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Properties of Fiberglass Crossarm in Transmission Tower - A Review

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Abstract

The main structure of the transmission line is the transmission tower. Transmission towers design must endure the weight of the trans-mission conductor at a certain height from ground. One of the main structures in transmission tower is crossarm. Crossarms of the trans-mission tower supports the transmission conductor. This paper is a review of past studies on fiberglass crossarm based on its mechanical properties and electrical performances. The aim of this paper is to analyze the mechanical properties which is including its tensile strength, elongation and hardness. It was discovered that the tensile strength increasing while hardness and elongation at break decreasing. In addition, the fiberglass has greater lightning power strength than the wood crossarm. It can be concluded that fiberglass crossarm can be used to replace conventional timber crossarm.

Keywords: electrical performances; fiberglass crossarm; mechanical properties; transmission line; transmission tower.

INTRODUCTION

The main structure of the transmission line is the transmission tower. Transmission towers design must endure the weight of the transmission conductor at a certain height from the ground. Besides, transmission tower also must able to sustain all kinds of natural disaster. Hence, to build up a transmission tower needs a large involvement from all three basic engineering concepts which is mechanical, civil, and electrical engineering concepts which are evenly applicable [1]. An electricity transmission tower consists of many parts. One of the main structures in an electricity transmission tower is crossarm. Crossarms of the transmission tower supports the transmission conductor. Normally, the substances used for crossarms in transmission tower are wood, steel and fiberglass [2]. Fiberglass has greater composition compared to other two materials. This is because fiberglass is nonconductivity and has higher mechanical strength to weight ratio. These properties make fiberglass crossarm a great potential to replace steel and wood crossarm [2]. The dimension of crossarms absolutely relies on the altitude of transmission voltage, configuration, and minimum forming angle for stress distribution.

Traditionally, transmission tower structures have utilized treated timber, steel, or concrete as a construction material. Recently, the adaptation of fiberglass as the materials in crossarms production has been applied. It is because fiberglass has smooth and solid covered surface with an outer layer of film which can protect the inner sur-face of the fiberglass crossarm that could cause flashover [2]. The fiberglass crossarm unable to use as a main element in the insulation system. This is because the surface leakage current will occur until it can burn the crossarm itself especially under wet condition. It has to be installing as a multi-insulation system to increase the lightning insulation strength of transmission line.

Based on previous study, fiberglass was presented as an insulator in transmission system because it has greater nonconductor strength. However, due to inconsistency of the Malaysian weather, many newly installed fiberglass crossarms fail within a short duration due to heavy rain, lightning, wind, as well as humidity condition under wet and hot conditions. This issue becomes crucial since it will affect electricity production and incur additional costs for repairation and maintenance. The failure of the fiberglass crossarm at the transmission tower will be analyzed using nonlinear finite element method [3].

EVOLUTION OF CROSSARM

There are four main materials commonly used as the structures in transmission tower which wood, steel concrete and fiber reinforced polymers. Historically, wood is the first material used as the structures in transmission line. Wood is a resourceful material for structural purposes and has been used for a very long time [19]. Wood selected as one of the structures that has inexpensive cost whereas the cost of wood production is quite low when compared with the other two materials. However, wood need an extra inspected since it was

exposed to attack by natural enemies such as woodpeckers, termites and rotting. Due to some reasons, the avail-ability of large quantities of good quality of wood is limited since it is difficult to find adequate suppliers. Other than that, wood crossarm is difficult to transport because of it is heavy weight.

Steel selected to become the alternative material to replace the wood crossarm. Steel has flexible design, so it can be designed to the shape required. Besides. steel is lightweight and does not bio-degrade. However, rusting can't be preventing from spreaded in steel which is caused by aggressive environments, chemicals and pollution which can significantly decrease its lifespan. Based on past studies, it was observed that steel transmission structures have good track records and some of them can withstand for more than 100 years [19]. However, steel is electrically conductive and induction can also create currents which causes hazardous for the installing personnel making live, energized structural work more dangerous.

Alternative materials are needed for a better improvement of transmission line such as using fiberglass reinforced polymer. Fiberglass are more recent using in market and has lowest life cycle costs and longest expected lifespan up to 80 years compared to wood crossarm. Other than that, it can be easily installed and transported to difficult access area which can saving on installation costs. Besides, fiberglass crossarm is electrically non-conductive making live line energized work much safer. Overall conclusion, fiberglass crossarm has many benefits making it a good potential to utilize as transmission line structures [19].

