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Assessment of NR/EPDM Blend Ratio using Graphical Method

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Abstract*: In this proposed work, Natural Rubber (NR) and Ethylene Propylene Diene Monomer (EPDM) are blended using Graphical method in 50:50 ratio. The blends are characterized by electrical characteristics like surface resistivity, arc resistance and mechanical properties such as comparative tracking index, elongation at break and tensile strength as per standard ASTM and IEC. Graphical method type of blending overcomes the drawback of Optimal Blend Ratio (OBR) which gives an approximate solution. The composite blended gives good electrical, mechanical characteristics with good weathering resistance.

***Keywords* : Polymeric insulator; Blend composition; Ethylene Propylene Diene Monomer; Natural Rubber.**

I. INTRODUCTION

Polymeric materials have outstanding chemical, physical, mechanical and electrical properties compared with ceramic and glass insulator, hence used in medium/high voltage cable insulation and jacket materials. The electrical and mechanical characteristics of NR and EPDM can be improved by blending two materials in proper ratio [1-4]. EPDM exhibits a saturated polymer back bone structure which results in stable, heat resistance, oxidation resistance, weather ageing, high tensile strength and oil swell resistance properties. Infrared (IR) spectral analysis reveals bonding capability of blends [5].

The effect of NR/EPDM blend ratio to improvise electrical and mechanical characteristics is investigated using conventional methods and graphical method. The conventional method gives only approximate solution so there is need for optimization technique. The identification of suitable blend ratio depends upon the applications, such as high tensile strength, high dielectric strength and arc resistance.

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In practical situations it is difficult to identify the suitable blend ratio for specific application. Optimal blend must provide good mechanical and electrical characteristics. The electrical and mechanical characteristics are tested using suitable experiments and plotted using graphical method for cable applications [6]. Several computational techniques like Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Improved PSO (IPSO) are used to solve the complex engineering problems. In our future work PSO is used to identify the suitable blend ratio for cable applications [7,8]. PSO has population based evolutionary algorithm with simple concepts, high computation efficiency and easy to implement compared to other algorithm. PSO is initialized with population of random variable. It is associated with random velocity and potential solution called particles. Particles are flown through problem space. In PSO any weightage is assigned randomly to any particular parameter such as electrical/mechanical or both. PSO is implemented for two different sets. One set has equal weightage of key parameters i.e. one electrical & one mechanical and another set consists of unequal weightage of key parameters [9, 10]

II. SYNTHESIS OF NR/EPDM BLEND

NR and EPDM material were purchased from M/S Joy Rubbers, India. NR is of RNA type. EPDM is in the ratio of 52:48 of ethylene: propylene. Blending is the technology of converting the raw rubber resin into useful materials through the addition of various ingredients [11]. The preparation of NR/EPDM blends were carried out in two roll mixing mill dispersion kneader machine with chamber temperature at 35°C. Conventional mixing procedures are used for preparation of these blend materials. At initial condition NR is masticate for 3 minutes followed by moulding in electrically headed plate machine for 5 minutes. The compounds are moulded by compression at 70°C using hydraulic hot press machine. Sheet specimens are made by zeon blend compositions hot press machine as listed in Table-I.

Table- I: Sheet Specimens blended compositions

MATERIALS (phr)	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5
NR (%)	100	70	50	30	0
EPDM (%)	0	30	50	70	100
Dicumyl per oxide	2.5	2.5	2.5	2.5	2.5
ZnO	5	5	5	5	5
Stearic acid	2	2	2	2	2
MBT	0.5	0.5	0.5	0.5	0.5
TMTD	1.5	1.5	1.5	1.5	1.5
Sulphur	1.75	1.75	1.75	1.75	1.75

The commercial graded chemicals like Stearic acid, Zincoxide (ZnO), Sulphur, Mecapto Benzo Tiazole (MBT), Tetra Methyl Thiuram Disulphide (TMTD) were used as additives to increase vulcanization rate by activating the accelerators. The weightage of additives are expressed in parts per hundred (phr) of rubber shown in Table-I.

