Preparation and Characterization of Natural Rubber Nanocomposites

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ABSTRACT - Natural rubber nano composite shows good mechanical properties with lower amount of nano clay. This report presents a new strategy for development of natural rubber-clay nano composite with enhanced properties by incorporation of lower loadings (2-5 phr) of montmorillonite clay (MMT) and lower loadings (2-5 phr) of montmorillonite clay (OMMT). The effect of MMT, OMMT loading on cure characteristics and mechanical properties were evaluated. Incorporation of MMT and OMMT enhanced mechanical properties such as tensile, tear, hardness, abrasion and rebound resilience and accelerated the vulcanization process.

KEYWORDS: Clay, rubber, MMT, OMMT, CTAB

INTRODUCTION

In the modern world, natural rubber is combined with daily human life. They are huge industries available all over the world to manufacture rubber product to complete the world necessities. Usually rubber products are not produced only by using natural rubber due to its poor properties. In order to reduce these poor properties, vulcanization is done with the rubber. Fillers are also added to enhance various desired properties and to reduce cost. These fillers cause to increase environment and health related issues. As a solution to the above issues, there is a new trend to use nanocomposites in the rubber compounding. Adding a small amount of nano material causes to increase mechanical and thermal properties of rubber)A. Amarasiri, 2013(. In this research, OMMT clay is prepared by adding cetyltrimethylammonium bromide (CTAB) to MMT clay. In addition, variation of rubber properties was studied by varying the MMT and OMMT loading.

METHODOLOGY

Materials

Ribbed smoked sheet (RSS) rubber, di-benzothiazole disulfide (MBTS), zinc oxide (ZnO), stearic acid, phenolic type antioxidant, montmorillonite (MMT) clay and Cetyltrimethylammonium bromide (CTAB) were used in this research.

Preparation of MMT, OMMT filled rubber sheet

MMT and OMMT filled rubber sheet prepared by using Brabender plasticorder and two-roll mill. Formulation of each sample was given in Table 1.

Table 14 Formulation of NR composites

Ingredient Loading (phr) per 100 RSS / Sample No	MMT	OMMT	MA	Sulfur	ZnO	Stearic acid	MBTS	Antioxidant
1	0	0	0	2	5	2	2	1
2	2	0	0	2	5	2	2	1
3	5	0	0	2	5	2	2	1
4	0	2	0	2	5	2	2	1
5	0	5	0	2	5	2	2	1

Preparation of OMMT clay

15g of MMT clay was added to 500g of distilled water and mixed well by using a magnetic stirrer. Prepared sample was then dispersed in the attrition mill for another 30 minutes at 600rpm. A 10 % wt solution of CTAB solution was prepared by using 6.55g of CTAB and distilled water. Then prepared CTAB solution was added to the previous milled MMT solution, which is in the attrition mill. Then mixing was proceeded for another 30 minutes in attrition mill. After that, prepared solution was kept in the sonicator about 15 minutes for further mixing. The dewatered suspension was washed several times with distilled water using vacuum filtration until no yellow-white precipitate with $AgNO_3$ solution)Jayaraj, 2018(. Then filtered sample was put in the oven at 70 ^{0}C to remove moisture in the sample. After drying process sample was powdered by using a blender.

Spectroscopy analysis for clay modification.

Fourier Transform Infrared Spectroscopy use to identify chemical bonds in a molecule by producing an infrared absorption spectrum. KBr pellet method is used to verify the clay modification.

Determination of cure characteristics

Rheometer is used to analyze vulcanization characteristics of rubber such as M_I, M_L, M_H, ts_2, ts_5, t_{50} and t_{90}.

Preparation of Natural rubber nano composite

Natural rubber vulcanizates at different MMT, OMMT loadings were prepared using an electrically heated hydraulic press.

Determination of mechanical properties

Dumbbell and angle specimens were cut from vulcanized sheet to determine the tensile and tear properties. Hardness, abrasion and rebound resilience of rubber vulcanizates were determined using a dead load hardness tester, rotary drum abrasion tester and vertical rebound resilience tester respectively.

