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INFLUENCE OF THE ADDITION OF PARAFFIN AND GRAPHITE ON ETHYLENE PROPHYLENE DIENE MONOMER (EPDM) FOR THERMAL ENERGY STORAGE

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ABSTRACT

This study aims to determine the effect of the paraffin: graphite ratio on the thermal resistance of the Phase Change Material (PCM). PCM mixed with Ethylene Propylene Diene Monomer (EPDM) which has good compatibility with paraffins as a base polymer for preparing paraffin graphite composites. The samples was prepared by using heating method at 180^{o}C for 20 minutes with a variation of the ratio 9:1 and 8:2 with mass ratios PCM70 : EPDM30, PCM80 : EPDM20, and PCM90 : EPDM10. Based on the results of tensile strength testing, thermal stability analysis and SEM. the maximum tensile strength is obtained at a mass ratio of 80% : 20% with a ratio of 9:1 which is 9.34 Mpa, has a thermal stability of 307.04^{o}C at onset and Endset at a temperature of 399.50^{o}C, However, there is an aggregate form that is agglomerate and has large pores, as well as a rough surface on the sample. While the results of the Morphology test using SEM, the best interaction between polymers with a mass ratio of 70%:30% at a ratio of 9:1, with a very well mixed surface, smooth, no lumps formed.

Keywords: EPDM; Graphite;Paraffin;PCM;Polymers

Introduction

Utilization of solar heat is used throughout the world because solar energy has a high frequency and is widespread. In a solar thermal system, collecting sunlight and transferring solar energy and storing it as heat energy is very important. The device or heat transfer fluid in the solar thermal collector plays an important role in collecting sunlight and transferring it to thermal energy[1]. Using the heat transfer fluid directly to absorb sunlight and store thermal energy can reduce the heat loss of the collector in the environment and eliminate the energy loss between the surface of the collector and the heat transfer fluid, thereby obtaining higher storage capacity and receiving efficiency. In this case, the heat transfer fluid must have good photo-thermal performance, high thermal conductivity, and large thermal storage capacity, where PCM has a large enthalpy and thermal conductivity which can increase the photothermal energy [2].

Thermal energy storage is one of the most efficient methods for storing thermal energy. Heat energy transfer occurs when the transformation changes from solid to liquid or from liquid to solid [3]. This is called a shape change or phase change. Initially in solid-liquid iPCM this happens in cases like conventional storage changes where energy is released according to heat absorbed. Unlike conventional energy storage changes, PCM can absorb and release heat at near constant temperatures. PCM can release heat more than 4-5 times per unit volume compared to conventional icon energy stores such as water or stone [4].

To meet the need for national electrical energy consumption which continues to increase in line with the increasing use of electrical energy or electrification as well as changes in the lifestyle of the Indonesian people. According to data from the Ministry of Energy and Mineral Resources in 2019, electricity consumption in Indonesia in 2018 reached 1,064 kwh/capita, up 5.4 percent from the previous year. For this year, the government targets public electricity consumption to increase to 1,129 kwh/capita.

Phase change materials (PCM) are functional materials that can physically change to store and release heat energy during heating and cooling processes. PCM can be classified into solid-solid, solid-liquid, gas-solid, and liquid-gas PCM according to the phase transition mechanism[5][6]. Among them, solid-liquid PCM is the most widely used because of its large latent heat and small volumetric change during phase transition. Solid-liquid PCM mainly includes organic PCM (such as paraffins, fatty acids), and inorganic PCM (such as hydrated salts). Phase change materials or hereinafter known as Phase Change Materials (PCM), which are often referred to as materials that can store latent heat, are materials that have the ability to release very high heat energy for a long period of time without changing temperature[7-9].

One of the phase change materials that can be used as heat energy storage is paraffin. The availability of very abundant paraffin at a very economical price, easy to obtain and non-toxic, and has a fairly high latent heat of 200-250 kJ/kg with a melting temperature of 24 , suitable to be combined with metal materials and non-corrosive so that the heat transfer is very high. Awake[10]. Although paraffin exhibits desirable properties as PCM, polymers and paraffins have a lower thermal value of 0.2 W.m.K. Therefore, the addition of exposed graphite serves to increase their thermal conductivity and also to overcome the low heat transfer rate. Adding a small portion of expanded graphite to the mixture by extrusion can increase the thermal conductivity of PCM[11-12].

EPDM consists of alkanes with low melting temperatures, these alkanes can be combined well with paraffins to form mixtures with lower melting temperatures. The ethylene-propylene-diene polymer can improve the compatibility of the Phase changer material[13]. The ethylene-propylene-diene polymer can be changed in the material. The phase changer in the narrow space to improve the mechanical properties, and the optimal ratio of the ethylene-propylene-diene copolymer can increase the dispersion of the expanded graphite to increase the thermal conductivity[14-15].