III. EXPERIMENTATION AND CHARACTERIZATION OF NR/EPDM

The test conditions and procedures for the electrical and mechanical characteristics of the polymers used are explained below.

A. Tensile Strength and Elongation at Break (EB)

The tensile strength and Elongation at break are determined as per standard ASTM D412. Tensile strength is obtained from the cross head movement at constant rate using universal testing machine. EPDM elastomer possesses good mechanical strength and outstanding resistance to attack by oxygen, ozone and weather [12].

B. Arc Resistance

Arc resistance is measured in seconds as per standard ASTM D495. A voltage of 12.5 kV is applied to the sample, whose size is 5 x 5 x 0.3cm. Voltage is increased gradually in steps until the arc occurs between the electrodes. The carbon path developed on the surface of the material leads to conduction.

C. Surface and Volume Resistivity

The surface and volume resistivity of the samples are measured as per standards IEC 60093 and ASTM D257 respectively using Million Mega Ohm meter MM-108D by prestige electronics. The thickness and diameter of the specimen are 3mm and 100 mm respectively. A DC supply of 500V is applied for 60 seconds at room temperature between main and guarded electrode to determine surface and volume resistivity.

D. Comparative Tracking Index (CTI)

CTI is measured as per standards IEC 60112 by CEAST meter. A 500V is applied to the test specimen of 3mm thickness. Ammonium chloride is used as electrolyte. The solution of ammonium chloride drops are made to fall between the electrodes at 30seconds interval. The voltage corresponding to 50 drops is noted and the corresponding numerical value of voltage is called as comparative tracking index (CTI). The voltage is applied in the range of 150-600V to the samples.

E. Dielectric Strength

Dielectric strength of sample is measured as per the standards IEC 60243-1 and ASTM D149. A sample of diameter 100mm and thickness 1mm is placed between the electrodes and the voltage applied is gradually increased at constant rate of 2kV/s till dielectric breakdown occurs. The voltage at which breakdown occurs is noted as dielectric breakdown voltage. Dielectric breakdown strength is calculated from the ratio of dielectric breakdown voltage to the thickness of the specimen.

IV. RESULTS AND DISCUSSION

The electrical & mechanical parameters of the blend are measured as per given standards and comparison was done to obtain the suitable blend ratio. The characterization is done thorough Graphical method. As one of high voltage insulation applications, EPDM applied to a polymer housing arrestor, cables, insulating sleeving and tapes, potting and encapsulating purposes[13-17].

In graphical method point of intersection gives approximate blend ratio for the specific application. Disadvantage of graphical method is identification of exact optimal blend from the various blend ratios. Optimal blend ratio is predicted by varying the number of parameters [17-20].

A. Results and Discussion on Dielectric Strength

The dielectric strength of different blend ratios are compared with tensile strength of different blend ratios and the comparison shows the impact of natural rubber in the blends. The Fig.1 shows the proportion of natural rubber is increased then the dielectric strength is also increased in the blends. The % decrease in dielectric strength is given as 50% of EPDM = (39.1-29.3) /39.1 × 100 % = 25.06. The % increase in tensile strength is given as 50% of EPDM = (4.58-2.25) /2.25 × 100 % = 103.5.

From the Fig.1, 50:50 blend ratio of NR/ EPDM is the best composition for the specific application and it is obtained by intersection between the curves. For above equations 50:50 blend ratio is reduced by 25% and tensile strength is improved by 103%. In Fig.2 the relationship between dielectric strength and percentage elongation at break are plotted. If the content of EPDM increases then the dielectric strength decreases, with increase in % EB.

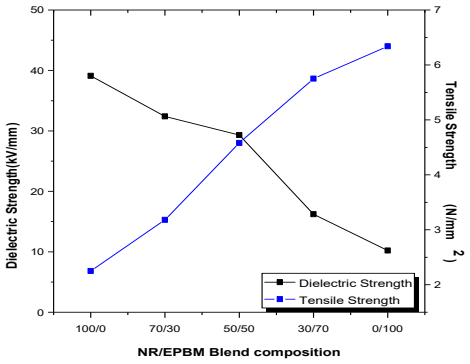

Fig. 1.Effect of Blend Composition on Dielectric Strenght and Tensile Strength.

