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Study of Material Properties and Integrity of Natural and Artificial Rubber Composites

PG Dhanarajan¹, K Ramanathan², M V Navaneethkrishnan²

Assistant Professor, Department of Mechanical Engineering, Sriguru Institute of Technology, Coimbatore, Tamilnadu,
India¹

U.G. Student, Department of Mechanical Engineering, Sriguru Institute of Technology, Coimbatore, Tamilnadu, India²

ABSTRACT: The preparation and characterization of Rubber Ferrite Composition (RFC) containing calcium ferrite (CaFe) is being studied. The calcium ferrites are incorporated into the matrix of natural rubber and artificial rubber separately according to a special recipe for loading of fillers. The calcium ferrites are prepared by conventional synthesis techniques. Calcium ferrites are characterized by using X-Ray diffractometer. After characterization they are incorporated into the rubber matrix by mechanical method. Sulphur is also incorporated into the RFC to study its effects on various properties. The mechanical properties such as elongation, modulus, tensile strength, and hardness of the RFC are evaluated. The results are correlated.

KEYWORDS: rubber ferrite composition; rubber matrix; elongation; modulus; tensile strength; hardness

I. INTRODUCTION

Calcium ferrite have several unique properties like hardness, corrosion resistance, higher magnetization value and also its cost is very low. Magnetically ferrites are classified into two namely, soft ferrites and hard ferrites [1]. These ferrites are incorporated into the natural and artificial rubbers to obtain desired properties, thus forming rubber Ferrites Composites (RFC). RFC,s are used as electromagnetic wave absorbers in the VHF and UHF bands [2,3]. The incorporation of magnetic fillers in the matrix of rubber gives it magnetic properties and also changes its physical properties [4]. The addition of ferrite fillers in the rubber also gradually increases its dielectric constants [5]

II. RELATED WORK

The properties of rubber can be enhanced by incorporation of calcium ferrite and sulphur in the matrix of rubber. The steps involved are summarized as follows.

1. Calcium ferrite compounds were prepared by dissolving calcium ferrite and iron nitrate with a molar ratio of 1:1, 0.5:1 & 1:0.5 in a distilled water at concentration of 0.5 mol/L. Then the solution is evaporated dried at 80°C and final product is in powder form.
2. The obtained calcium ferrite powder was analyzed using x-ray powder diffraction (XRD) technique using x-ray diffractometer.
3. The powder is added to the rubber in a bowl and the compound is homogenized using a two mill roll under a condition which is explained in the experimental section.
4. The tensile properties are found using universal testing machine and hardness is found using type A durometer. The values are tabulated.

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III. EXPERIMENTAL

SYNTHESIS OF CALCIUM FERRITE:

Calcium ferrite compounds were prepared using calcium nitrate and iron nitrate with different molar ratios, 1:1, 0.5:1 & 1:0.5. the reaction mixtures were prepared by intimately mixing aqueous solutions obtained by dissolving calcium nitrate and iron nitrate in a distilled water at concentration of 0.5 mol/L. The solution was evaporated dried at 80°C in a hot plate apparatus. Then the final product was collected as in the form of powder.

STRUCTURAL EVALUATION:

The calcium ferrite powder prepared by the synthetic technique were analyzed by x-ray powder diffraction (XRD) technique using x-ray diffractometer .

