Partial Discharge and Mechanical Characteristics of NR-LLDPE-Ti0$_2$-Coconut Coir Fibre

Aulia [1.2], Hadi Nur[3], Zulkurnain Abdul Malek[1], Yanuar Z. Arief[1], Muhamd Fahmi [3], Z. Adzis[1]
[1] Institut Voltan dan Arus Tinggi, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia
[2] Laboratorium Teknik Tegangan Tinggi, Universitas Andalas, Padang, 25146, Indonesia
[3] Institut Ibnu Sina, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

***Abstract*- Organic materials are abundant, renewable, cheap and fully biodegradable. They are promising since they may be blended with plastic to enhance the mechanical and electrical properties of polymer matrix composites. In this research, sisal composites were manufactured from 1% NaOH treated coconut coir fibres (CCF) blended with Standard Malaysian Rubber (SMR), linear low density polyethylene (LLDPE) and titanium dioxide (TiO_2). The influence of fibre loading on the composites in the tensile tests and electrical properties tests has been evaluated. Partial discharge (PD) test was done to evaluate the electrical performance of the composites under constant 6.5 kV AC source for 1 hour utilizing the CIGRE Method II . The partial discharge characteristics were observed using picoscope and LabView 8.5 software. Then, tensile tests were carried out to evaluate the mechanical performance of the fibre reinforced composite materials. The results of PD characteristics and mechanical properties of composites obtained showed enhancement of the mechanical properties and improvement of the PD resistance of the composites with the addition of CCF. It is demonstrated that the composites containing 16 wt% CCF, 48 wt% NR, 32 wt% LDPE and 4 wt% TiO_2 showed a good mechanical and PD resistance. Therefore, this composite is suggested to be used as electrical insulating material with better electrical and mechanical properties.**

I. INTRODUCTION

Organic materials are promising materials that may be blended with plastic to enhance the mechanical and electrical properties of polymer matrix composites [1-3]. Over the past decade, there has been growing interest for the use of lignocellulosic fibre as reinforcing element within the matrix to produce a bio-composite polymer. Bio-composites are defined as composites materials that bind with natural fibre such as bagasse, kenaf and coconut husk. Natural fibre has many advantages including high biodegradability, low cost, low density, environmentally friendly and good mechanical properties. One of the natural fibres that attract research is coconut coir fibre (CCF). Key factors that make it favourable are its abundant availability, naturally produced be used as the filler in a polymeric composite and for other use of purpose are the key factors of interest to study its properties.

Some basic aspects about CCF were studied. The preparation and characterization of CCF were presented in [1, 2, 4& 5]. The physical properties of CCF studied in [3] presented that each variety of coconut will have a different fibre forms affecting the physical properties of that fibre.

The early stage composite material from CCF and plastic was introduced by Owalubi in early 1980's [6-9]. It was found that pre-treatment of CCF with gamma radiation increased the tensile and flexural strength of the composite. 30% CCF content mixed with polyvinyl chloride (PVC) and poly propylene (PP) results in acceptable tensile and impact strength [8]. In 2005, further studies on mechanical properties of the blend were studied [10, 11]. In agreement with the previous study, results show that CCF introduced to low density polyethylene (LDPE) and wax in certain composition improves tensile strength and hardness . Adding the CCF to LDPE improves thermal stability of the polymer [12]. If CCF is mixed with natural rubber, it will increase the tensile strength[2]. The different result for tensile test was presented when CCF is added to polypropylene (PP) [13], where the tensile strength decreases with increasing CCF content in the blend. The strength reduces as the fiber couldnot support the stresses transferred from the polymer matrix. This due to poor reinforcement of the fibre in the PP. On the other hand the same study showed that tensile modulus, flexural modulus and the dielectric properties increase with the increase of CCF filler loading to PP.

