A COMPARATIVE STUDY OF THERMAL AGEING PROPERTIES OF KENAF FIBER AS INSULATING PRESSPAPER IMMERSED IN MINERAL OIL

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DYLAN EMANUEL ANAK CHRISTIA

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ABSTRACT

After liquid insulation, solid insulation is one of the most important insulation materials in transformers. This solid insulation is primarily composed of cellulose, often known as Kraft paper. To maintain resource stability, it is necessary to optimise the utilisation of raw materials. Demand for softwood is increasing, which slows down the manufacturing industry's ability to maintain production, particularly of electrical-grade products; therefore, natural fibre plants should be the greatest option for replacing the demand for softwood.

Kenaf (Hibiscus Cannabinus L) is one of the non-wood lignocellulose which potential to be a new material as electrical grade product. It is necessary to comply to a few IEC requirements to ensure that Kenaf press paper is suitable for use in power transformers. The testing methods for paper insulation include Thermogravimetric Analysis (TGA), Degree of Polymerization (DP), and resistivity volume.

The thermal ageing of insulation paper is also performed at a temperature of 90°C for a period of 240 hours to 720 hours. The degree of polymerization workflow is determined based on IEC Standard 60450 and the viscosity of the dissolved solution. Thermogravimetric Analysis (TGA) was used to analyse the thermal resistance of Kenaf insulation paper in order to determine the paper's ability to tolerate such high thermal pressure. Finally, the substance's resistivity is measured to determine if Kenaf insulation can insulate the conducting material.

The results indicate that the degree of polymerization of Kenaf press paper is acceptable in accordance with the standard, and that the thermal resistance of Kenaf advances marginally during the second phase of degradation. The degree of polymerization generally affects the volume of resistivity.

ABSTRAK

Selepas penebat cecair, penebat pepejal adalah salah satu bahan penebat yang paling penting dalam transformer. Penebat pepejal ini terutamanya terdiri daripada selulosa, sering dikenali sebagai kertas Kraft. Untuk mengekalkan kestabilan sumber, adalah perlu untuk mengoptimumkan penggunaan bahan mentah. Permintaan untuk kayu lembut semakin meningkat, yang memperlahankan keupayaan industri pembuatan untuk mengekalkan pengeluaran, terutamanya produk gred elektrik; oleh itu, tumbuhan gentian semula jadi harus menjadi pilihan terbaik untuk menggantikan permintaan untuk kayu lembut.

Kenaf (Hibiscus Cannabinus L) merupakan salah satu lignoselulosa bukan kayu yang berpotensi untuk dijadikan bahan baharu sebagai produk gred elektrik. Adalah perlu untuk mematuhi beberapa keperluan IEC untuk memastikan bahawa kertas penekan Kenaf sesuai digunakan dalam pemgubah kuasa. Kaedah ujian untuk penebat kertas termasuk Analisis Termogravimetrik (TGA), Darjah Pempolimeran (DP), dan isipadu kerintangan. Penuaan terma kertas penebat juga dilakukan pada suhu 90°C untuk tempoh 10 hingga 30 hari. Tahap aliran kerja pempolimeran ditentukan berdasarkan Piawaian IEC 60450 dan kelikatan larutan terlarut. Analisis Termogravimetrik (TGA) digunakan untuk menganalisis rintangan haba kertas penebat Kenaf bagi menentukan keupayaan kertas untuk bertolak ansur dengan tekanan haba yang tinggi tersebut. Akhir sekali, kerintangan bahan diukur untuk menentukan sama ada penebat Kenaf boleh menebat bahan pengalir.

Keputusan menunjukkan bahawa nilai darjah pempolimeran kertas penekan Kenaf boleh diterima mengikut piawaian dan daya tahan haba Kenaf lebih baik semasa peringkat kedua degradasi. Isipadu kerintangan umumnya dipengaruhi oleh tahap pempolimeran.

