Faculty of Mechanical Engineering

INVESTIGATION ON THE EFFECT OF MULTI FILLER LOADING IN GRAPHITE-POLYPROPYLENE COMPOSITE AS BIPOLAR PLATE

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DECLARATION

I declare that this thesis entitled "Investigation on The Effect of Multi Filler Loading In Graphite-Polypropylene Composite as Bipolar Plate" 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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Date :..

APPROVAL

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

Signature	:………………..
Supervisor Name	: Associate Professor Dr. Mohd Zulkefli Bin Selamat
Date	:………………………..

DEDICATION

To my beloved family

ABSTRACT

Materials used to fabricate the bipolar plates for Polymer Electrolyte Membrane Fuel Cell (PEMFC) need to have a good set of criteria such as light, strong, low-cost, easily fabricated, mechanically stable, and have low surface contact resistance. Additionally, PEMFC"s performance is much influenced by the materials used, type of flow channel design and shape to be fabricated on the bipolar plate surface. In this study, the fabrication of flow channel through hot compression molding method is developed. All materials used were in powder form, which are Graphite (G), Carbon black (CB) and Ferum (Fe) as fillers and the Polypropylene (PP) that acts as binder. The ratio of fillers (G/CB/Fe) and binder (PP) was fixed at 80:20. The fillers ratio was fixed in the range of (25 up to 65 wt%) G, (10 up to 30 wt%) CB and (5 up to 25 wt%) Fe and all fillers were mixed by using the ball mill machine. The second stage of mixing process is between the mixer of fillers and binder, which was mixed by using internal mixer machine. Subsequently, the compaction process through hot compression molding is done to produce G/CB/Fe/PP composite. Then, the in-plane electrical conductivity and mechanical properties such as flexure strength, bulk density and shore hardness is measure. Based on electrical conductivity, flexure strength, bulk density and shore hardness, sample with 15 wt% of Fe, has shown as the best result that is 137.39 S/cm^3, 34.04 MPa, 1.582 g/cm^3, 53.14 respectively. During hot compression molding process, at the same time the flow channel of serpentine type, cooling channel and the shapes of U or V shapes is pressed on the surface of the sample of bipolar plate. Thus, flow channel was investigated for accuracy of surface condition of flow channel dimensions (used coordinate measurement machine) and subsequently, compared with the actual drawings and it"s process ability. Meanwhile based on the analysis of flow channel dimensions (width, depth, rib, angle draft), the V shape is shown to give a smooth surface, with the dimensions difference between samples and drawing of about 0.118 up to 0.27%. While for the process ability, the V shape is much easier to release from the mold. As a summary, this study revealed that the flow channel dimensions (width, depth, rib, angle draft) and coling channel with V shape can be fabricated through hot compression molding method with high accuracy.

ABSTRAK

*Secara umum, bahan yang digunakan untuk fabrikasi plat dwikutub Polymer Electrolyte Membrane Fuel Cell (PEMFC) hendaklah mempunyai kos yang rendah, mudah direka, ringan, kuat, mekanikal stabil, dan mempunyai rintangan sentuhan permukaan yang rendah. Selain itu, prestasi PEMFC ini banyak dipengaruhi oleh bahan-bahan yang digunakan, jenis reka bentuk saluran aliran dan bentuk yang akan dibina di atas permukaan plat bipolar. Dalam kajian ini, pembuatan saluran aliran melalui kaedah pengacuan mampatan panas. Semua bahan-bahan yang digunakan adalah dalam bentuk serbuk, Grafit (G), Karbon hitam (CB) dan Ferum (Fe) sebagai pengisi dan Polypropylene (PP) yang bertindak sebagai pengikat. Nisbah pengisi (G/CB/Fe) dan pengikat (PP) telah ditetapkan pada 80:20. Nisbah pengisi telah ditetapkan dalam julat (25 sehingga 65% berat) G, (10 sehingga 30% berat) CB dan (5 sehingga 25% berat) Fe dan semua pengisi diaduk dengan menggunakan mesin kempa bola. Peringkat kedua proses pencampuran adalah antara campuran pengisi dan pengikat, yang diaduk dengan menggunakan mesin pengadun dalaman. Selepas itu, proses pemadatan melalui pengacuan mampatan panas dilakukan untuk menghasilkan G/CB/Fe/PP komposit. Kemudian, kekonduksian dalam satah elektrik dan sifat-sifat mekanikal seperti kekuatan lenturan, ketumpatan pukal dan kekerasan diukur. Berdasarkan kekonduksian elektrik, kekuatan lenturan, ketumpatan dan kekerasan, sampel 15% Fe telah menunjukkan hasil yang terbaik iaitu 137.39 S/cm, 34.04MPa, 1.582 g/cm^3, 53.14 masing-masing. Semasa proses pengacuan mampatan, pada masa yang sama saluran aliran jenis serpentine dipilih, saluran penyejukan bentuk U atau bentuk V ditekan pada permukaan sampel plat dwikutub. Oleh itu, saluran aliran telah dikenalpasti ketepatan permukaan dimensi saluran aliran (menggunakan mesin koordinat pengukuran) dan kemudiannya, dibanding dengan lukisan sebenar untuk mengetahui keupayaan proses. Sementara itu berdasarkan analisis dimensi saluran aliran (lebar, kedalaman, tulang rusuk, sudut draf), bentuk V ditunjukkan untuk memberikan permukaan yang licin, dengan perbezaan dimensi antara sampel dan lukisan kira-kira 0.118 sehingga 0.27%. Manakala bagi keupayaan proses, bentuk V adalah lebih mudah untuk melepaskan dari acuan. Sebagai ringkasan, kajian ini mendedahkan bahawa saluran aliran (Lebar, kedalaman, tulang rusuk, sudut draf) dan penyejukan saliran dengan V bentuk boleh direka melalui kaedah pengacuan mampatan panas dengan ketepatan yang tinggi.***