In recent years, a wide range study of use of CCF can be found in many papers. For example CCF can absorb contaminants like heavy metal, sulphate and other anions from the ground water [14-18], including battery waste water [16]. This material also can be used to absorb audible noise [19-21]. In different studies CCF can improve the tensile strength and modulus rapture of concrete [22], and concrete properties [23] in general. But the reinforcement of the matrices such as LDPE, PVC and PP with CCF for electrical purpose are yet to be studied extensively.

In this paper, an investigation on CCF added blend in improving the fibre-matrix interfacial bonding has been done. The fibre matrix interfacial bond strength is expected to be very weak in composites of cellulosic fibre (which is hydrophilic in nature) and polyethylene (PE which is hydrophobic). Therefore, physical or chemical modification to the surface of lignocelluloses has been carried out to alter the crystalline structure of the cellulose to obtain better adhesion between fibre and matrix. The properties of composites depend on fibre length, distribution and content. This experiment is to investigate mechanical and electrical properties of CCF reinforced linear low density polyethylene (LLDPE), Standard Malaysian Rubber (SMR10) and titanium dioxide (TiO_2). With proper percentage weight combination,

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these materials can offer more compact products, reduce maintenance and lower operating cost. To get a better composition, electrical performance test and tensile test were carried out to analyze their characteristic and performance. Some analysis were done in previous studies [24, 25], but only limited papers discussed about PD characteristic of LDPE/SMR10/fibre/TiO_2 blend. Thus this paper includes the analysis of the blend without CCF as well.

II. EXPERIMENTAL SET UP

A. Material Preparation, Composition and Sample Code

The main source of raw material is coconut coir (which was collected from coconut milk stalls at the local market). Then, the ripped coconut coir was collected into a container before dried under sunlight for about a day to remove water content [17]. After that, that coconut coir were dried by placing it inside the oven at 80^0C for about half day (5-8 hours) to reduce its moisture contents.

The dried coir fibres were ground using grinder machine until fine particle were formed. A dry condition is most important during drying and storing process due to the susceptible of water content of coir fibres. Silica gels were placed as desiccators together with coir fibres to prevent moisture absorption.

Natural rubbers were processed by using Twin Hot Rolling Machine at 140□C until it is totally melted. After that, the polyethylene was added until both compounds were mixed completely. Then, the coir fibres were added. Lastly, the TiO_2 were added into the mix. The mix of natural rubber (SMR-10) and linear low density polyethylene (LLDPE) that blends with the 60:40 of ratio were formed.

Table 1 shows the sample code for every composition of nano-bio fibre composite material. The matrix used is Standard Malaysian Rubber (SMR) 10 and linear low density polyethylene (LLDPE). The filler used is nano titania (TiO_2) and bio-fibre in micrometer size.

TABLE 1
SAMPLE COMPOSITION AND CODE BASED ON WEIGHT (G)

Sample Code	Material (w%)			
	SMR10	LLDPE	TiO2	Coconut Coir Fibre
SMR00	100	0	0	0
SMRTI	95.2	0	4.8	0
SMRPE	60	40	0	0
CCF00	57.1	38.1	4.8	0
CCF05	54.5	36.4	4.5	4.5
CCF10	52.2	34.8	4.3	9
CCF15	50	33.3	4.2	12.5
CCF20	48	32	4	16

B. Partial Discharge Experimental Set up

An AC voltage of 6.5 kV $_{rms}$ at 50 Hz was applied to the test electrode while the plane electrode was earthed. Within the given experimental conditions, it was assumed that no PD took place from areas other than the void. Fig. 1 shows the laboratory set-up consisting of an AC high voltage supply and its measuring system, the CIGRE METHOD II (CM-II) electrode system [26], and the data acquisition system (PC-connected Picoscope 6).