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LIST OF ABBREVIATIONS

BDV	Breakdown voltage
HV	High voltage
DP	Degree of polymerization
FTIR	Fourier Transform Infrared Spectroscopy
MO	Mineral oil
TGA	Thermogravimetric analysis
IEC	International Electrotechnical Commission
R&D	Research and Development
SF6	Sulphur Hexafluoride
TUK	Thermally Upgraded Kraft
KE 10	Kenaf Presspaper with 240 hours thermal aging
KE 20	Kenaf Presspaper with 480 hours thermal aging
KE 30	Kenaf Presspaper with 720 hours thermal aging
NKE	Kenaf Presspaper without thermal aging

CHAPTER 1

INTRODUCTION

1.1 Background

Demand in electrical supply is keep increasing rapidly due to acceleration of population growth along with development in technology [1]. Acceleration of demand in electrical energy arise the need of efficient transmission systems and distribution system to carry out huge electrical supply to the client. In power system, transformer is the most crucial part to vary the voltage level by stepping-up and stepping-down while to maintain the system stability with low level of power losses [2]. Transformer mainly composed two component of insulation types which are solid insulation and liquid insulation [3]. Each component is important to maximize the efficiency of transformer operation by isolating the current conducting part and work as cooling system.

Cellulose insulation paper is a crucial part implemented in electrical power transformer, in which cellulose paper works as solid insulator between of two conducted winding coils [4]. The most common raw material used to make the solid insulation paper is a soft-wood pulp. However, Kenaf fibre one of the polymer celluloses have excellent potential to replace conventional insulation paper (Kraft press-paper) due to source suitable for paper-making industry. It is come with various traits, including mechanical strength, electrical performance and thermal stability compared to the Kraft paper [5]. All the mentioned traits are important to determine the lifespan of transformer and decrease the downtime operation in distribution transformer in order to avoid premature ageing.

Exposure of Kenaf in Malaysia in getting popular since it is on of non-wood natural fiber being used and full of fiber sources. In Malaysia, Kenaf had been utilize in other industry such as paper making and textile. Encouragement by of Malaysian government is the one motivates R&D industry to explore more to use the availability of raw material in other industry especially in manufacturing electrical grade product.

In transformer, the impregnated-oil cellulose insulation paper degenerate during the operation due to the presence of thermal energy. Thermal aging of insulator press-paper may downturn the overall performance in term of mechanical strength and electrical performance [3], [4]. Aging of insulation paper may escalate the risk of shorting between two conducted winding coils due to changes in structure of paper's physical and chemical's atom arrangement within molecules [6].

1.2 Problem Statement

The thermal ageing features that initiate and speed up the process of disintegration of cellulose paper are responsible for the widespread occurrence of the degeneration of solid insulation, which consists of cellulose paper [7]. Given that this is a fact, the lifespan of a transformer can range anywhere from 25 to 40 years, depending on the strength of the solid insulation paper [4], [7], [8]. This can be determined by calculating the degree of polymerization (DP) value. In addition, the earlier researcher stated that thermal energy is not the only factor that contributes to the deterioration of insulation paper. According to this researcher, there are many factors that contribute to the deterioration of insulation paper throughout the environment, such as mechanical, electrical, and chemical stresses [9]. To be able to sustain all the stresses stated toward the solid insulation of transformers, the dielectric and thermal stability of the material must be quite high [10]

Since 1920, Kraft paper has been utilized as an insulating paper. Mineral oil (Paraffin-mineral oil) was also used as a liquid dielectric, protective barrier for the core, and for cooling purposes [11]. This Kraft paper was originally mass-produced from softwood, a common raw source for paper and bio composites [5], [12]. The key benefits of this wood-based polymer material at the time were the availability of softwood, its mechanical and dielectric strength. However, the demand for softwood in other applications may cause a global fiber supply deficit. Kenaf Fiber is one natural fiber polymer that is not derived from wood that can be used to combat this issue. According to Abd El-Syed [13], Kenaf Fiber has the potential to replace traditional wood-based papermaking raw materials.

The diversity of characteristics of natural fibers, particularly non-wood fibers, was influenced by their origin, age, and extraction method. Kenaf fiber, also known as Hibiscus Cannabis, is an example of a non-wood polymer consisting of 65.7% cellulose and 21.6% lignan [13]. This kenaf fiber is also a fast-growing softwood, as it requires only 120 to 150 days to mature and can be harvested twice annually. In terms of time to maturity, kenaf fiber is eighty times faster than other softwoods currently utilised in paper manufacturing. In addition, the selection of Kenaf Fiber as a replacement is primarily owing to its superior mechanical qualities, eco-friendly raw materials, and biodegradability [14].

This study's primary objective is to analyses the qualities of Kenaf Fiber insulation paper in accordance with standard used in evaluation of insulation paper and whose mission is to replace conventional solid insulation in power transformers. In the list of objectives, electrical characteristics and tensile strength are of the utmost importance. Thermogravimetric analysis (TGA), volume resistivity, and degree of depolymerization will be utilised to determine the characteristics of Kenaf Fiber.