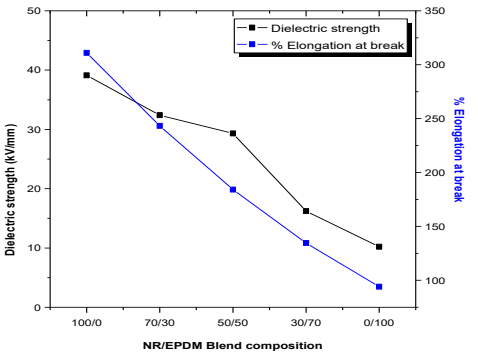

Fig. 2.Effect of Blend Composition on Dielectric Strenght and % EB.

B. Results and Discussion on Arc Resistance

In Fig.3 the effect of blend composition on arc resistance and tensile strength is shown. EPDM is hydro carbon in nature, it increases the resistance towards electric arc when EPDM content is low [4]. The % decrease in arc resistance is given as 50% of EPDM = (612-375) /612 × 100 % = 38.7. From the above calculations, arc resistance for 50:50 blend of NR/EPDM is decreased by 39% and tensile strength is increased by 103%. The intersection point gives better dielectric strength and tensile strength.

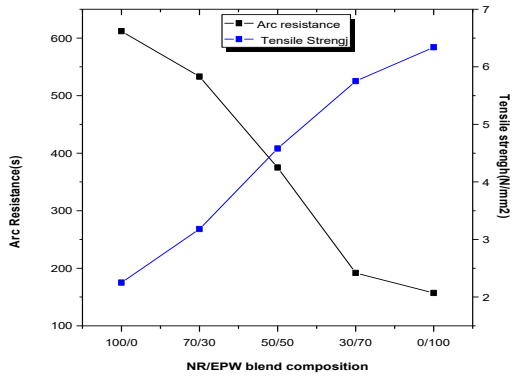

Fig. 3.Effect of Blend Composition on Arc Resistance and Tensile Strength.

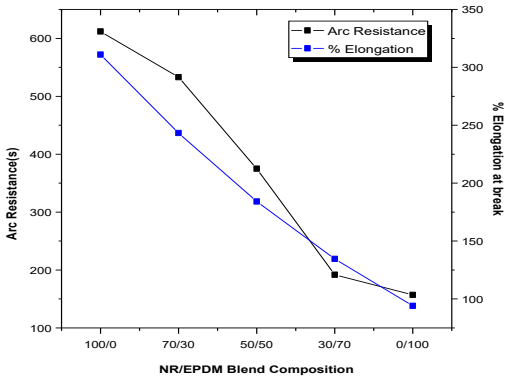

Fig. 4.Effect of Blend Composition on Arc Resistance and %EB.

The Fig.4 shows the effect of blend composition on arc resistance and % EB. The increasing EPDM content decreases the % EB and increases the arc resistance.

C. Results and Discussion on Volume and Surface Resistivity

The Fig.5 and Fig.6 show the effect of blend composition on volume and surface resistivity with respect to tensile strength. If NR content is increased, it increases the volume and surface resistivity of the material. It is obtain clearly above 70 weight percentage of NR in the blend. Tensile strength is decreased when the NR content is increased in the blend. 50:50 blend ratio of NR &EPDM gives higher volume and surface resistivity.

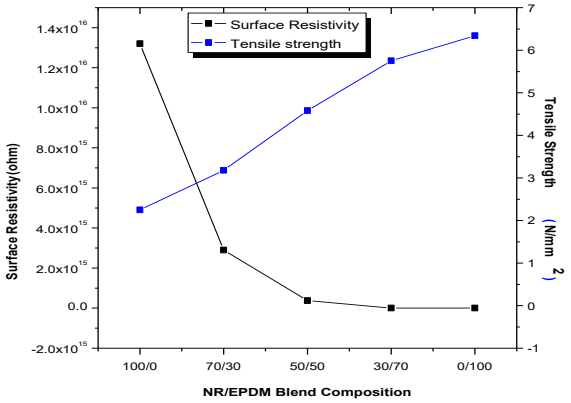

Fig. 5.Effect of Blend Composition on Surface Resistivity and Tensile Strength.

