OPTIMIZATION OF MWCNT MIXTURE IN MICROPCM COMPOSITE FOR THERMAL PERFORMANCE TESTING AT DIFFERENT AMBIENT TEMPERATURE

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DECLARATION

I declare that this thesis entitled "Optimization of MWCNT Mixture in microPCM Composite for Thermal Performance Testing at Different Ambient Temperature" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :...

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Enginering.

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DEDICATION

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ABSTRACT

The novel thermal management system using phase change material (PCM) is an effective way of latent heat storage as cooling application. Latent heat storage enables high energy storage density which reduces the footprint of the system and the cost. However, PCM has very low thermal conductivity making it unsuitable for large scale use without enhancing the effective thermal conductivity. In order to address this problem, multiwall carbon nanotube (MWCNT) has been impregnated into PCM to form a viable materials for thermal management system. The objective of this study was to investigate the thermal performances of microPCM/MWCNT and its properties includes mechanical and thermal properties. Basically, the composite was formed into dics shape sizing 30 mm diameter and 5 mm width using compactions technique. The composite was prepared with different mass fraction of MWCNT of 2, 4, 7, 10 wt% to obtain optimized mass fraction of composites. The thermal test was conducted based on modified ASTM standard. Thermal conductivity and latent heat capacity were calculated based on theoretical equations. Then, thermal performance test were performed at different ambient temperatures of 15, 27, 35 and 45˚C. From the study, it is interesting to find that the temperature of aluminum module,immitation of battery module was successfully reduced by attaching microPCM/MWCNT composite. It is shown in this thesis that successful implementation of thermal materials in alleviates peak energy load .

ABSTRAK

Sistem pengurusan haba baru menggunakan microencapsulated Phase Change Material (microPCM) adalah cara yang berkesan untuk penyimpanan haba pendam sebagai aplikasi penyejukan.. Penyimpanan haba pendam membolehkan kepadatan simpanan tenaga yang tinggi yang dapat mengurangkan kesan kepada sistem dan kos. Walau bagaimanapun, microPCM mempunyai kekonduksian haba yang sangat rendah menjadikannya tidak sesuai untuk penggunaan berskala besar tanpa meningkatkan kekonduksian haba yang berkesan. Bagi menangani masalah ini, Multiwall Carbon Nanotube (MWCNT) telah dicampur ke microPCM untuk membentuk bahan yang berdaya maju untuk sistem pengurusan haba. Objektif kajian ini adalah untuk mengkaji prestasi haba microPCM / MWCNT dan sifat-sifatnya termasuk sifat-sifat fizikal-mekanikal dan termal. Pada asasnya, komposit itu dibentuk menjadi bentuk disk bersaiz 30 mm diamter dan 5 mm tinggi menggunakan teknik compactions. komposit ini telah disediakan dengan pecahan jisim MWCNT yang berbeza iaitu 2, 4, 7, 10% untuk mendapatkan pecahan jisim komposit yang terbaik. Ujian termal telah dijalankan berdasarkan piawaian ASTM yang diubah suai. Kekonduksian termal dan kapasiti haba pendam dikira berdasarkan persamaan teori. Kemudian, ujian prestasi termal telah dijalankan pada suhu persekitaran yang berbeza daripada 15, 27, 35 dan 45˚C. Dari kajian ini, ia adalah menarik untuk mendapati bahawa suhu modul aluminium, sebagai simulasi modul bateri telah berjaya dikurangkan dengan meletakkan komposit microPCM / MWCNT. Ia dipaparkan dalam hasil kerja ini bahawa kejayaan pelaksanaan bahan termal dalam mengurangkan beban haba yang tinggi.