1.3 Objectives

The objectives for this experiment are:

1. To examine the physical properties of Kenaf paper insulation immersed in mineral oil.
2. To analyse the thermal endurance of the impregnated Kenaf insulation paper.
3. To determine the electrical performance of Kenaf paper insulation

1.4 Research Scope

The limitation of this study are:

The primary objective of this research was to concentrate on the effects of soaking kenaf press paper in mineral oil of the Nynas type. In addition, this study only makes use of one brand of mineral oil and one kind of kenaf labs kill press paper, both of which were sourced from the Malaysian Government's Kenaf and Tembakau Departments (LKTN).

The temperature of thermal ageing was set at 90 degrees Celsius for the purposes of this study, and the duration of the ageing process was set at 240 hours, 480 hours, and 720 hours. The sample of kenaf press paper will be evaluated using the methodology described in Chapter 3, which will be followed.

1.5 Thesis outline

The final year project consists of five (5) chapter. Chapter 1 discusses the general overview of cellulose insulation paper major objective of this study, extraction of problem to be solved and the limitation of this project research may face.

Chapter 2 which is literature review may consist of general knowledge of power transformer, history of kenaf fibre, introduction of kenaf fibre in all industries including automotive and composite and previous research of insulation press paper. All method of testing extracted in this chapter 2.

Chapter 3 which is methodology describe about the method of testing used according to the specific standard. Steps of execution and parameter of material and equipment explained well here. There are three methods testing such as Thermogravimetric Analysis (TGA), Degree of polymerization (DP) and Volume of resistivity. This method commonly used to evaluate the material used as solid insulation paper.

Chapter 4 which is result and discussion may consist of obtained result from the method of testing. Data obtained also analysed which presented in form of table and graph.

Finally, chapter 5 represented of conclusion and recommendation. This chapter mainly conclude the overall results obtained on chapter 4 with the relevant recommendation for future study of solid insulation paper.

Chapter 2

LITERATURE REVIEW

2.1 Overview

In this literature review, the history of the Kraft Pulping process in papermaking, the history of transformer insulation paper used in the power system, and the application of Kenaf Fiber in other industries such as aircraft manufacturing, roofing manufacturing, electrical industry, paper pulp, sports, and so on will be discuses. The morphology of Kenaf Fiber will be extracted in order to investigate the true potential of the non-wood fiber in the production of insulation paper. This Kenaf fiber was also compared to other commercially available fibers and fibers that are currently being researched.

2.2 Transformer

Transformers are a type of electrical equipment that are basically used to raise or lower the level of voltage according to the necessity while simultaneously boosting the efficiency of power distribution [2]. This common electrical equipment can be found on power generation plants to level up the voltage level for transmitting generated power or on distribution plants to lower down the voltage level for distribution purposes to the targeted lower-level voltage rating consumer, including commercial and residential areas. Both plants are used to distribute generated power to their respective consumers.

For example, when power is being transferred to a city in the vicinity, the source of the generated power steps up first in order to reduce the amount of power that is lost while it is going through a lengthy transmission line [2]. The amount of voltage was lowered for the use of the local transformer in order to ensure the user's safety. Core, winding, and insulating material are required components in the building of a transformer. Additionally, there are a few other essential components that must be present. The primary component that is required for a transformer to function properly is depicted in the **Figure 2.1**, which depicts a three-phase power transformer.

