Dielectric Property of Waste Tire Dust-Polypropylene (WTD-PP) Composite For High Voltage Outdoor Insulation Application

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Abstract— **High voltage insulation technology is still undergoing continuous development and improvement from time to time, from conventional ceramic type since to newly polymeric composite insulation material. This includes the development of new composite materials. This paper focused on the possibility of using Waste Tire Dust-Polypropelene (WTD-PP) composite with Alumina Trihydrate (ATH) as the main reinforcement filler for high voltage insulation material. Compound of WTD-PP without and with ATH were prepared with different compositions of WTD-PP content and different amount of ATH filler. A step of processes to produce this newly polymeric composite is presented in this paper. The basic requirement to determine and evaluate the performance of the selected materials as high voltage outdoor application shall comply to the international standard, BS EN 62039:2007. This standard lists several requirements of electrical and mechanical properties that must be fulfilled for materials to be used for high voltage outdoor application. Experimental work has been conducted on the dielectric strength of WTD-PP composite. Breakdown test complying with BS EN 60243-1:1998 is adopted to examine the breakdown strength of this newly polymeric composite. It was found that the breakdown strength of these composites is less than 10kV/mm due to it carbon black content but can be used for lower voltage insulation application.**

Keywords- Waste Tire Dust, Insulation, Dielectric strength, Polypropylene, Alumina Trihydrate

I. INTRODUCTION

Insulation plays an important role in determining the performance and lifetime of high voltage equipment. The dielectric strength and electrical field being stressed on the insulating material are the major factors that lead to failure of the insulation[1]. Insulation technology has shown tremendous and continuous development and improvement from time to time, from the used of conventional ceramic type since the early 1900s to the recent development of newly breed of insulation using polymeric composite materials[2]. It is being widely accepted by many power utilities worldwide, including Malaysia. It was reported[2] that there are many advantages of polymeric composite material over conventional ceramic material. Meanwhile, a detailed comparison between ceramic and polymer electrical insulation includes; their advantages, disadvantages and flashover mechanism were explained in[3]. A good insulation system will give better design, performance and life span of the electrical apparatus.

The application of polymer composites has increased greatly because it is a relatively easy way to obtain new materials with balanced properties. Since polymeric composite insulation is accepted, a large number of studies and research activities for improvement on their performance had been made. These include the development of new materials, the understanding of deterioration of chemical, electrical and mechanical over the stress, design and manufacturing process of material, and also development of practical testing, monitoring, reliability methods of measuring and service performance.

At present, the most commonlly used polymeric material for high voltage applications are silicone rubber (SIR), ethylene propylene monomer (EPM), ethylene propylene diene monomer (EPDM), ethylene vinyl acetate (EVA) and composite of SIR and EPDM or EPM [4,5]. Although it has been used widely, some factors such as ageing performance, expected lifetime and their long-term reliability are still not known and has become a concern to the users. Problems of erosion and surface tracking are also being observed in the presence of severe contamination and sustained moisture [6]. The Handbook of Electrical and Electronics Insulating Material [3] has summarized the requirements and categories covered such as electrical and electronic insulating materials and classification of electrical key properties for insulating material. It also comprises of definitions, steps of materials selection, classifications, requirements, test methods, recommended practices of electrical insulating materials and also type of reinforcement or filler to enhance the performance of polymeric or its composite material. Based on these informations, this experimental study was carried out. The aim of this study is to determine the possibility of using Waste Tire Dust (WTD) and Polyproplene (PP) for high voltage insulation material application such as for cable termination, outdoor insulator and bushing.

Disposition of scrap tyres has become one of the major problems all over the world, especially in advanced and developed countries. Data from the Malaysian Industrial Developement Authority (MIDA) shows that an average of 150,000 tons of waste tyre are disposed in Malaysia every year [17].The investigation of tensile properties, swelling resistance, morphology and thermal properties of WTD-PP compounding were reported [9]. Several research activities, in application of waste tyre in the form of WTD with other thermoplastic polymer material such as EVA and natural latex are mentioned [10]. Meanwhile, the performance of waste tyre compounding as construction materials were also reported [11].