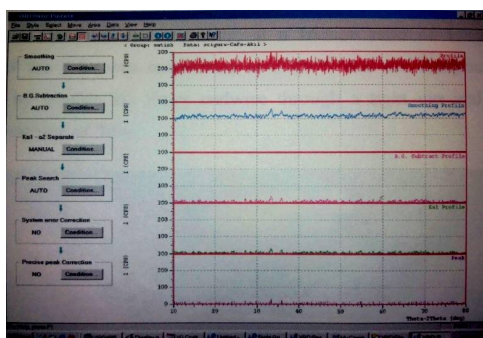


FIG 1 XRD Analysis diagram

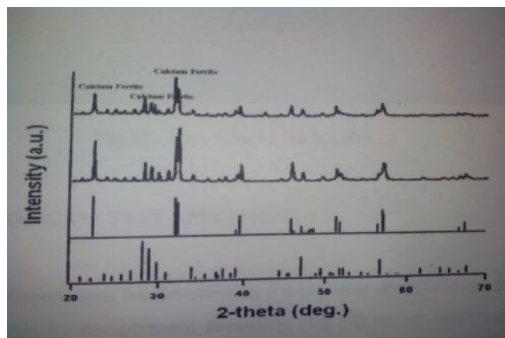


Fig 2 XRD spectrum of calcium ferrite

The XRD spectra of these ferrites is shown in figure 2. The evaluation of the structural parameters indicated that the compounds were monophasic without any detectable impurities and were crystalline in nature.

HOMOGENISATION OF THE RUBBER COMPOUNDS:

The mixing of rubber with the compounding ingredient was done in a bowl and the homogenisation of the compound was carried on a laboratory (15×33cm) two roll mill shown at a friction ratio of 1:1.25. The temperature of the rolls was maintained at 60±5°C and the compound was homogenized by passing six times endwise through a tight nip and finally sheeted out at nip gap of 3 mm.

MOULDING OF TEST SPECIMENS:

The test specimen for determining the physical properties are prepared in standard moulds by compression moulding on an electrically heated press having 45×45 cm plate at a pressure of 140 kg cm^{-2} on the mould. The rubber compounds are vulcanized up to their respective optimum cure time at 150°C. Mouldings are cooled quickly in water at the end of the curing cycle and stored in a cool and dark place for hours and are used for subsequent physical tests. For samples having thickness more than 6mm (abrasion resistance, compression set, etc.) additional curing time based on the sample thickness is given to obtain satisfactory mould.

PHYSICAL TEST METHODS:

Tensile properties of the vulcanite are determined as per ASTM 0 412 (1980) using dumb-bell specimens on an universal testing machine, model 4411 test specimen. All tests are carried out at 28±2°C. Dumbbell specimens for the tests are punched out from the compression moulded sheets along the mill grain direction using a standard die. The thickness of the narrow portion is measured by bench thickness gauge. The sample is held between the two grips on the

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UTM, the upper grip of which is fixed. The rate of separation of the power actuated lower grip is fixed at 500mm/min. The tensile strength, elongation at break and modulus at different elongations are recorded and evaluated after each measurement by the microprocessor.

HARDNESS:

Durometer hardness tester is used for measuring the relative hardness of soft materials. It is based on the penetration of specified indenter forced into the material under specified conditions. It consists of a pressure foot, an indenter and a dial gauge. The indenter is spring loaded and the point of the indenter protrudes through the opening in the base. There are several instruments used to measure the hardness of soft sponge up to ebonite type material. The most commonly used are durometers Type A. The hardness number derived from either scale are just numbers without any units. Type A durometer is used for measuring the hardness of relatively soft materials. The hardness measured using Type A durometer is expressed in a unit called 'shore A'. On shore a scale 0 would be soft and 100 hard S4-S8.

IV. RESULTS AND DISCUSSION

MECHANICAL PROPERTIES OF RUBBER FERRITE COMPOSITES

Rubber ferrite composites, as mentioned earlier are composite materials with ferrite fillers as one of the constituents and natural or synthetic rubber as the base matrix. In these composites both the magnetic filler and the polymer matrix chosen affect the processability and other physical properties of the final product. In tailoring composites for various applications it is necessary to select the proper filler and polymer matrix. The physical and chemical properties of the magnetic composites will possibly be influenced by the interactions with the filler and the matrix. It is important to study the processability of the polymers since the final vulcanized product is to be prepared by moulding.

The mechanical properties of these composites containing various loadings of the magnetic filler were investigated. The effect of sulphur on the mechanical properties of these RFC were also studied. The preparation of Rubber Ferrite Composites (RFC) and analysis of mechanical properties assume significance not only in tailor making compounds, but also in understanding various properties and the related mechanisms.