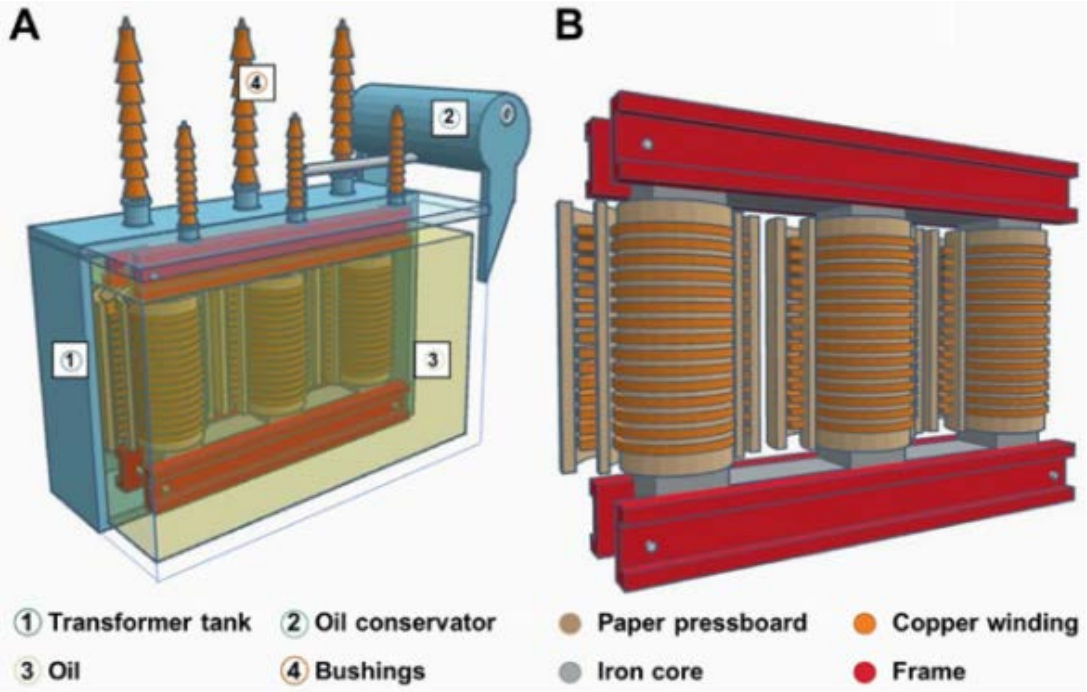

Figure 2.1: Illustration of three-phase core type power transformer (A) and core section of transformer with solid insulation material (B) [2]

Presspaper, pressboard, and mineral oil were the three types of insulation that were typically utilised by transformers in order to successfully isolate the winding conductor while the device was in operation. The common goal is to prevent electrical breakdown as well as short circuits [6]. In most cases, the most important factor in determining the performance of a particular insulating raw material is the technology that is currently in use, as well as the cost and quality of the materials [15]. In accordance with Rohith, Transformer insulation can be divided into three distinct types: solid insulation (including kraft paper, pressboard, upgraded thermal resistant paper, epoxy resin, and silicon rubber), liquid insulation (including mineral oil (MO), natural ester oil, and synthetic ester oil), and gas form insulation (including sulphur hexafluride (SF6)). The classification of transformer insulation that is now utilised in high voltage (HV) equipment may be seen in the **Figure 2.2**.

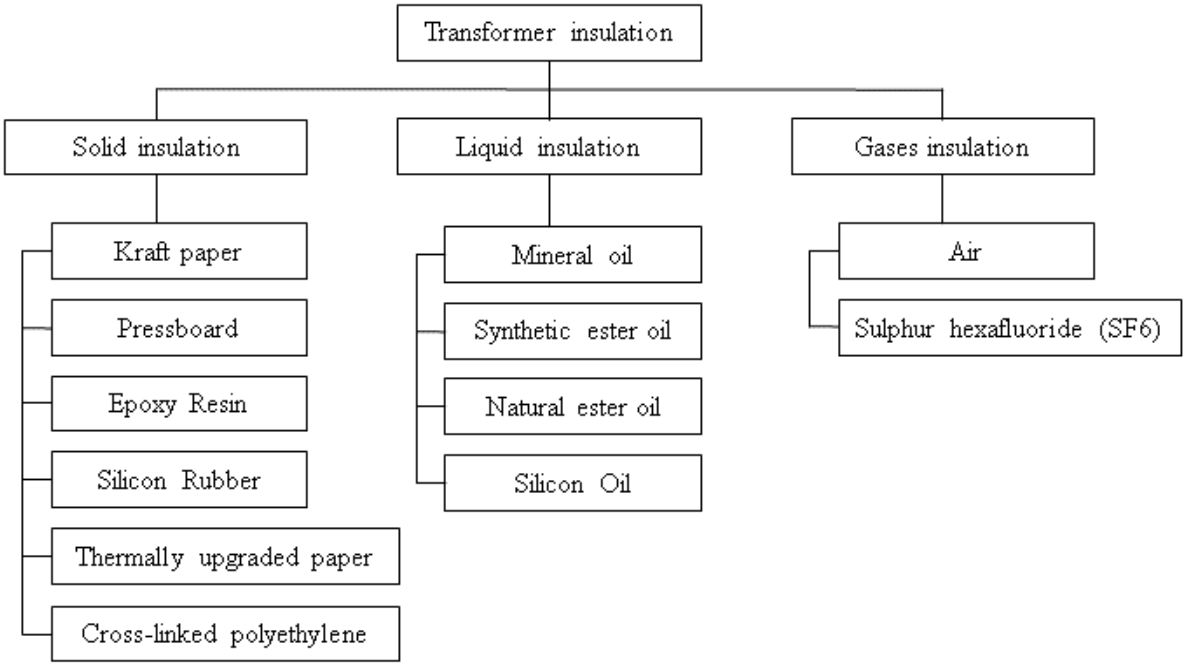

Figure 2.2: Classification of transformer insulation.

