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Impulse Flashover Characteristics Of Oil Palm Trunk (OPT) Veneer Plywood

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Abstract*— Oil palm is one of the largest crop industries in South East Asia, thus, it is of importance to use all parts of the Oil palm trees. Recently Oil Palm Trunks (OPT) have been used to make veneer, which can be processed to produce plywood. Even though OPT plywood doesn't have the same mechanical properties as timber, with proper treatment and adhesives during the processing of veneer to plywood, it can be made to compete with hardwood. OPT plywood has been used in various applications from wooden appliances to housing and roofing structures. These structures are at risk of surface flashovers through lightning and electrical breakdowns. However, no study has been conducted on the effects or characteristics of OPT plywood. In this paper, the effects of impulse surface flashover under different conditions on three-layered OPT plywood has been analyzed. Experiments were conducted to identify the characteristics of OPT under clean and dry, clean and wet, and contaminated surface conditions for both parallel and perpendicular fiber orientations. The 50% breakdown voltage was determined by the up and down method. Results identified the importance of the fibre orientation and the decrease in breakdown voltage under contaminants.

Keywords*— *Oil Palm Trunk, plywood, high voltage

I. Introduction

Indonesia and Malaysia are the 2 largest oil palm producers in the world. The 2 countries account for more than 80% of the world supply of oil palm [1]. Hence, it has become a crop of major importance as it contributes significantly to the economies of both countries respectively [2].

Palm oil is produced from the kernel of the fruit of the oil palm tree [3]. Palm oil is used for the making of soap, cosmetics, cooking oil etc. and is the main product produced from oil palm trees. An oil palm tree is capable of producing fruit for 20-30 years. However, for sustainable plantation of oil palm, the question of what can be done to the trees after the life cycle of it comes to an end is an important aspect. Currently, countries such as Malaysia are developing methods and producing biomass using the oil palm trees that are not economically viable for palm oil production [4]. But this account for a fraction of the oil palm trees that cannot produce palm oil, as the infrastructure for biofuel is still underway. Hence, a majority of such trees are wasted. However, the use of Oil Palm Trunk (OPT) as softwood has become more prominent in recent time as it provides economic viability to otherwise wasted resources.

OPT can be processed into veneer form for the production of plywood [5]. OPT has relatively low mechanical performance compared to timber, however, with the phenol-

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formaldehyde resin treatment, the properties can be improved significantly [6]. Therefore, it can be used as a substitute for timber in many cases, as it is much cost-effective.

The increased use of plywood as a substitute for timber exposes it to instances of high voltage conditions such as lightning. This study looks into the High Voltage (HV) surface flashover characteristics of OPT plywood with parallel and perpendicular fiber orientations, under clean and polluted surfaces.

i. Applications of plywood

Plywood is used as a construction material for housing and furniture, thermal insulation, and electrical insulation.

In the earlier stages of plywood technology components that were used to build houses were produced rather than the house itself [7]. These include floors, beams, inner walls etc. Prefabricated plywood boards are used in recent time to make housing structures from bottom-up [8]. These structures can be built rapidly, does not require highly skilled labor and is cost effective.

Further, fitting of plywood on walls and floors gives thermal insulation to housing structures in temperate countries. Low thermal conductivity makes thermal insulation possible [9].

In recent time plywood has been used for roofing of house [10]. This is a critical aspect because under the application of roofing plywood is susceptible to direct strikes of lightning. The recent studies on the lightning fatalities in Africa and Central Asia also reveal that many injuries are pertinent to accidents happened while the victims are indoors [11]–[13]. Many of these housing structures are wooden or clay walled with thatched roofs. In the recent years, there is a growing practice in the low income societies in Africa and South Asia to build up their residential structures with plywood used for packaging, left-out by the industries. Therefore, it may be of interest to find the outcome, when a direct lightning strike, a side flash or a high voltage breakdown impulse attach to such structure. Note that despite some stern regulations, people in many developing countries, especially in less-privileged rural areas, people seek shelter under the transmission line corridors [14].

Wood fiber on electrical insulation is a relatively new area of research and development. It has been identified that cellulose, hemicellulose, and lignin are the main properties related to electrical insulation [15]. Cellulose and hemicellulose have similar chemical compositions, therefore, has similar dielectric properties. Increase lignin, on the other hand, increases the di-electric loss [15].

Plywood is based on wood fibers which are comprised of cellulose, and lignin, thus research is conducted towards its electrical insulation and dielectric properties.

II. METHODOLOGY

The experiment was conducted using 3 layered OPT plywood. The construction of the plywood was done using OPT veneer, where 3 sheets of veneer were placed perpendicular (in fiber orientation) to one another and with the aid of phenol formaldehyde resin as a bonding agent is pressed to form the plywood. The constructed plywood sheet for the experiment has a thickness of 1cm.