Figure 1: Example of Fiberglass crossarm

Overview of Transmission Tower System in Malaysia

The high-voltage electric power transmission network called Na-tional Grid, Malaysia was located in Peninsular Malaysia. Tenaga Nasional Berhad (TNB) is a private company that fully responsible to operate the electric power transmission network in Peninsular Malaysia while for Sabah and Sarawak electrical grids owned by Sabah Electrical Sdn Bhd and Sarawak Energy Berhad. In Peninsular Malaysia, more than 420 transmission substations with a total generating power of 105,305 MVA, are connected together by approximately 21,000 circuit-kilometers of hanging lines and underground cables generate at 132,275 and 500 kilovolts (kV) [14]. The commencement of the National Grid was gradually take place in 1964 when the Bangsar Power Station was linked to the Connaught Bridge Power Station, then the line afterwards extended to Malacca [15].

TNB's Transmission Division generates three types of voltage for transmission line which is 132 kV, 275 kV and 500 kV transmission voltage acknowledged as the National Grid. The single largest transmission structure developed in Malaysia is 500 kV. It was also became the important transmission system in Peninsular Malaysia. Besides, the 275 kV is the huge transmission system while 132 kV is the medium transmission system in transmission tower.

Figure 2: Example of Transmission Tower in Malaysia

Flash overvoltage is the main cause of the transmission line disruption in Malaysia [18]. Malaysia is one of highest region that experiencing an extremely high amount of lightning strikes every year. The impact from this lightning will giving a very high Ground Flash Density (GFD) which has very much affected the performance of the Transmission lines in Malaysia. Based on past studies, it was found that the 132 kV Kuala Krai to Gua Musang (GMSG) line which is located in the North-East Malaysia has the highest recorded lightning tripping in Peninsula Malaysia [17]. A transmission line near Serendah, Selangor also had broken down which results a power blackout in northern peninsular Malaysia.

Methodology of Testing

Elongation at Break Test

It was revealed that the elongation at break of the composites decreased with the addition of fiberglass fillers. This could be associate to the stiffness and brittleness of the fiberglass and

the epoxy resin waste. Other than that, the composites developed lower elasticity than the virgin polypropylene. In addition, the breakage of the material commence from the interface between polymer matrix and additives [4].

Hardness Test

Based on past study, it was shown that the hardness was increased with increasing filler loadings [4]. This could be associate to the stiffness and rigidity of the fiberglass. Besides, the main reason for this increases causes by the toughness of the polyester.

Tension Test

The tension test was carried out to analyze the short fiber-reinforced materials reaction towards failure. From past studies, the tension test was conducted according to the ASTM D 3039M-14 standard [11], the standard test method for evaluating tension properties of polymer matrix composite materials [5]. The Generalised Probabilistic Approach (GPA) has been selected to analyze the reaction towards failure of a short fibre-reinforced material. It was discovered that the joint application of the GPA stipulates more precise failure predictions for tension [5]. The results obtained from past paper computed from Weibull parameters shows that the failure probability of tension is quite fast rather than three-point bending test and four-point bending test.

Three-point Bending Test

Since the fiberglass crossarm design structures is commonly controlled by the bending capacity of the wind load, it was determined that full scale individual bending test needed to be conducted [6]. Three-point bending test was conducted follows the ASTM D 790-15e2 standard [12], the standard test method for flexural properties of reinforced plastics [5]. The results obtained from past study computed from Weibull parameters shows that the failure probability of three-point bending test is a bit slower compared to failure probability of tension but faster than four-point bending test.

Four-point Bending Test

The four-point bending test was conducted according to the ASTM D 6272-10 standard [13], the standard test method for flexural properties of reinforced plastics [5]. The results obtained from past study computed from Weibull parameters shows that the failure probability of four-point bending test is a slower compared to failure probability of tension and three-point bending test.

Mechanical Properties

Tensile Strength

The results obtained from past studies shows that the tensile strength increased with the increasing of the fiberglass content since the strength of the fiberglass (reinforcing element) is greater than that of pure polypropylene matrix. It was found that the great improvement in the tensile strength of the composites causes by the 10 wt% increasing in the filler. It was proven that all the fiberglass reinforced polymer waste filled polypropylene had improved tensile properties than the individual tensile properties of epoxy composites and pure polypropylene [4].

Elongation at Break

It was observed that when the fiber proportion is 40% for both virgin fibers and fiber wastes, will results decreasing in elongation at break of the composites [20]. According to past paper, this is due to the rigid fibers that block the motion of the polymer chains. Other than that, the composites developed lower elasticity than the virgin polypropylene. In addition, the breakage of the material commence from the interface between polymer matrix and additives [4].

Thermal

The results obtained from past studies shows that the fiberglass has high stiffness and low thermal conductivity over the 2-293 K temperature range [28]. Fiberglass can't burn and basically not effected by curing temperatures when used in industrial processing. At 700°F, fiberglass retains approximately 50 % of its strength while it retains 25 % at 1000°F.

Electrical Performances

Fiberglass Crossarms Critical Flashover (CFO) Voltages

The CFO voltages of the fiberglass crossarms in dry and wet con-dition were extensively reviewed and the outcome were presented in paper [2][7]. It was found that in dry condition, the fiberglass crossarm has higher CFO than under wet condition. Different from Critical Flashover voltage characteristics, the Critical Flashover voltage per unit length of the fiberglass crossarm expected to be decrease as the length of the fiberglass crossarm increase.