Mechanical properties of the RFCs were determined using a Universal Testing Machine, Model 4411 Test System. Dumbbell shaped samples were cut from the prepared RFCs containing CaFe, at loadings of 30g, 60g and 90g according to ASTM D 412 (1980). Parameters namely tensile strength, modulus at different percentage elongations and elongation at break, which are some of the most important indications of the strength of the material were determined. The effect of sulphur on the mechanical properties of these RFC were also studied using dumbbell specimens cut from the prepared RFCs containing the various loadings of sulphur.

CaFe (g)	TENSILE STRENGTH (PSI)	ELONGATION AT BREAK (%)	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
40	442	240	45	26.21
70	368	180	50	16.60
100	412	145	55	21.53

Table 1-Mechanical properties of nitrile rubber based RFCs containing calcium ferrite

The tensile properties and hardness of the RFC containing various loadings of CaFe in Nitrile Rubber (NBR) are shown in table 1.

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SULPHUR LOADING(g)	TENILE STRENGTH (PSI)	ELONGATION BREAK (%)	AT	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
2	442	240		45	26.21
4	552	292		47	27.77
6	458	231		52	26.70

Table 2-Mechanical properties of nitrile rubber based RFCs containing 40g of calcium ferrite and various loading of sulphur

The tensile properties and hardness of the RFC containing various loadings of sulphur in NBR are shown in table 2.

CALCIUM FERRITE LOADING (g)	SULPHUR LOADING(g)	TENILE STRENGTH (PSI)	ELONGATION AT BREAK (%)	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
40	2	442	240	55	26.21
70	4	368	180	50	16.60
100	6	412	145	45	21.53

Table 3- Mechanical properties of nitrile rubber based RFCs containing various composition of calcium ferrite and of sulphur

The tensile properties and hardness of the RFC containing various loadings of Cafe and sulphur in NBR are shown in table 3.

Table 4-Mechanical properties of natural rubber based RFCs containing calcium ferrite

CaFe (g)	TENILE STRENGTH (PSI)	ELONGATION AT BREAK (%)	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
30	990	807	15	12.16
60	325	441	30	15.45
90	249	96	45	9.26

The tensile properties and hardness of the RFC containing various loadings of Café in Natural Rubber (NR) are shown in table 4.

SULPHUR LOADING(g)	TENILE STRENGTH (PSI)	ELONGATION BREAK (%)	AT	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
2	990	807		15	12.16
4	495	573		25	10.14
6	1635	568		30	24.83

Table 5-Mechanical properties of natural rubber based RFCs containing 30g of calcium ferrite and various loading of sulphur

The tensile properties and hardness of the RFC containing various loadings of sulphur and 30g of calcium ferrite in NR are shown in table 5.

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CALCIUM FERRITE LOADING (g)	SULPHUR LOADING(g)	TENILE STRENGTH (PSI)	ELONGATION AT BREAK (%)	HARDNESS (SHORE A)	MODULUS (kg/cm ²)
30	2	990	807	15	12.16
60	4	325	441	30	15045
90	6	249	96	45	9.26

Table 6-Mechanical properties of natural rubber based RFCs containing calcium ferrite and various composition of sulphur.

The tensile properties and hardness of the RFC containing various loadings of Cafe and sulphur in NR are shown in table 6.

TENSILE STRENGTH

The values obtained by study of tensile value at various percentage of calcium ferrite and sulphur with natural rubber and nitrile rubber, it is found that the tensile value decrease to a particular level with the increase in the percentage of calcium ferrite and sulphur. Then the tensile strength of the composition is found to be increasing with the further increase in the percentage of calcium ferite and sulphur with the nitrile rubber. Thus by changing the composition percentage of ferrite and sulphur the tensile strength value of rubber products can be changed as per our requirement and type of products. The decrease in tensile value occurs till 60% of calcium ferrite and sulphur to 4 gms. Then after further increase in percentage of loading the tensile value increases. The suitable variation of percentage of calcium ferrite and sulphur can be done to obtain suitable value of tensile strength for natural rubber and nitrile rubber.

ELONGATION

By analyzing the elongation profile of natural rubber and nitrile rubber by varying the calcium ferrite percentage and varying the percentage of sulphur, it is found that rapid change in the elongation value is observed with the increase in percentage of sulphur and calcium ferrite. This reduction in elongation occurs due to the increase in the metal component and sulphur in the composition with rubber. The elongation value is observed to be reducing at a faster rate due to increase in the percentage of calcium ferrite and sulphur. The increased amount of the calcium ferrite and sulphur makes the rubber composite harder thus reducing the elongation. The elongation value is inversely proportional to the percentage of increase in sulphur and calcium ferrite.