RESULT AND DISCUSSION

FTIR analysis

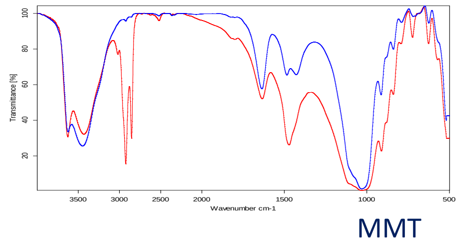

Figure 1 FTIR result analysis

Figure 1 shows three additional peaks at 2900, 2850 and 1450 cm^{-1}. The peaks at 2900 cm^{-1} and 2850 cm^{-1} are happened because of C-H asymmetric and symmetric stretching vibrations in CTAB. The peak at 1450 cm^{-1} is attributed to the bending vibration of CH_3 in CTAB. The appearance of these additional peaks conformed that the CTAB molecules were incorporated into the MMT structure and were not washed away during removal of bromide ions.

Cure characteristic

According to results, t_{90} values of MMT and OMMT filled sample were lower than control. Researches suggested that organoclay facilitates the formation of zinc-amine complexes with primary amine and sulfur and thereby accelerate the first stage of the curing process.)Jayaraj, 2018(Proteins in natural rubber are denatured in the presence of CTAB and hence soluble in natural rubber. Because of that curing rate increased. In addition, increase in MMT, OMMT load, increases rubber-soluble protein in NR. Therefore, t_{90} show a further decrease with nano clay loading.

Mechanical properties

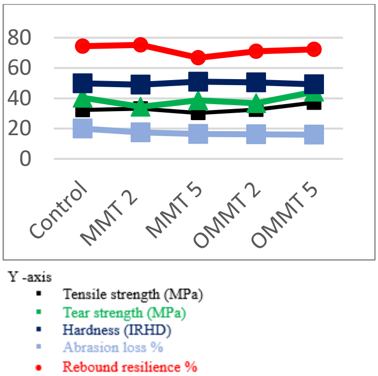

Figure 15 Mechanical properties variation with loading

Tensile/Tear strength

When the amount of MMT was increased from 2 phr to 5 phr, tensile strength decreased. This is due to the formation of aggregates in the vulcanization at higher loading and it cause to form weak points in the rubber matrix. Due to that, catastrophic failures initiate. However, when the OMMT loading are increased from 2 phr to 5 phr, tensile strength increased. This is due to the better intercalation of layers. Since, OMMT is developed by adding CTAB, it makes more voids between clay layers to facilitate rubber layers. For certain limit, adding OMMT can increase void. Hence, tensile strength can be increased. Also, finely dispersed clay layers cause to divert rubber layers in a zigzag path and increase tensile strength. Tear strength of the vulcanized sample was increased when 5 phr of MMT is incorporated into natural rubber than 2 phr of MMT. This is due to the higher dispersion of clay layers allow to create high amounts of voids and make it easier for rubber layers to enter between clay layers. OMMT is further developed than MMT. Hence 2 phr OMMT incorporated rubber shows greater tear strength than 2 phr incorporated MMT. Similarly, 5 phr OMMT shows higher strength than 5 phr MMT.

Hardness/Abrasion/Rebound resilience

Plasticity of rubber chains is reduced when more fillers are incorporated in rubber matrix by giving highly rigid composite. Hence, substantial hardness is increased when MMT loading is increased from 2 phr to 5 phr. Even though this is the general expected outcome, increasing OMMT load causes to reduce hardness. This may be caused due to an experimental error.

The abrasion percentages of all samples were less than controller sample and resistances were increased when the clay loading is increased. OMMT samples showed less abrasion percentage than MMT samples, because of intercalation of clay and rubber layers. This can be due to higher crosslink density of the former.

Increasing nano clay load causes to increase rebound resilience. This may be caused due to high reinforcement between filler and the elastomer. Since, OMMT clay having greater interlayer distance, it shows better rebound resilience.

CONCLUSION

In order to verify clay modification, FTIR test was conducted. Samples of prepared rubber compound were subjected to cure characteristic test. The t_{90} of each sample is found and it was between 5-14 minutes. According to the hardness test, it is found that, increasing nano clay cause to increase in hardness. It is assumed that plasticity of rubber matrix is reduced when more fillers are incorporated. In addition, increasing nano clay load causes to increase in rebound resilience. From the results of tensile test, it has found that adding MMT causes to reduce tensile strength. It is due to weak rubber matrix due to the formation of aggregates. However, adding OMMT causes to increase in tensile strength. This is due to the better intercalation of layers. Tear test results also indicate that the increasing nano clay load caused to increase tear strength. In the abrasion test, it is found that increasing nano clay causes to increase abrasion resistance.

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