AC Flashover Voltage of Fiberglass Crosssarms

Based on previous study, the fiberglass crossarm needs to be set up with the insulators [2]. The outcome was recorded from the test conducted at the AC voltage of the fiberglass crossarm which is in dry and wet condition was discussed in the past paper [7]. It was discovered that when compared with the tests under dry condition, the flashover voltage of the fiberglass

crossarm with three porcelain insulators in wet condition lessen by approximately 50 to 60 percent. The current flows over the wet surface of the fiberglass rod under the wet condition. A conductive path flows over a non-conductive fiberglass when the fiberglass crossarm surface is completely wet. Therefore, the leakage occurs on the surface that has a very low electrical resistance. In addition, if the leakage current level became high and time applied voltage is long, it would produce extensive heat that would cause destruction to the fiberglass croassarm composite.[2]. Several fiberglass crossarms were tested under different condition such as lightning power voltage, positive and negative polarity, AC voltage, dry and wet condition [2]. It was observed that the longer the crossarms, the lower the value of Critical Flashover voltage and AC flashover voltages per unit length [2]. The completed failure of the protective coating on the topside of the crossarm was discovered when a rough surface was seen on the bare fiberglass. Thus, these damages surface results the loss of the crossarm's electrical mechanism.

Differences of Fiberglass and Wood Crossarms

It was found that the Critical Flashover voltage of the fiberglass crossarm is higher than the wood crossarm under dry and wet condition if the length of the crossarm is same [2]. Other than that, the Critical Flashover voltage of wet fiberglass crossarm has greater Critical Flashover voltage than the dry wood crossarm. Therefore, the Critical Flashover voltage of the fiberglass crossarm is the highest in dry condition while the wood crossarm is the lowest under wet condition.

Besides, it was discovered that Critical Flashover voltage per unit length of the fiberglass crossarm is greater than wood crossarm. The variance of the Critical Flashover voltage per unit length between fiberglass crossarm and wood crossarm is closely same aside with the length of crossarm under dry and wet condition [2]. Table 1 shows the comparison of the electrical strength between wood and fiberglass crossarm with the Alternate Current (AC) voltage and the Critical Flashover (CFO) voltage.

Table 1: Electrical Strength between wood and fiberglass with Alternate Current voltage and Critical Flashover voltage under dry and wet condition

Crossarm	Electrical Strength			
	AC Voltage		CFO Voltage	
	Dry	Wet	Dry	Wet
Wood	Insulation	Conduction	Insulation	Insulation
Fiberglass	Insulation	Conduction	Insulation	Insulation

Calcium Carbonate Acts as Filler in Fiberglass Crossarm

Fiberglass is a one of plastic composites that mechanically increase the toughness and stiffness of plastics [22-24] which the resin gives extra protection to the fiber due to the strong cementation between two materials [25]. However, utilizing resin as the binder for fiberglass crossarm is costly. Hence, utilize low-cost easily available fillers may be advantageous to bring down the cost. The aim of using fillers is to improve the properties of material and to reduce the cost of component. Besides, the use of calcium carbonate fillers is useful as laminating or coating of thick components. The effect of using calcium carbonate on the composition of glass fiber composite such as tensile strength, impact strength and flexural strength has been studied to analyse the amount of fiberglass feature loss due to the substitution of cheap fillers.

Based on past review, the fillers such as silica and calcium carbonate can fill up the amount of 25% and 50% respectively the weight of the resin [21]. In composite manufacturing, it was observed that the silica fillers show more difficulties on processing than the calcium carbonate. Despite from all that, the silica fillers are approximately 20% more cheaper than the calcium carbonate fillers. It was found that the tensile strength decreased but the flexural strength was necessarily increased. Increasing of the filler concentration will causes the tensile strength and impact strength decrease for both fillers due to the higher filler loading which the interstitial volume must have been occupied by filler so that there might be less matrix available to contribute for the tensile and impact strengths.

CONCLUSION

As the conclusion, the fiberglass crossarm unable to use as a main element in the insulation system in transmission tower. Other than that, it was discovered that the tensile strength increase while elongation and hardness decreased. In addition, the fiberglass has greater lightning power strength than the wood crossarm. Fiberglass crossarm is a good insulator in the transmission line when it serves as the second insulation component. Besides, fiberglass crossarm can increase the lightning power strength of the insulation system. It also concludes that, the Critical Flashover voltage of the insulator with the addition of fiberglass crossarm is extremely higher when compared with wood crossarm under the identical situation. Therefore, when taking all parameters from past studies, it can be concluded that fiberglass crossarm has good ability to replace the conventional timber crossarm.

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