2.3 Liquid insulation in transformer

2.3.1 Mineral oil

Mineral oils are the most renowned liquid insulation in power transformer since for a long time ago. Mineral oil normally refining from crude oil resources and compose of thousand hydrocarbon compounds, for example, alkene and cyclic as shown in the **Figure 2.3**. The major reason of mineral of being the first choice because of cost-effective mineral. However, it is one of source form renewable energy. Suitability of mineral oil with kraft paper technically approved since mineral oil can has a good physical and electrical properties and manage to hold out against thermal and electrical stress.

Mineral oil, on the other hand, has several drawbacks, as stated by Lioa et al [16]. These drawbacks include the fact that it is a non-biodegradable product, that it comes from non-renewable sources, and that there won't be enough of it in the future. If it is not disposed of in the appropriate manner, the fact that it is a non-biodegradable product means that it has the potential to pollute the surrounding environment, which could influence the soil and water and contribute to pollution. Numerous researchers have contributed to the hunt for a new source to replace mineral oil, and they have suggested ester oil as one of the potential new options [16], [17].

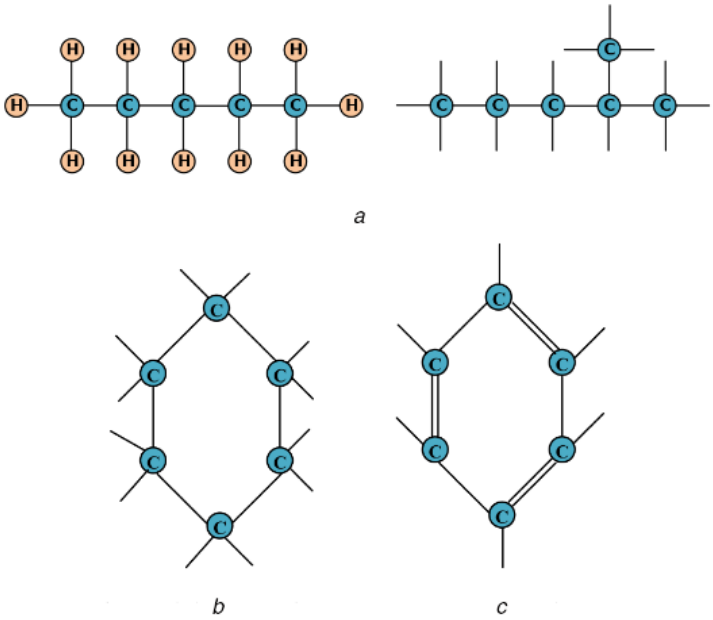

Figure 2.3:Structure of mineral oil hydrocarbon [17].

2.3.2 Natural esters

Natural esters commonly assumed as substitution for conventional mineral oil because of the major advantages such as, environment-friendly, non-poisonous, good thermal resistance and excellent electrical properties. Natural ester also one of triglycerides which consisting fatty acids group linked to molecule of glycerol [6].

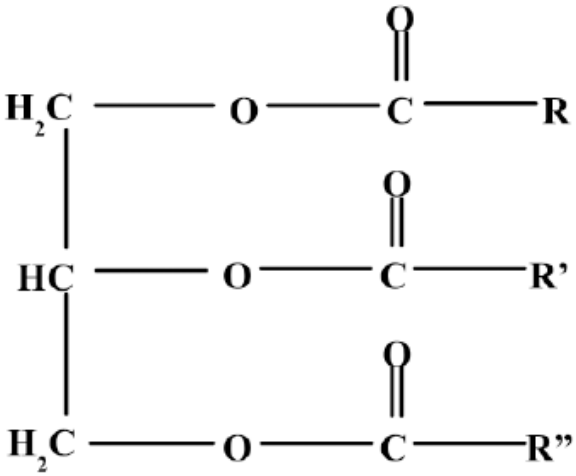

Figure 2.4: Triglyceride ester molecule [17].