Usually PCM is adsorbed with porous materials such as expanded graphite, form

graphite, CNT Array and 3D graphite to form a phase change composite. Phase change composites have greater thermal stability, which can largely increase the rate of charge/discharge of thermal energy in thermal utilization systems. In addition, the phase change composite with carbon-based materials has good optical extinction properties, the photo-thermal performance of the phase change composite can be greatly improved, so that the phase change composite can directly absorb solar energy and transfer to water or other heat transfer fluids. Carbon-based phase change composites used as optical and thermal acceptors have been reported in previous studies [16-18].

This study aims to determine the effect of the paraffin: graphite ratio on the thermal resistance of the Phase Change Material (PCM) using the heating method at 180oC for 20 minutes with a variation of the ratio 9:1 and 8:2 with several mass ratios PCM and EPDM. he Phase Changing Material is miscible with other polymers such as Ethylene Propylene Diene Monomer (EPDM) which has good compatibility with paraffins. Prepared PCM with good mechanical properties, good EPDM mixture is used as a base polymer for preparing paraffin graphite composites. The obtained PCM would have high tensile strength, high thermal conductivity, and large latent heat.

Materials and Methods

1. Ingredients

Technical grade of paraffin (OP70, T m from ~ 65°C). Expanded graphite (EG). Ethylene propylene diene monomer rubber (EPDM). All chemicals were used as received without further purification in cations.

2. Paraffin and Graphite EPDM PCM Preparation

Preparer Paraffin, Graphite and EPDM Materials. Mixing with a fixed ratio of EPDM gel using a DSM Xplore co-rotating extruder at a melting temperature of 180ºC and a screw speed of 100 rpm. PCM EPDM polymers with various 9:1 and 8:2 fillers were mixed in a ratio of 70%:30% (PCM70-EPDM30) where each total mixture weighed 20 grams to ensure full filling of the extruder. Also prepare 80%:20% and 90%:10% polymers with filler variations of 9:1 and 8:2 from the total weight of the mixture as a comparison sample. Next, the PCM (Paraffin: Graphite) + EPDM polymer mixture was inserted into the ASTM 638 D-Type I Standard specimen mold which was coated with aluminum foil. Then compaction (compressing) with a Hot Press tool at a temperature of 180 for 20 minutes under atmospheric pressure.

3. Characteristics of PCM

The material that has been formed is left at room temperature until it solidifies completely. Test the mechanical properties of Tensile Strength with the UTM Exceed Model E43. Thermal Stability and Morphological Analysis of New Material PCM + EPDM Using SEM JSM-6510 LA. The material that has been formed is allowed to stand at room temperature until it solidifies completely SEM JSM-6510 LA.

4. *Thermo Gravimetric Analysis (TGA) Characterization*

The manufacture of these composites requires mixing the filler and matrix at high temperatures, so that the degradation effect on the properties of the filler-containing material can be calculated. Research has analyzed the thermal stability studies of PCM EPDM composites through TGA. The direct evidence of the perfect interaction is the increase in heat resistance through TGA (Thermal Gravimetric Analysis) testing, namely the onset temperature from 200 for pure PCM increases to 399.50ºC for EPDM based PCM.

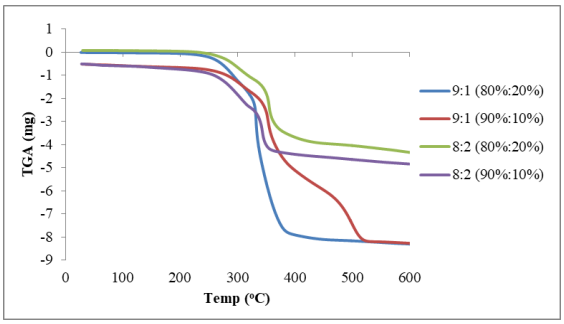

Figure 1. TGA analysis chart on sample (——) 9:1 (80%:20%, Sample (——) 9:1(90%:10%), Sample (——) 8:2 (80%:20%), and Sample (——) 8:2 (90%: 10%) Against Temperature