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MicroPCM	-	Microencapsulated Phase Change Material
MWCNT	-	Multiwall Carbon Nanotube
EV	-	Electric Vehicle
HEV	-	Hybrid Electric Vehicle
BEV	-	Battery Electric Vehicle
PHEV	-	Plugin Hybrid Electric Vehicle
Pb-A	-	Lead Acid
NiMH	-	Nickel Metal Hydride
Li-Ion	-	Lithium-Ion
Avg	-	Average
SOC	-	State of Charge
TMS	-	Thermal Management System
LHU	-	Latent Heat Unit
GHG	-	Greenhouse Gas
ICE	-	Internal Combustion Engine
USABC	-	US Advanced Battery Consortium
SLI	-	Starting, Lighting and Ignition
FCV	-	Fuel Cell Vehicles
EMA	-	Ethylene Maleic Anhydride
HCI	-	Hydrochoric Acid
SWCNT	-	Single Wall Nanotube
MPCS	-	Phase Change Materials Slurries
DSC	-	Diffrential Scanning Calorimetry

A	-	Heat transfer area
C	-	Constant current rate (1C=15A)
Cp	-	Specific heat capacity
h	-	Entalphy
I	-	Current
m	-	Mass
k	-	Thermal conductivity
L	-	Length
Q	-	Heat generation
W	-	Watt
T	-	Temperature
K	-	Kelvin
V	-	Voltage
W	-	Watts
J	-	Joule
kg	-	kilogram
H	-	hours
Pa	-	Pascal
t	-	Tickness

LIST OF PUBLICATIONS

JOURNAL

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CONFERENCE ATTENDED

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Abdullah A.Z.I., Abdollah M.F.B., Tuan T.B., Amiruddin H., Yamin A.K.M, Tamaldin N. Thermal performance of carbon-based microencapsulated phase change materials. Proceedings of Mechanical Engineering Research Day 2015, pp. 17-18, March 2015.

LIST OF AWARD

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CHAPTER 1

INTRODUCTION

1.1 Background

An alternative fuel vehicle is a vehicle that runs on a fuel other than traditional petroleum fuels and also refers to any technology of powering an engine that does not involve solely petroleum. Alternative fuel vehicle development continues to grow due to fuel consumption and environmental friendly. It has promise a significant reduce especially in petroleum consumption, operating cost and greenhouse gas (GHG). Plug-in vehicle is one of the options which combine the fuel and electricity technologies. In plug –in vehicle system, battery pack is the most expensive component in the vehicle, which needs to be reduced to make the plug-in vehicle more competitive compare to other vehicles. Furthermore, the good battery needs to be efficient of power, energy, weight, size and life. Several of battery types are being tested and evaluated, of which Lithium Ion (Li-on) battery is, so far, the most promising. This is because of its high energy density. One of plug-in vehicle type is electric vehicles (EV).The major issue for EV battery module is thermal management of battery module that lead to performance, battery life and safety concern. The high energy of Li-on is needed for high power applications of EVs. The high usage of Li-on battery will lead the battery modules to premature aging, accelerated capacity fade, and over heat. Therefore, a passive thermal management is essential to control the battery operating temperature for optimal performance of HEVs. Researchers have proposed Phase Change Material (PCM) as promising candidate for cooling material because of its high latent heat capacity, make PCM capable in removing large quantities of heat generated by the battery modules. PCM has also proper thermal characteristics such as no super cooling, low vapor pressure, chemical stability and self-nucleating behavior. By this unique characteristic, PCM is widely tested to solve the problem especially in thermal energy storage systems, thermal insulator and temperature control.