In order to identify the surface flashover voltage characteristics, two aluminum rods were considered as HV and grounded electrodes (rod-rod configuration) and were placed on top of an OPT plywood sample of dimensions 15cm × 5cm × 1cm, with a gap length of 10 cm between the two electrodes. The rods were aligned in a straight line through the center of the sample and fastened to the sample with rubber bands as shown in Fig 1 and Fig 2.

The up and down method was adopted with 25 shots in order to obtain 50% breakdown voltage (V50%) as per (1) and standard deviation as per (3) [16] [17].

$$V_{50\%} = V_0 + \Delta V \left(\frac{A}{k} \pm \frac{1}{2}\right) \tag{1}$$

$$A = \textstyle\sum_r^i = 1^{ik} i \tag{2}$$

$$s = 1.62 * \Delta V \left(\frac{kB - A^2}{k^2} + 0.029\right) \tag{3}$$

$$B = \textstyle\sum_r^i = 1^{i^2 k} i \tag{4}$$

The Marx generator used for the experiment was a 450 kV, 3 stage voltage impulse generator with 150 kV per stage. The generator was manufactured by Terco, Sweden. Only a single stage was used throughout the experiment to identify V50% as no sample had a higher breakdown voltage in a single trigger than 100 kV. Samples were tested with a standard lightning impulse 1.2/50 μs. As the material is more likely to be exposed to lightning impulses than to switching impulses, due to its potential outdoor applications, the standard lightning impulse was used.

Tests were run on both dry and wet surface with no contaminants, and bentonite contaminated surface. Bentonite was used to represent partially conducting contaminants. The modification of surface flashover characteristics of insulators under bentonite contamination (in the application of lightning voltage impulses) have been studied in detail by Rusli et al [18]. An approximately uniform layer of bentonite was obtained on the surface by blowing off the excessive bentonite away.

After each break down the sample was cleaned and contaminated with bentonite again. During the wet surface testing, the sample was dunked in water after each breakdown occurred.

All data on breakdown voltage were recorded and after each breakdown, a photograph of the sample was obtained.

The tests were repeated with OPT samples of which the orientation of fibers is along the electrodes (in the direction of the gap) and also that is perpendicular to the electrodes (fiber orientation of the outer layers of the plywood were used to define the orientation), as illustrated in Fig 1 and Fig 2. The red arrow indicated the direction of the breakdown channel and the blue arrows indicate the fiber orientation.

III. RESULTS AND DISCUSSION

Results of the experiment are illustrated in Table 1. Highest 50% breakdown voltage is recorded for the sample with fibre orientation parallel to the gap length and the surface is clean and dry. After the application of up and down method, the surface of the sample showed fractures and damage to the fibres. However, the highest observed damage and fractures to the fibres were present in the sample with fibre orientation parallel to the gap length and the surface was contaminated with bentonite, illustrated in Fig 3.

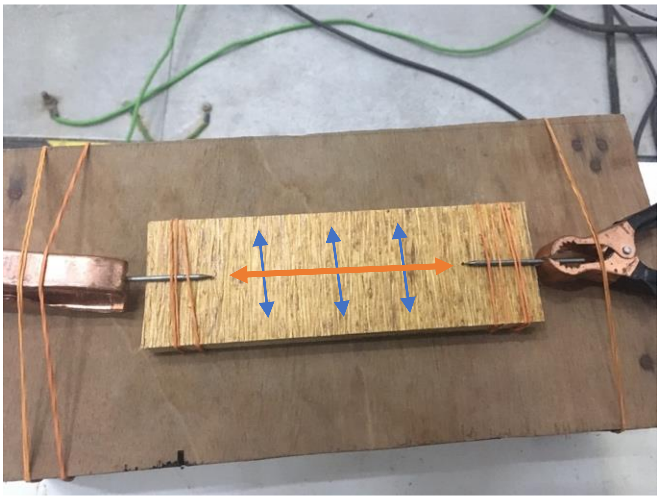

Figure 1: Dry sample with no contamination setup for perpendicular fiber orientation

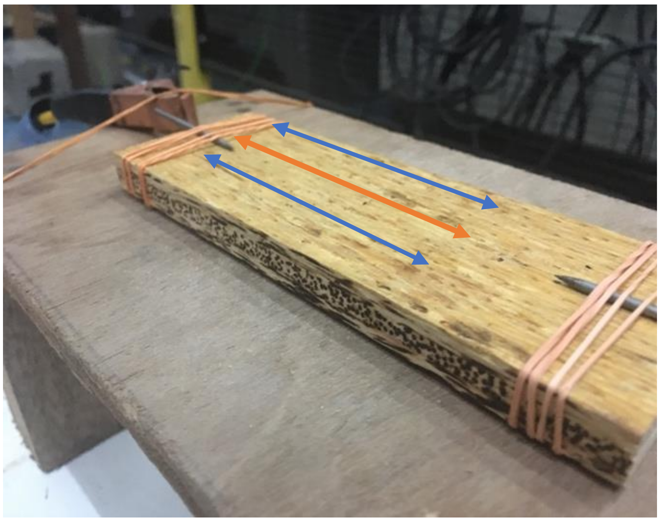

Figure 2: Dry sample with no contamination setup for parallel fiber orientation

The area of the damage is clearly visible along the channel of the current at breakdown between the rods. $V_{50\%}$ was significantly lower in the wet sample with fibre orientation parallel to the gap length. However, in this case, the standard deviation was almost comparable with the $V_{50\%}$ value. Interestingly, no surface damage was observed in all the samples with fibre orientation perpendicular to the gap length. This clearly shows that the fibre orientation of composite wood makes strong impact in determining the level of damage, in addition or on top of the influence of breakdown voltage.