Figure 1 above is a plot of the decrease in mass on the y-axis and the increase in the ratio on the x-axis. The graph shows that all PCM EPDM samples undergo single decomposition because the onset and endset only occur once. Onset is the temperature at which the sample begins to degrade thermally and endset is the temperature at which the sample retains its mass from the combustion reaction. The degradation temperature of EPDM PCM in this study was in the range of 250°C-400°C. Based on Figure 3.1, Pure PCM begins to decrease in mass at a temperature of 200 [19]. PCM with the addition of 20% and 30% EPDM at a comparison of 9:1 and 8:2 began to degrade at a temperature of 307.04°C, respectively; 293.85°C ; 303.29°C and 293.09°C. These results indicate that the addition of EPDM in Paraffin: Graphite polymer succeeded in increasing the thermal stability compared to pure PCM without mixing. The higher the concentration of filler added, the better the thermal stability of the material, which is characterized by an increase in the degradation temperature. The increase in degradation temperature is caused by the bond in the polymer and filler which is fused more strongly so that it is difficult to break and the decomposition of the material becomes slower. The study with the maximum degradation temperature was shown by PCM with the addition of 20% EPDM at 307.04°C. While the PCM study with the addition of 10% EPDM is the lowest with a degradation temperature of 293.09 °C.

The effect of the paraffin:graphite ratio on increasing thermal stability where the more paraffin the thermal stability decreases because when the temperature rises to 200, paraffin will decompose completely, while EPDM polymer does not decompose below 250, and completely decomposes up to 300, Graphite has a temperature much higher decomposition, so the residue of the TGA test is graphite. It is proven that EPDM with a ratio of 9:1 with a mass ratio of 80%:20% can be combined with paraffin and graphite as the latest matrix and filler innovation to improve the thermal properties of PCM materials.

5. Tensile Test Results with Universal Tensile Test Machine (UTM)

At this stage, a tensile strength test (Tensile Strength) will be carried out on the PCM EPDM sample which aims to determine the effect of the mass ratio of paraffin: graphite into EPDM on the mechanical characteristics of the tensile strength (Tensile Strength) of the material. The observational data on the tensile strength test results are shown in Table 3.1.

Table 1. Tensile Strength Test Results Data Table with Universal Tensile Text Machine (UTM) Tool

Comparison Paraffin : Graphite	Mass Ratio (Paraffin : Graphite) : EPDM	Tensile Strength Test (Mpa)
9:1	70 % : 30%	3,4
	80% : 20%	3,9
	90% : 10%	3,2
8:2	70 % : 30%	2,8
	80% : 20%	3
	90% : 10%	2,2

From Table 1. it is known that the tensile strength of the EPDM PCM obtained ranges from 2.5 to 3.9 MPa.

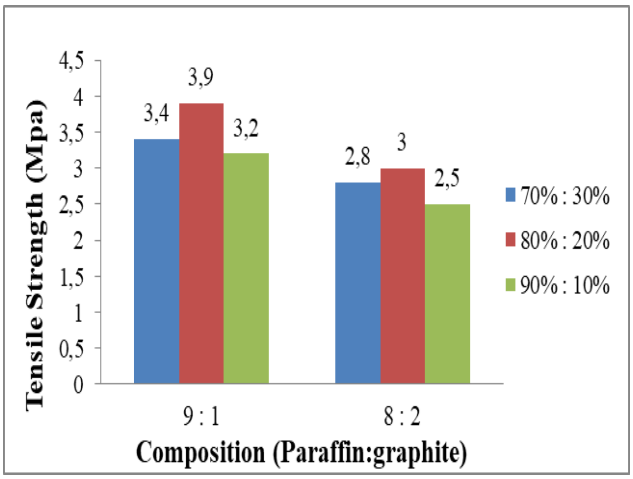

Figure 2. Comparative Variation Graph (Paraffin: Graphite): EPDM VS Strong Value Tensile Strength (MPa) on the EPDM PCM.

Figure 2. shows a graph of the relationship between Comparative Variations (Paraffin: Graphite): EPDM vs. tensile strength values measured in % with tensile strength values (Tensile Strength) in MPa units on PCM EPDM. From the graph above, it can be seen that the sample with 80%:20% PCM EPDM at a ratio of 9:1 has a better tensile strength to the polymer when compared to other polymers. However, the addition of filler has a threshold, when it exceeds the acceptable threshold for a polymer, what happens is that the polymer becomes brittle and weak, so an ideal filler composition is needed.