MODULUS

With the variation in the percentage of ferrite loading and sulphur the modulus value is observed to be changing in some format for certain level and change in profile is obtained in the modulus value. The modulus value increases with increase in level of loading of cadium ferrite and sulphur to a level of 70% calcium ferrite and 4gm sulphur. With further increase in the percentage of calcium ferrite and sulphur the modulus value start decreasing. Upto a level of ferrite and sulphur loading the modulus value is directly proportional to the loading and later it is inversely proportional to further increase in the percentage of ferrite and sulphur loading with natural rubber and nitrile rubber. So based on the requirement of modulus value the loading of calcium ferrite and sulphur percentage with rubber can be decided.

HARDNESS

The profile followed by natural rubber and nitrile rubber with the increase in the percentage of calcium ferrite and sulphur is directly proportional to the hardness value. The profile shows that the hardness value increase with increase in the percentage of composition of calcium ferite and sulphur with the natural rubber and nitrile rubber. The hardness value is observed to be increasing at a rapid rate by the increase in the amount of calcium ferrite and sulphur in the

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composition with natural rubber and nitrile rubber. The change in hardness value happens due to the increase in the amount of metal and sulphur content in rubber. It is clear from the profile of graph that the increased amount of ferrite loading and sulphur has made the composition harder than normal rubber.

COMPARISON

Figure 3 shows the comparison of all properties of NBR based RFCs containing the various loadings of calcium ferrite.

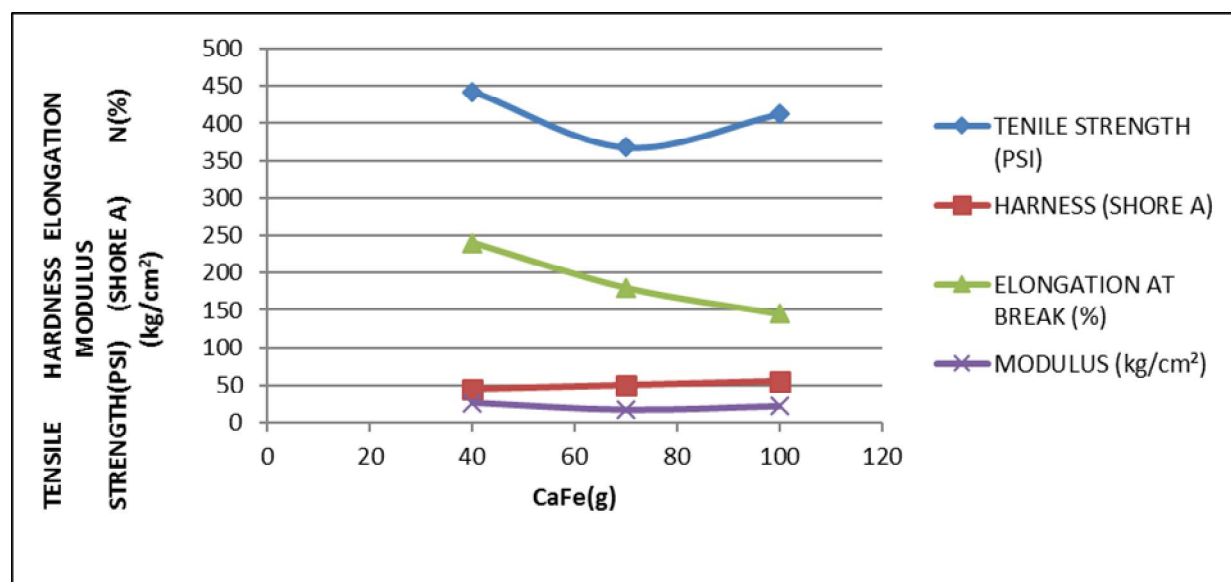


Fig.3-Comparison of all properties of NBR based RFCs containing the various loadings of calcium ferrite

With the variation of calcium ferrite in rubber the comparison of hardness, tensile strength, elongation and modulus it was found that the tensile value is high and has large variation with other properties. Only the values of hardness and modulus come closer and seem to maintain the same profile of change. The tensile value is getting reduced and then slowly increases with the increase in the percentage of calcium ferrite loading. The elongation gets decreased with addition of calcium ferrite

Figure 4 below shows the comparison of all properties of NBR based RFCs containing the various loadings of sulphur.

