered and chlorinated.

Physio-mechanical properties

Tensile strength (N/mm^2) and elongation at break (%) were investigated as physio-mechanical properties of prepared glove samples according to the ISO standards mentioned in Table 2.

Table 2: ISO Standards for Physio-mechanical Properties

Properties	ISO Test Method
Tensile strength	ISO 37-1977(E)
Elongation at break	ISO 37-1977(E)
Resistance to heat aging	ISO 188, ASTM D 573

Tensile strength of samples was examined to measure the maximum ability of glove samples to withstand to an applied stress by universal tensile testing machine INSTRON model 3365, with a cross-head speed of 500 mm/min. Three specimens were used for each measurement and the average was taken for calculations. Elongation at break of the test pieces was measured from the same tensile machine to investigate the maximum elongation at the tensile strength. Aged tensile properties of samples were investigated using an aging oven by aging samples for 24 hours at 100ºC.

III. Results and Discussion

Figure 1 shows the tensile strength of glove samples which are unaged (before aging) and aged (after aging). According to the results, the highest unaged tensile strength has been recorded by S3 (30 phr) and it is statistically different with the rest of the samples. Unaged tensile strength of S1 (20 phr), S 2 (25 phr), S 4 (35 phr) and S 5 (40 phr) are statistically on par with each other. Aged tensile strengths are on par with one another by achieving the highest at 30 phr calcium carbonate loading level. The lowest tensile strength has been recorded by S5 (40 phr) in both aged and unaged samples.

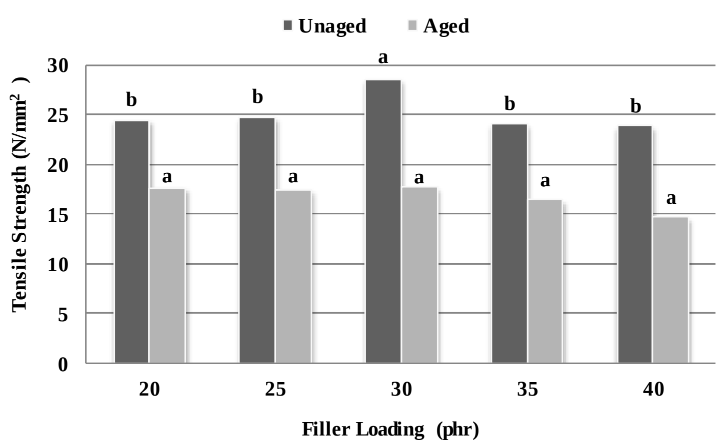

Figure 1: Tensile Strength of Aged and Unaged Glove with Filler Loading

To select the best treatment, it should be fallen with the product specification of NR latex disposable glove. According to the product specification which industrially accepted for the NR latex disposable glove unaged and aged tensile properties of the glove must be greater than 17 N/mm^2. Unaged tensile properties of the all treatments are greater than 17 N/mm^2 but aged tensile properties only S1, S2 and S3 treatments are greater than 17

N/mm^2 and S4 and S5 treatments are less than the specified value 17 N/mm^2.

There is a remarkable reduction of aged tensile strength with filler loading level. Such a phenomenon is attributed to the heating of the films, which caused enhanced stiffening as a result of the interaction of the curatives with the filler particles and the rubber molecules (Srivastava et al, 2010).

According to the Figure 2, the highest elongation at break in unaged sample has been achieved by S1 (20 phr) which is statistically different to the other samples. In aged glove samples, the highest elongation at break has been recorded by S3 (30 phr) that is statistically different other treatments. S1 (20 phr) and S2 (25 phr) are statistically on par with each other in both before and after aging. The lowest elongation at break has been recorded by S5 (40 phr) in both aged and unaged samples. Also the S3 has lower elongation at break, and previously it has got the maximum tensile strength. Therefore, it could have the optimum calcium carbonate loading compared to the other samples prepared.