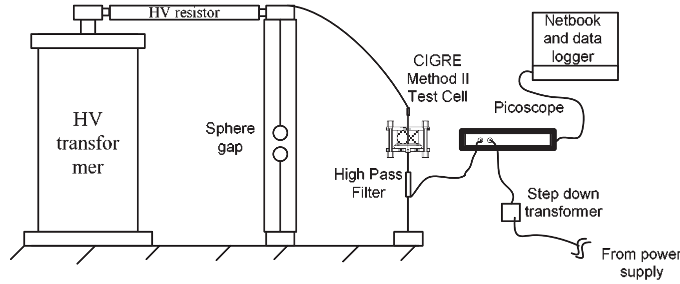

Fig. 1 Test set-up for the partial discharge test

III. RESULT AND ANALYSIS

A. Partial Discharge Inception Voltage, V_{pd}

Partial inception voltage (V_{pd}) is the lowest voltage at which the first PD event detected. This event is related with insulation material properties and depends on the dimension of the void, gas pressures and kind of gas inside the cavity [26]. Table 2 shows the partial discharge inception voltage (V_{pd}) for every sample. Sample CCF00 has the lowest V_{pd}, 3 kV and sample CCF05, CCF10 and sample CCF15 has highest V_{pd} 7kV. Addition of CCF to the composite material can change the V_{pd} but not continuously with increasing DDF content.

TABLE 2
PD INCEPTION VOLTAGE (V_{pd}) FOR EVERY SAMPLE

Sample Code	PD inception voltage, V_{pd} (kV)
SMR00	4.5
SMRTI	4.5
SMRPE	4.5
CCF00	3
CCF05	7
CCF10	7
CCF15	7
CCF20	4.5

B. Total PD Number Analysis

Fig.2 shows the histogram of total PD numbers of each sample after 1 hour of PD testing. It could clearly be seen that the highest PD numbers is measured for sample CCF10, where the coconut coir fibre (CCF) content is 10 g, and lowest PD numbers was recorded for sample SMRTI that contained SMR and nano TiO_2 filler.

Addition of TiO_2 to the SMR gave the best PD performance during the test. On the other hand, the PD performance was decrease significantly by adding the polyethylene (PE) to the sample SMRTI. The PD numbers jumped from 2739 for SMRTI to 8581 for SMRPE and then to 109552 for CCF00.

Some improvement were attempted to add 5 g of CCF to the composite but unfortunately the improvement stopped when 10 g of CCF added to the composite. The improvement was then regained when adding 15 g and 20 g CCF to the composite. The performance is almost equal with the SMRPE sample containing SMR and PE.

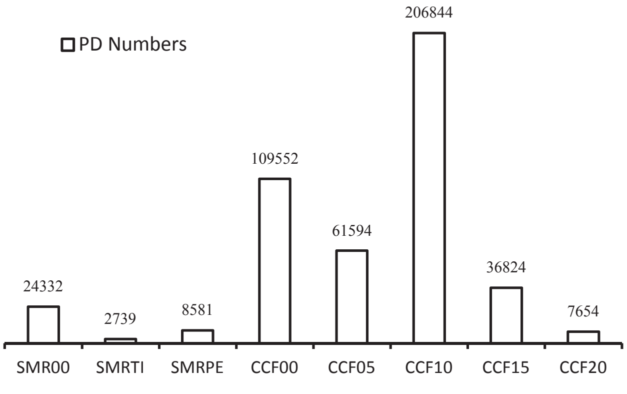

Fig. 2 Comparison of total PD Numbers for every sample

C. Mechanical Properties of the Samples

Two types of results will be discussed in the study of the mechanical properties of bio-filler composite samples. The first will be on the tensile strength and for the second is on the tensile modulus, also known as Young's Modulus. Table 3 shows the tensile strength and Young's Modulus for each type of sample with its percentage of coconut coir fibre added into the samples.

Seven specimens of different composition of samples were used include the non-filled sample using the tensile machine. The best five results of each type of samples will be taken. The relationship of tensile strength and modulus with the amount of wood fillers was shown in Fig. 11 and Fig. 12 respectively.