This study focusses on the possibility of using waste rubber from scrap tyre with thermoplastic or polymeric material as high voltage outdoor insulation. It is attempted to discover a new valuable composite from a waste material with a concept of green technology that being beneficial to our environment, health and economy. It also involves the effect of different level of Alumina Trihydrate (ATH) as reinforcement filler. PP is selected as matrix material due to their low cost, processability, good balance of properties and wide range of applications [8]. It also has excellent electrical, chemical and mechanical properties such as dielectric strength, dielectric constant, tensile strength, good chemical resistance and water absorption performance[7]. Meanwhile, waste tyre has superior elasticity properties, good weathering resistance and their ability to withstand hot and cold environment condition. The ATH is used as reinforcement and filler to improve flammability performance of the compounding. Selection Guide for Polymeric Material for Outdoor Use Under HV Stress - BS EN 62039:2007 [12] stated the minimum requirement that needs to be complied. The standard also lists several references and standards which relates to electrical and mechanical properties requirement that has to be fulfilled for this type of materials. For dielectric strength of WTD-PP compounds, it is examined according to BS EN 60243-1[13].

II. MATERIALS

Polypropylene is a highly versatile resin that is suitable for processing in molding or extruded compound. There are a wide range of types that can be obtained depending on their grade such as homopolymer, copolymer or terpolymers. In this study, homopolymer grade 211 is selected due to its excellent dielectric properties. A synthetic rubber is produced by a chemical process called polymerization that is similar to the way plastic are processed. The synthetic rubber that is normally used for tyre manufacturer is styrene-butadiene rubber and butadiene rubber, which are classified as Buna family. Other raw material in tyres that are vulcanized into one compound with synthetic rubber is natural latex, carbon black, nylon or polyester cord, resins, oil and sulphur. WTD is a recycled product from the mechanically process of scrap tyres.

Alumina Trihydrate (ATH) is used as fillers and it is also known by several names such as Hydrated Alumina, Aluminum Trihydrate, and Aluminum (III) Hydroxide. At present, ATH is commonly used in polymeric material for outdoor application. With the proper size and amount of ATH, it will improve flammability properties of the polymeric compounding in-terms of their tracking and erosion resistance as well as ageing performance. From the previous studies, it has been shown the ATH filled above the optimum level will affect the hydrophobicity of the insulating material [14]. With reference to [15], typically industries use 50-150 in part per hundred (pph)of formula by weight of ATH in compound or equivalent to 40-60% of the compound total weight. The description of materials used is shown in Table 1.

TABLE I. DESCRIPTION OF MATERIAL USED

Material	Description	Manufacturer
Waste Tire Dust WTD	Styrene butadiene rubber SBR and Butadiene rubber BR. Size: 420-841μ	Sin Rubtech (M) Sdn Bhd.
Polypropylene	Homopolymer Grade 112 Melt point: 180-250°C	Polypropylene Malaysia Sdn Bhd.
Alumina Trihydrate ATH	Chemical: $Al(OH)_3$ Size: 14.5μ	Hamburg, Chemicals Germany.

III. SAMPLE PREPARATION

The WTD-PP compounds were prepared based on formulas of 0/100, 20/80, 40/60, 60/40 and 80/20 wt% with the amount of ATH filler 0, 50,100 and 150pph. This material was weighed accordingly based on their formulation as shown in Table 2. There are 16 different types of composition that were carried out. In order to achieve a maximum effectiveness and the compound is uniformly dispersed throughout the formulation, it is prepared by melt mixing in the internal mixer, Haake Rheomix Polydrive R600/610 at roller rotor speed of 50 rpm and temperature is set at 180°C. For each composition, the optimum amount of compounding is approximately about 50 grams per run.

TABLE II. COMPOUNDING WEIGHT IN GRAMS

WTD-PP (wt%)	ATH (pph)	WTD (g)*	PP (g)*	ATH (g)*
20/80	0	10	40	0
20/80	50	6.7	26.7	16.7
20/80	100	5	20	25
20/80	150	4	16	30
40/60	0	20	30	0
40/60	50	13.3	20	16.7
40/60	100	10	15	25
40/60	150	8	12	30
60/40	0	30	20	0
60/40	50	20	13.3	16.7
60/40	100	15	10	25
60/40	150	12	8	30
20/80	0	40	10	0
20/80	50	26.7	6.7	16.7
20/80	100	20	5	25
20/80	150	16	4	30

*Weight per 50g compounding

The mixing process of the compounds is divided into two parts; WTD-PP formulated without and with ATH filler. For the WTD-PP compound without the ATH filler, the mixing processes were carried out continuously for up to 8 minutes. For the WTD-PP compound with ATH filler, the WTD-PP was melted in the mixer about 3 minutes prior to addition of ATH, and the processing is considered finish after a total time of 8 minutes. The data were monitored and recorded, to confirm that the mixing process is in optimum condition.