By the change of sulphur percentage the tensile, hardness, elongation and modulus value changes and follows a different profile compared to that with calcium ferrite change by keeping sulphur constant. The tensile and elongation seems to follow the same profile with increase in value by increase in sulphur content and decrease after a limit. The hardness and modulus value follow same profile and has a same change of value when observed. Thus variation of sulphur and calcium ferrite makes considerable change of properties.

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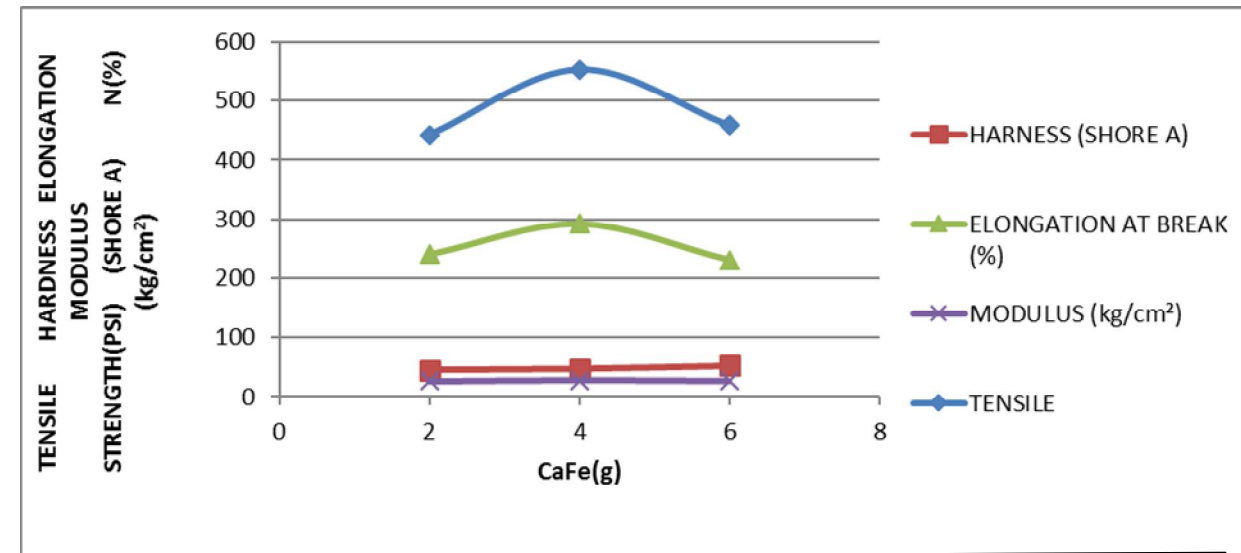


Fig.4-Comparison of all properties of NBR based RFCs containing the various loadings of sulphur

Figure 5 & 6 shows the comparison of all properties of NR based RFCs containing the various loadings of calcium ferrite and its effect on the addition of sulphur.