TABLE 3
TENSILE DATA FOR DIFFERENT COMPOSITES

Type of Sample	Percentage weight of Coconut Coir Filler (w%)	Tensile Strength, (MPa)	Young's Modulus,E (MPa)
SMR00	0	0.44	752.70
SMRTI	0	0.48	791.13
SMRPE	0	2.65	510.13
CCF00	0	3.75	532.88
CCF05	5	3.02	565.44
CCF10	10	2.83	779.07
CCF15	15	3.02	965.82
CCF20	20	2.41	592.28

The highest value of tensile strength of bio-filled composite that recorded was at 3.75 MPa possessed by sample CCF00 that consists of SMR, LLDPE and TiO2, and the lowest was 0.44 MPa possessed by SMR00 that content only SMR. Adding a TiO_2 to SMR has no significant effect to the tensile strength of the composite material as can be seen in Fig. 4. The significant improvement of tensile strength can be made by mixing the SMR and LLDPE and further by adding TiO_2 to SMRPE sample.

Fig. 3 also shows that by having a greater amount of coconut coir fibre, it will proportionally decrease the mechanical properties of the samples. Fig. 3 shows the stress-strain curve data of composite that have coconut coir fibres as filler. From the testing result, a slight decrease was observed in the tensile strength when the amount bio-filler is increase. Although the tensile strength is decrease, but the values are still higher than sample SMR00, SMRTI and the SMRPE for sample CCF05, CCF10 and CCF15. Only when the amount of CCF filler is more than 15 g, the tensile strength starts to decrease.

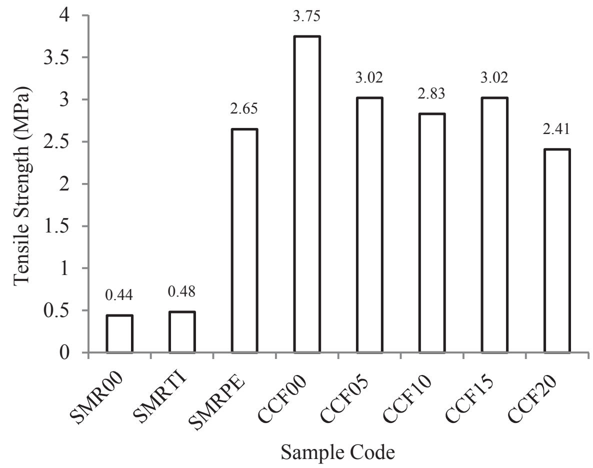

Fig. 3 Effect of coconut coir fibres filler content on the tensile strength

Fig. 4 shows the plots of Young's modulus versus the type of samples. Actually, the types of samples are related to the amount of filler contents. Hence, the figure showed that high amount of bio-fibre filled samples has higher value of stiffness until a certain amount of CCF is added. One possible explanation for this behaviour is that when the samples become less stiff, it increases its flexibility caused by the increase of movement in the molecular chain structure.

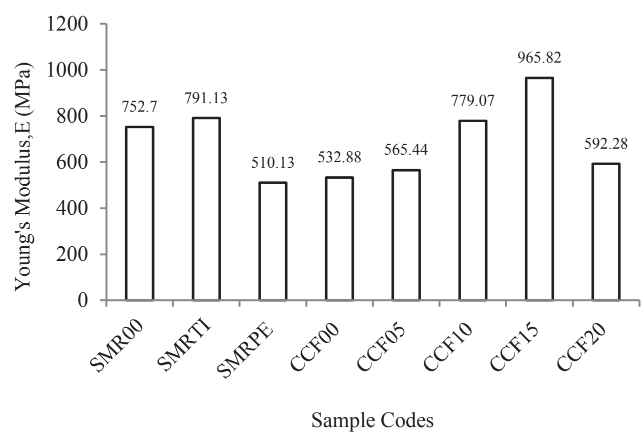

Fig. 4 Effect of coconut coir fibres filler content on the Young's modulus

CONCLUSION

There is a significant role of bio fibre content to control the PD activities inside the nano composite material. Additional w% of CCF possibly will improve the performance of the composite material under PD test, but the result showed that additional of CCF not directly improve the PD resistance. The result of PD test also showed that adding more than 10% improve the PD resistance significantly. This bio nano composite material has the potential to be used as the electrical insulation

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