The Tensile Strength value of the six samples is in the range of 2.5 to 3.9 MPa, while the Tensile Strength PCM EPDM value at a ratio of 9:1 with a variation of 70%:30% has a maximum tensile strength of 3.4 MPa. The graph above shows that the Tensile Strength of the EPDM PCM sample at a ratio of 9:1 with a variation of 80%:20% is the highest tensile test value compared to other samples, which is 3.9 MPa, in the PCM EPDM sample with a mass ratio of 80%:20 % at a ratio of 8:2 The tensile strength reaches 3.2 MPa. Meanwhile, PCM EPDM with the addition of 30% EPDM has the lowest Tensile Strength value, this also occurs in PCM polymers. and PCM at a ratio of 8:2 with the addition of 10%, 20%, 30% EPDM filler, which are 2.8 respectively; 3 and 2.2 MPa, this figure is also the lowest Tensile Strength value of the six composites formed. The decrease in the tensile strength value is due to the composition of the EPDM filler having exceeded the threshold level, namely because the ratio of mass ratio is 8:2 which shows that the mechanical properties of tensile strength and stiffness in PCM can be increased by adding 10%-30% EPDM into the polymer. Effectively improve mechanical properties, if it exceeds 10%-30%, it will decrease its tensile strength and also for too long the sample is in the melting device which causes the crosslink bond in the polymer to decrease by high temperature so that it affects the tensile strength which should increase.

6. Morphological Structure Test Results with Scanning Electron Microscape (SEM)

Scanning Electron Microscopy (SEM) is used as a morphological analysis technique that can identify the surface of a material with a higher resolution than conventional optical microscopes. This method makes it easier for researchers to observe what happens in and around the interface between the material and the oxide layer in detail. The morphology of the EPDM PCM microstructure was observed using a SEM tool as evidenced by SEM photos in Figure 3.

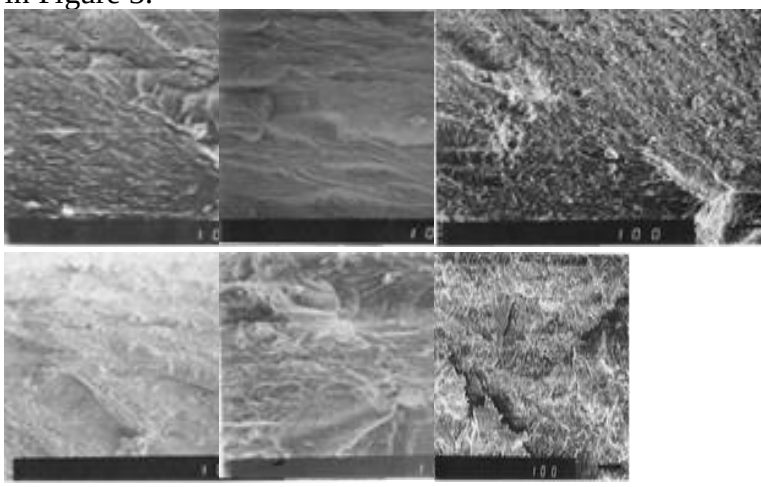

Figure 3. SEM test results

Magnification of x100 shows that the six structures have very large differences, namely the PCM sample with a ratio of 9:1 at a mass ratio of 80%:20% has a smoother surface and forms a good interfacial bond between the matrix and filler compared to the PCM matrix with a ratio of 9:1 at a mass ratio of 90%:10% which indicates some form of agglomerate and large pores, as well as a rough surface.

This happens because based on the research in the study [20] which ha.been carried out in

previous studies, that the surface of the EPDM PCM sample turns rough with the increase in the mass fraction of the EPDM PCM. PCM EPDM has a structure where PCM EPDM has a large tensile strength with a larger mass fraction than Pure PCM. EPDM can provide a continuous composite structure, so that the sample has a large elongation at break with a large EPDM mass fraction.

If it is associated with the tensile test and thermal degradation test, the results of this SEM test are also correlated where the surface structure of the PCM composite with a ratio of 9:1 at a mass ratio of 80%:20% is the best because it produces good tensile strength and thermal stability as well.

Conclusions

The effect of the paraffin:graphite ratio on the increase in thermal stability is where the more paraffin the thermal stability decreases, and the higher the concentration of filler added, the better the thermal stability of the material where in a ratio of 9:1 with a mass ratio of 80%:20%, 307.04^{o}C Onsite and Endset at 399.50 ^{o}C. The higher the tensile strength value, the better the polymer, but the addition of filler has a threshold accepted by the polymer. Based on the results of the tensile test, it is shown that the PCM composite at a mass ratio of 9:1 with a mass ratio of 80%:20% is the optimal filler composition for PCM composites with a tensile strength value of 3.9 MPa. While the results of the Surface Morphology test using SEM, the surface turns rough with increasing PCM EPDM fraction, the best interaction between composites with a mass ratio of 80%:20% at a ratio of 9:1, with a very well mixed surface, smooth, no lumps formed.

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Competing Interest

All authors confirmed there is no conflict of interest.

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