Figure 1 show, an example of the mixing process characteristic. It is clear shown in the graph; the compound is well mixed after 4 minutes of mixing process due to deformation of stable plateau region.

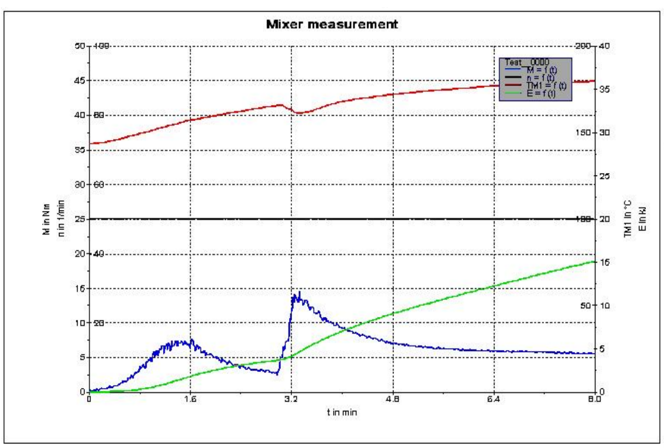

Figure 1: Compounding characteristic of $WTD_{40}/PP_{60}/ATH_{100}$

In order to get the optimum results, the compounds were made in granulate form using a crusher machine prior to compression by a hot press machine. The compounds were then compressed using Gotech-GT 7014 hot press machine with initial setting of 5 minutes preheating time, 6 minutes compression period with a pressure of $70kg/cm^3$ and temperature of 220°C. The machine then produces flat sheet specimens with 3mm thickness. Lastly, the compound sheet is immediately cooled between two plates with internal water flow for 12 minutes.

IV. DIELECTRIC STRENGTH TEST

BS EN 62039: 2007 [4] has defined the basic requirement and related information to determine and evaluate the performance of materials as high voltage outdoor insulation application. This standard mentioned the minimum value of electrical or breakdown strength for the polymeric specimen. By using a 3mm sample specimen, the breakdown field strength should be greater than 10kV/mm, and the preferred test method is BS EN 60243-1 [5]. The test was conducted with short time rapid rise 2000V/s and unequal diameter electrodes -25mm/75mm Ø with stainless steel 304. No of specimen that was conducted are 3 samples per compounding. Figure 2 and 3 show the testing arrangement for determination of the breakdown strength and the sample specimen as per standard BS EN 60243-1.

Figure 2: Electrode set-up complying with BS EN 60243-1

Figure 3: Specimen for dielectric testing

V. RESULTS AND ANALYSIS

The performance of WTD-PP compounds formulation on their dielectric strength property is shown in Figure 4(a)-(d) and was summarized in Table 3. The figures show that, the dielectric strength of WTD-PP and ATH filler formulation of all compounds is less than the minimum requirement at 10kV/mm. From the figures, the maximum value of dielectric strength is at 7.06kV/mm-($WTD_{20}/PP_{80}/ATH_{100}$). PP and rubber have excellent dielectric strength and electrical properties (> 15kV/mm respectively).But, due to the present of carbon black between 30-37% in WTD as anti abrasive [16] it will influence the dielectric strength performance of these compounds. The behavior of carbon black is classified as having good conductivity ($3x10^4$ S/m) with high electron mobility, and this decreases volume resistivity as well as reduce dielectric stress of these compounds can withstand. On the other hand, the conductive performance of carbon black is intrinsically a function of the quality of its dispersion. Dispersion is influenced by the compounding process; with further increase of WTD in the compound wt% it will increase in-homogeneity and hence reduces the dielectric strength property. In [8] reports, in-homogeneous and size of WTD can be associated to lack with of particle with particle interactions which contribute to a weak resistance to mechanical stress. A similar thing could be happening to electrical field stress.