Table 1: Breakdown Voltage characteristics of OPT plywood. A; Dry & Clean; B: Wet & Clean; C: Contaminated with bentonite

Fiber orientation perpendicular to the gap length			Fiber orientation parallel to the gap length		
A	B	C	A	B	C
Highest Voltage for breakdown (kV)					
100	70	95	95	55	90
Lowest voltage for break down (kV)					
75	50	70	80	35	80
50% breakdown Voltage ($V_{50\%}$) in kV					
82.50	53.50	81.25	84.81	43.83	83.50
Standard deviation (S) of $V_{50\%}$ in kV					
12.96	11.25	9.85	7.23	14.35	4.77

Figure 3: Bentonite contaminated sample with parallel fiber orientation before and after 25 voltage impulses (12 breakdowns)

Hence, it can be stated with certainty that if an arc occurs parallel to the fibers the damage will be severe, and the degradation of the material will be apparent to the naked eye. Further, a wetted surface has a much high chance of an arc occurring as the breakdown voltages are significantly lower. However, any structural damage was not visible to the naked eye, though a reasonable conclusion can be drawn towards the degradation of the sample as a pungent order was given off after each impulse.

In the case of plywood as a roofing and walling material the above tests are quite important, as it determines the level of protection provided to the structure. Hence such information should be taken in to account during risk assessment.

The previous studies on the behavior of various types of wood under high voltage conditions [19] show that there are several original wood types that can be used as HV insulation materials. Abungu [19], working on 13 types of wood found in Kenya, reports that Bluegum. Meru oak, Mahogany and Elgon Teak have high dielectric strength and low dielectric loss tangent. They have investigated the material behavior by impregnating the wood with transformer oil and also by varnishing dry wood. The effects were tested on the flashover voltage and leakage current and compare the performance untreated dry wood. The impregnation of wood with transformer oil has slightly lowered the flashover voltage and increased the leakage current whereas, the coating of varnish has increased the insulation performance initially. However, the varnish coating has deteriorated very fast when the wood is exposed to open atmospheric conditions. This is study could be a pre-cursor to the investigations that can be extended on the present study.

OPT veneer plywood can be used as electrical insulation. Even though damage was apparent in some instances, only the 1st layer showed evidence of damage in the 3 layer OPT plywood board. Therefore, a strategically placed (with regard to the fiber orientation and surface contamination) OPT plywood can be a cheaper alternative to existing electrical insulation. It is also of interest to investigate the behavior of surface flashover characteristics of various types of plywood materials with a coating of different insulation protection paints such as RTV. In most intended outdoor applications OPT Veneer Plywood is advised to be used with a weather shield paint-coating. The studies will be extended in the future for materials with such coatings as well.

In order to identify the extent of the damage of the perpendicular fiber orientated samples an SEM scan should be conducted on the said sample before and after each breakdown. Possible damage under continuous currents should also be considered to draw more conclusive evidence of the performance of the OPT plywood. The present study is a pre-cursor to detailed investigation with regard to similar materials.

IV. CONCLUSION

OPT plywood is a relatively weak soft wood that falls short in mechanical properties relative to hardwood timber. However, with proper processing and impregnation of a resin such as phenol formaldehyde as a bonding agent the mechanical properties can be improved significantly. Thus, it can be used as a cheaper substitute for timber in some cases.

Plywood has been used for housing and furniture construction, and as a thermal insulator due to its low thermal conductivity. In recent years, research has been conducted on the electrical insulation of plywood due to its composition of cellulose, hemicellulose, and lignin.

With the increased use of OPT plywood as a substitute for timber, it is at risk of being exposed to HV conditions. In this study, the characteristics of OPT plywood are tested and analyzed under HV surface flashover conditions.

Tests were run on samples under dry, wet and contaminated (with bentonite) conditions, with fiber orientations perpendicular and parallel to the rod-rod gap direction. Experiment results illustrate that the highest damage to the fibers was identified in the bentonite contaminated sample that had a fiber orientation parallel to the rod-rod gap. The water-soaked surface of OPT plywood causes the breakdown voltage to be reduced by approximately 50% relative to that on the uncontaminated dry surface. Therefore, for applications of OPT plywood where there is a possibility of surface arcing we recommend waterproofing of the surface.

Further tests are being run and considered to better understand OPT veneer plywood as an electrical insulation material. These tests include a scanning of the samples before and after each breakdown arc and the degradation of each sample under continuous currents.

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