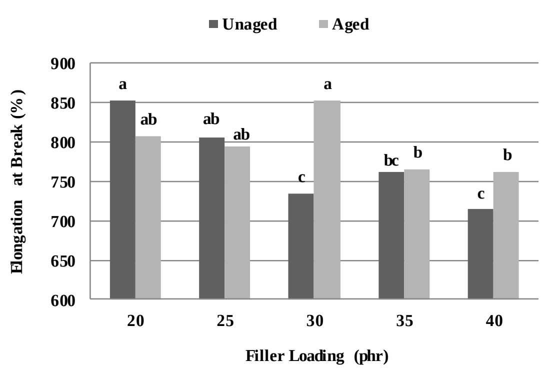

Figure 2: Elongation at Break of Aged and Unaged Glove with Filler Loading

There is an increment of aged elongation at break at S3 (30 phr). The reason could be the formation of sulfur bonds at aging conditions which presents as residue without participating to the vulcanization. According to the product specification given for the NR latex disposable glove unaged and aged elongation at break properties of the glove must be greater than 700 (%). Unaged and aged elongation at break of all samples is fallen within the standard level of NR latex disposable glove. Therefore, there is a potential to use these filler loading levels in NR disposable glove manufacturing. But to keep the tensile strength above the standards it has to omit the S4 and S5 filler loading levels because they have shown a lower aged tensile strength in comparison to unaged tensile strengths of S4 and S5.

As illustrated in Figure 3, the highest unaged force at break has been achieved by S3 (30 phr) that is statistically different with other samples. S1 (20 phr), S2 (25 phr),) S3 (30 phr) and S5 (40 phr) are statistically on par with each other. The lowest force at break was recorded by the S4 (35 phr). There is a remarkable reduction of aged force at break with filler loading phr compared to unaged force at break. The reason may be the stiffening as a result of the interaction of the curatives with the filler particles and the rubber molecules. Aged tensile properties have reduced and as the result of that aged force at break has reduced.

According to the product specification given for the NR latex disposable glove unaged force at break must be greater than 9 N. Unaged force at break in sample S3 is greater than that of 9N, also force at break of S1, S2 and S3 samples are not significantly different according to the statistical analysis. Force at break in aged samples of S4 and S5 have much deviated from the S1, S2 and S3 samples.

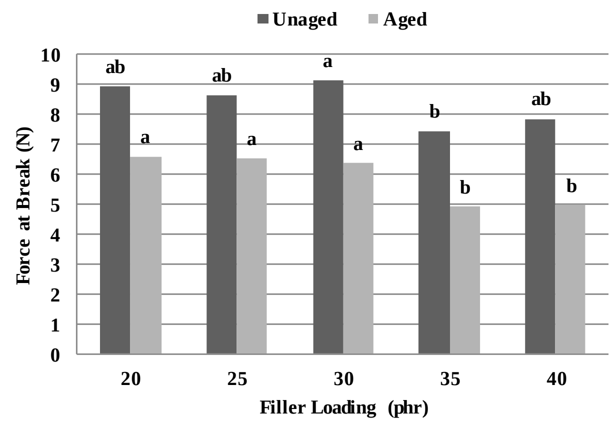

Figure 3: Force at Break of Aged and Unaged Glove with Filler Loading

Therefore, there is a potential to use 20, 25 and 30 phr calcium carbonate loading levels by achieving better physio-mechanical properties in NR latex disposable gloves. But at higher levels of filler loading, the inferior properties have indicated.

IV. Conclusions

The results of the investigation revealed that the physical properties of natural rubber latex disposable gloves are affected by changing amounts of $CaCO_3$ filler loading phr. There is a significant effect of different amount of filler dispersions on tensile strength, elongation at break and force at break.

Study indicated that the S3 sample containing 30 phr of calcium carbonate can be considered as the best sample compared to the specifications of the properties of natural rubber latex disposable gloves. Samples having 30 phr calcium carbonate loading (S3) has been resulted the best tensile strength for unaged and aged glove samples which is above 17 N/mm^2. Elongation at break of aged and unaged glove samples is above 700% as well as force at break of unaged glove samples is above 9N and that in aged glove samples is above 6N. Even though S3 has a lower force at break in aged glove sample, its tensile strength and elongation at break have achieved the required specifications. Also S1, S2 and S3 samples have not shown a significant variation with each other with respect to the force at break according to the statistical analysis. Also to reduce the cost of production it is essential to use maximum amount of fillers by keeping the optimum physio-mechanical properties in the product.

Therefore, the S3 contains the optimum amount of $CaCO_3$ filler dispersion (30 phr) which is important to reduce the cost of production. Similarly, it contains good physical properties compare to the standard level of physio-mechanical properties of natural rubber latex disposable glove.

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