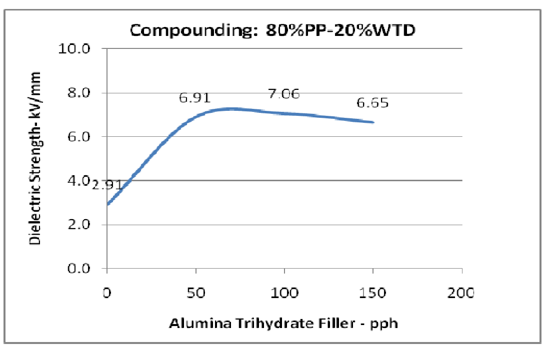

Figure: 4(a)

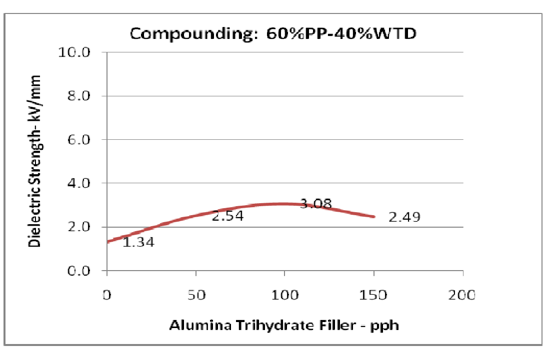

Figure: 4(b)

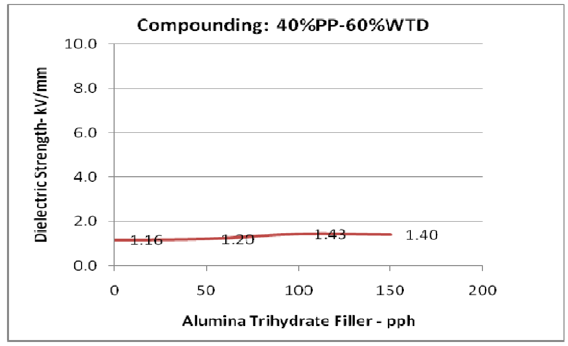

Figure: 4(c)

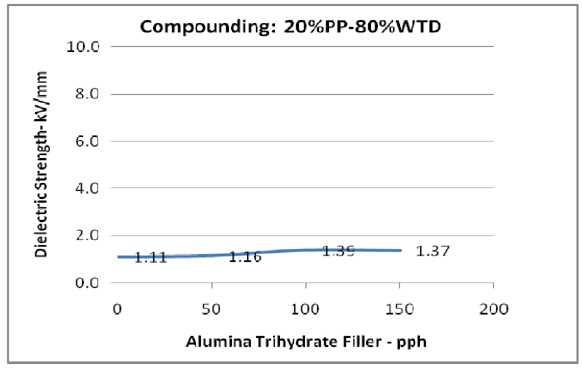

Figure: 4(d)

Figure 4: Dielectric strength properties of WTD-PP compound with ATH filler

TABLE III. DIELECTRIC STRENGTH OF COMPOUND IN KV/MM

Compound of WTD and PP	Alumina Trihydrate Filler			
	0pph	**50pph**	**100pph**	**150pph**
80wtd-20pp	2.91	6.91	7.06	6.65
60wtd-40pp	1.34	2.54	3.08	2.49
40wtd-60pp	1.16	1.20	1.43	1.40
20wtd-80pp	1.11	1.16	1.39	1.37

The figures also show the significance of ATH filler as anti flammable agent into dielectric strength property of the compounds. Comparing to Figure 4(a) and 4(b) - (d), it clearly shows that with ATH filler dielectric strength of compounds have great improvement. The bonding between ATH filler particles and PP base polymer chain, resulting in high resistance to electrical tracking and flammability could be responsible for the increase in breakdown strength. But for WTD-high ratio formulation shown in Figure 4(b)-(d), the dominance of carbon black and the lack of interaction between the particles into the compounds due to in-homogeneity will reduce the effect of ATH filler. Also obviously, ATH at 100pph ratio provided a greater improvement of dielectric strength. This is similar to the finding that was reported in [14].

VI. CONCLUSION

This study was carried out to investigate the dielectric strength of WTD-PP compounding with ATH as reinforcement filler. The observations have been made from this study are; 1) the formulations ratio of WTD-PP and ATH filler compound is not suitable to get the optimum dielectric strength as well as good insulator for high voltage application, 2) the significant effect and improvement of ATH filler level into the compounds at high and lower ratio of PP polymer chain. ATH filler only affects the dielectric performance of the compounds at a high ratio of PP.

VII. ACKNOWLEDGEMENT

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