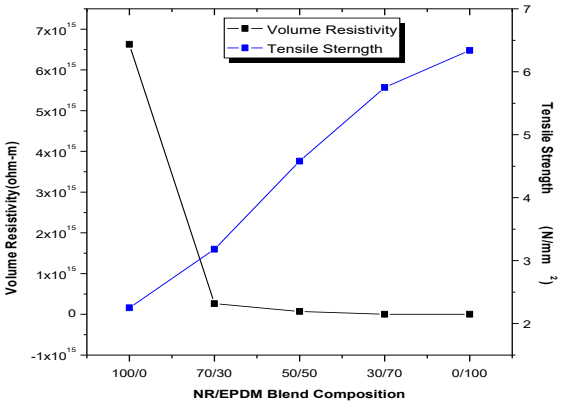

Fig. 6.Effect of Blend Composition on Volume Resistivity and Tensile Strength.

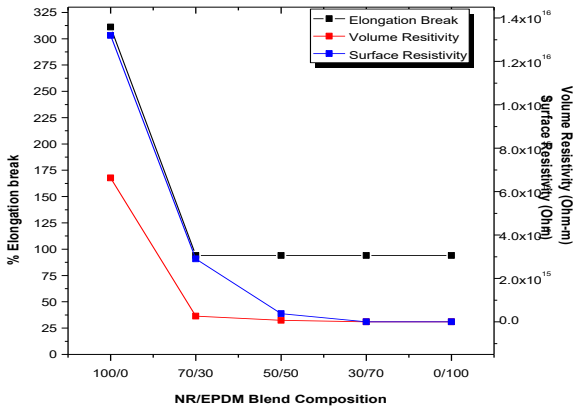

Fig. 7.Effect of Blend Composition on Volume Resistivity and Tensile Strength.

From the Fig.7, the decreasing content of EPDM decreases % EB. The surface &volume increases with decreasing of EPDM content.

D. Results and Discussion on Comparative Tracking Index

From Fig.8, tensile strength increases with increasing EPDM content. The values of CTI are obtained from the figure 8.

If the CTI increases due to increasing proportion of NR. The intersection point gives optimal blend. The % decrease in CTI is given by 50% of EPDM = (551-490) /551 × 100 % = 10. From the above calculation, the CTI for 50:50 NR and EPDM blends is reduced by 10% and the tensile strength of the blend is improved by 103%.

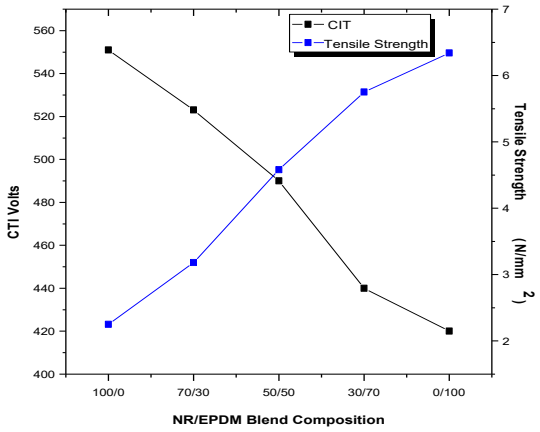

Fig. 8.Effect of Blend Composition on Comparative Tracking Index and Tensile Strength.

V. CONCLUSION

The mechanical properties are increased by increasing EPDM content. NR/EPDM composition gives better mechanical strength and has less effect on electrical properties. The electrical properties are increased by increasing NR content in the blend composition. Adding of EPDM to NR increases the mechanical properties by 103 %. The 50:50 blend ratios of NR and EPDM gives better electrical and mechanical characteristics using graphical methods. The intersection point gives approximate optimal solution. The changes in insulation characteristics of 50:50 blend ratio of NR/ EPDM by taking reference from 100% NR

- The tensile strength is increased by 103.5%.
- The dielectric strength is reduced by 25%
- The arc resistance is reduced by 39%.
- The comparative tracking index is reduced by 10%.

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