However, PCM has disadvantage in low thermal conductivity, which means the heat absorbed by PCM is slow and inefficient. The researches were focused on this problem. Encapsulated phase change material is one of enhanced phase change material by encapsulating PCM, commonly paraffin in polymeric network structure to obtain form-stable structure. The polymeric structures prevent the leakage of PCM during solid – liquid phase, therefore it can be used in applications widely without need extra encapsulation. However, polymer wall of the PCM with low thermal conductivity will decrease heat transfer capability. Therefore, the high thermal conductivity materials need to be added to PCM as to increase its thermal conductivity. It is difficult to form an ideal enhanced PCM to satisfy all the desirable properties. The enhanced phase change material were proposed in many studies by using different methods and materials such as placing fins in PCM structure, adding metallic structure, impregnate porous material and dispersing high thermal conductivity materials in PCM. Adding materials with high thermal conductivity is an alternative in enhancing the thermal conductivity of PCM but it gradually result the lower thermal performance in the long – term period because of size and surface property of addictive. It also add significant weight to the system. Nano technology developed the nano scale addictive which can solve the problem where the carbon nanotube is viable options as its high of thermal conductivity. Nano particle of carbon nanotube can be impregnated in PCM structure and react in holding the PCM when PCM reach it melting point.

In this study, microencapsulated phase change material/multiwall carbon nanotube (microPCM/MWCNT) composites are suggested as the battery module materials in order to improve the temperature distribution of battery, thus it could provide a better solution in optimizing the overall performance and life span of the battery. Thermal performance test based on modified ASTM C518-10 is conducted to study on thermal effectiveness of the microPCM/MWCNT composites. Later, the data will be analyzed and recommendations are made at the end of the study.

1.2 Problem Statement

The performance and life-cycle costs of electric vehicles (EV) and hybrid electric vehicles (HEV) depend inherently on energy storage systems such as batteries. Battery pack performance directly affects the all-electric (zero-emission) range, power for acceleration, fuel economy, and charge acceptance during energy recovery from regenerative braking. As the battery pack reliability depends on it cost, durability, and life, any parameter that affects the battery pack must be optimized. To optimize the performance of a battery pack, the thermal management system should deliver;

a) Optimum operating temperature range for all modules

b) Small temperature variations within a module

c) Small temperature variations among various modules.

d) Compact and lightweight

e) Low cost

The use of phase change material (PCM) as cooling medium has been suggested in recent year (NREL, 2004). However, majority of the commercial PCM have relatively low thermal conductivity; typical value ranges in between 0.2W/mK and 0.7W/mK (Hauer, et al., 2005). This characteristic marks the low thermal performance and creates possible non-matching between thermal power supply and demand. Heat transfer enhancement techniques that provide sufficient thermal power are thus vital to ensure proper operation in the thermal management system. For thermal properties, examples are blending with highly conductive powders, notably carbon nanotube powder. In order to select the best qualified PCM and carbon based powder as a cooling material. Some criteria's required (Vitorino et al, 2016) as listed below:

a) The melting point of the PCM must be in a practical range of operation. Temperature interval going from 25 °C to 70 °C
b) The latent heat should be as high as possible to minimize the physical size of the heat storage.
c) A high thermal conductivity would assist the charging and discharging of the thermal system

To summarize, the need of optimal performance of a battery pack are some of the pressing issues that leads to the need for better thermal management system. However, this is not an easy task, as there are many requirements must be meted by thermal materials to be qualified as a better thermal management system. Thus this study will proposed the combination of micro-encapsulated Phase Change Material (microPCM) and Multiwall Carbon Nanotube (MWCNT) to form the high thermal properties material for better thermal management system.

1.3 Objectives

In summary, the objectives of this study are as follows:

a) To determine the thermal and material properties of microPCM/MWCNT composites.

b) To determine the optimal mass fraction of MWCNT in microPCM for thermal properties improvement.

c) To investigate the thermal performance of microPCM/MWCNT composites at different ambient temperatures of 15, 27, 35 and 45˚C.

1.4 Researches Scopes

The scope of this study are:

a) Use MWCNT as thermal enhancement material

b) The effect of microPCM/MWCNT were studied in range of 2-10% weight ratio

c) The ambient temperature for testing in the range of 15 to 45˚C by using modified heating and cooling chamber

d) Use direct dispersion method for compressing the specimen

e) Test on simulated heating module instead of real battery

f) MicroPCM/MWCNT studied will be in terms of materials and thermal properties.