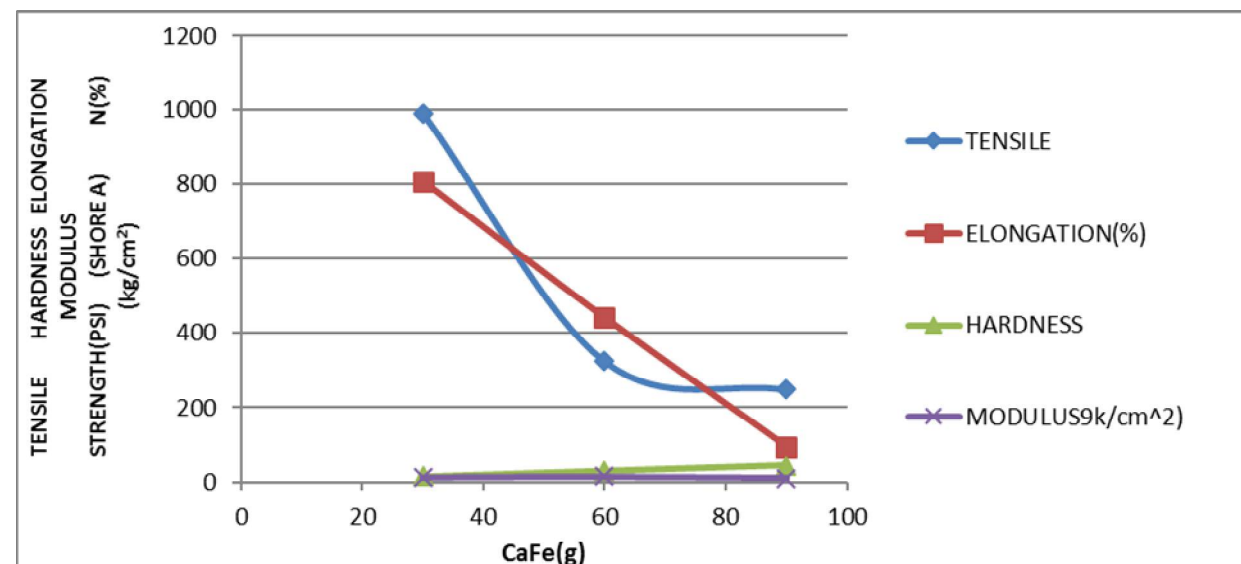


Fig.5-Comparison of all properties of NR based RFCs containing the various loadings of calcium ferrite

With the variation of the calcium ferrite percentage, the tensile strength and elongation value seems to be crossing each other at two points. The tensile value decrease and then remains stable. The elongation gets reduced to low value by the addition of ferrite. The modulus and hardness value seems to be interlinked and follows same profile of change. Rapid reduction in the elongation was observed.

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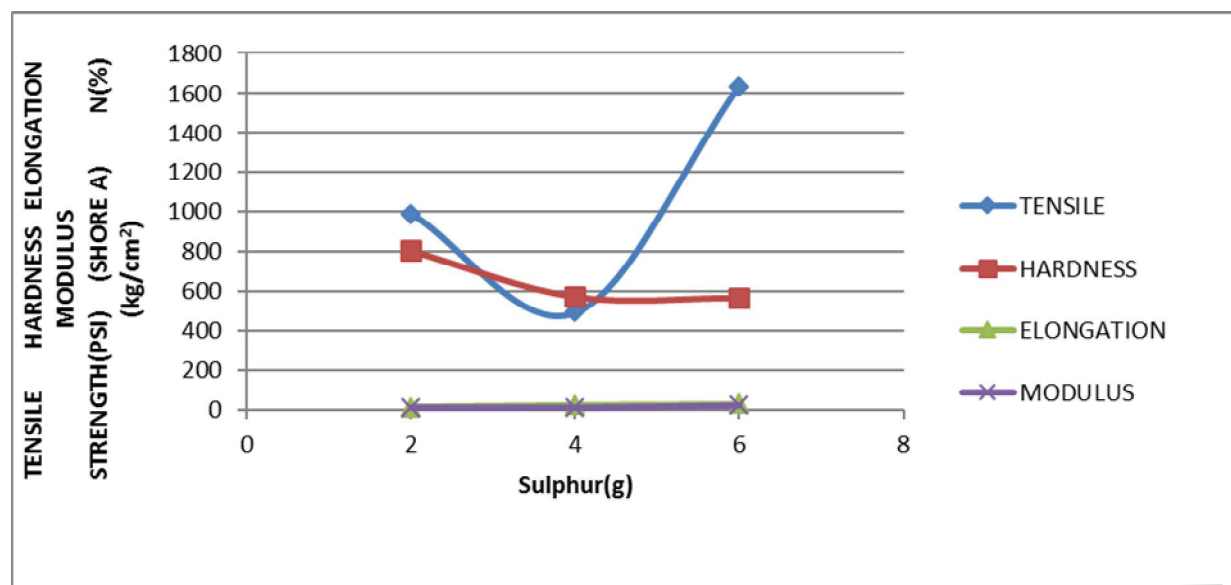


Fig.6-Comparison of all properties of NR based RFCs containing the various loadings of sulphur

The combination graph of the test result with change in sulphur content in rubber is done to analysis the properties. It is found that the tensile value decrease and then increase with further increase of sulphur loading. The gradual change of elongation is adsorbed. The modulus and hardness change follows the same profile and gets interlinked with each other. It is absorbed that with considerable change of the sulphur and calcium ferrite the mechanical properties of the composites are absorbed to be changing as per the requirements.

V. CONCLUSION

The mechanical properties of the natural and nitrile rubber ferrite composites can be enhanced by the incorporation of appropriate amount of ferrite filler and sulphur in the rubber matrix. The evaluation of mechanical properties revealed that the processability and flexibility of the matrix was not much affected even up to a high loading of ferrite fillers.

The profiles followed by natural and nitrile rubber with the increase in the percentage of calcium ferrite and sulphur have several enhancement of properties in the nitrile rubber matrix. So the metal rubber gives more advanced properties of rubber as well as metal.

REFERENCES

- [1] Khaled H. Mahmoud, Mahmoud H. Mekled, "Infrared Spectroscopy and Thermal Stability Study of natural Rubber-Barium Ferrite Composites," Journal of Chemical Engineering and science vol.2,2012,pp.350-358.y
- [2] M R Anantharaman, K A Malini, S Sindhu, E M mohammed, S K Date, S D Kulkarni, P A Joy, Philip Kurian, "tailoring magnetic and dielectric properties of rubber ferrite composites containing mixed ferrites". Journal of material science, vol. 24, NO.6, 2001,pp. 623-631.
- [3] G R Hamed and J haung, "Rubber chemistry technology" .,64,255,1991
- [4] Anantharaman M.R, S. Sindhu, S. Jegathesan, K.A Malini and Philip kurian, journal of physics D applied physics 32 (1999) 1801-1810
- [5] Praveen singh & T.E.Goel:Indian J. Pure and Appl Phys.,38(2000)213-219.
- [6] Anantharaman M.R,P.kurain, B.Banerjee, E.m.Mahammed, and M.George, Kautschuk Gununi kunststoffe, (Germany), 49,6/96,424-426.
- [7] jozefSlama, Anna Gruskova, L'udovit Keszegh, Mojmir Kollar: IEEE Trans. Mag.,3d,2(1994)1101-1103
- [8] K.A. Malini, E.M. Mohammed, S. Sindhu, P.A. joy, S.K. Date, S.D. Kulkani, P. Kurian and M.R. Anantharam, J. Mater. Sci.36(2001),5551-5557.
- [9] Anantharaman. M.R, K.A]. Malini, S.Sindhu, E.M.Mohammed, S.K. Date, P.A. Joy and Philip kurian, Bull. Matter. Sci.,24,6,(2001),623-631



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(An ISO 3297: 2007 Certified Organization)

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- [10] Anantharaman M.R, S. jagatheesan, S. Sindhu, K.A. Malini, C.N. chinnasamy, A. narayansamy, P.Kurian and K. Vasudevan, Plastic rubber and Composites processing Application, 27, 2, (1998) 77-81.
- [11] Anantharaman M.R, S. Sindhu, S. Jagatheesan , K.A.Malini and Philip kurain, Journal of Physics D Applied Physics 32(1999),1801-1810.
- [12] Mohammed E.M et al, Material Research bulletin 37(2002),753-768.
- [13] Katz h. Sand J. V. milewski, 'Handbook of Reinforcement of Plastics',1978, vannastrand Reinhold, New York. 6. Praveen singh & T.E. Goel: Indian J. Jre and Appl Phys., 38 92000)213-219.
- [14] Anantharaman M. R, K.A. Malini, S. Sindhu, E.M. Mohammed, andM. George, Kautschuk Gummi Kunststoffe, (Germany),49,6/96,424-426