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LIST OF ABBREVIATIONS AND SYMBOLS

PEMFC	-	Proton exchange membrane fuel cell
CPCs	-	Conductive polymer composite
ICPs	-	intrinsically conducting polymers
G	-	Graphite
CB	-	Carbon Black
CNTs	-	Carbon Nanotubes
CF	-	Carbon Fiber
PP	-	Polypropylene
DOE	-	Department of Energy
SEM	-	Scanning Electron Microscope
DMFC	-	Direct methanol fuel cell
AFC	-	Alkaline fuel cell
PAFC	-	Phosphoric acid fuel cell
MCFC	-	Molten carbonate fuel cell
SOFC	-	Solid oxide fuel cell
MEA	-	Membrane electrode assemblies
GDL	-	Gas diffusion layer
PVDF	-	Polyvinylidene fluoride
PEEK	-	Polyether ether ketone
PET	-	Polyethylene terepthalate
DSC	-	Differential Scanning Calorimetry
TGA	-	Thermo-Gravimetry Analysis
MWNTs	-	Multi-walled Nanotubes
SWNTs	-	Single-walled Nanotubes
MA	-	Maleic anhydride
EG	-	Exfoliated graphite

xGnPs	-	Exfoliated graphite nanoplatelets
TEM	-	Transmission electron microscopic
ASTM	-	American Standard Test Method
LC	-	Low degree of crystallinity
MC	-	Medium degree of crystallinity
SSs	-	Stainless steels
Eq.	-	Equation
H_2	-	Hydrogen
O_2	-	Oxygen
e^-	-	Electron
wt.%	-	Weight percentage
Scm^{-1}	-	Siemen/centimeter
cm	-	centimeter
μA	-	micron Ampere
MPa	-	Mega Pascal
mK	-	mili Kelvin
°C	-	Degree Celcius
g/cm^3	-	gram/centimeter^3
~	-	is equavalent to
<	-	is less than
>	-	is greater than
Φc	-	percolation threshold
σ_m	-	maximum electrical conductivity
F	-	filler
σ_p	-	conductivity of the polymer matrix
vol.%	-	Volume Percentage
psi	-	pound per square inch
e.g.	-	example
Ωm	-	ohm meter
nm	-	nanometer
Ω cm	-	ohm centimeter
g	-	gram
rpm	-	Revolutions per Minute

mm	-	milimeter
x	-	multiplied by

LIST OF PUBLICATIONS

JOURNAL PAPER

1. **M.Y M. Yusuf**, M.Z. Selamat, J. Sahari, M.A M. Daud, M. M. Tahir,H.A Hamdan. *Fabrication Of A Flow Channel For Production Of Polymer Composite Bipolar Plate Through Hot Compression Molding*. Journal of Mechanical Engineering and Sciences (JMES) UMP. 2017. DOI: http://doi.org/10.15282/jmes.11.1.2017.3.0224
2. Mohd Zulkefli Selamat, Farhana Masron, **Muhammad Yusri Md Yusuf** and Anita Akhmar Kamarolzaman Musthafa Mohd Tahir and Safaruddin Gazali Herawan *Effect Of Stannum On Properties Of Graphite/Stannum Composite For Bipolar Plate.* Applied Mechanics and Materials, Vol. 699, pp. 157-162, 2015. DOI: https://doi.org/10.4028/www.scientific.net/AMM.699.157

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1. **M.Y M. Yusuf**, M.Z. Selamat, J. Sahari, M.A M. Daud, M. M. Tahir, H.A Hamdan *Manufacturing Of Flow Channel For Production Of Polymer composite Bipolar Plate Through Hot Compression Molding ICEI2016.*
2. Mohd Zulkefli Selamat, **Muhammad Yusri Md Yusuf**, Tio Kok Wer, Siti Norbaya Sahadan, Sivakumar Dhar Malingam, and Noraiham Mohamad *Effect of formation temperature on properties of graphite/stannum composite for bipolar plate.* AIP Conference Proceedings 1717, 040022 (2016).

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CHAPTER 1

INTRODUCTION

1.1 Background

The Proton Exchange Membrane Fuel Cell (PEMFC) is a zero production control source, which has high proficiency, low temperature operation, and high power density. Bipolar Plate is one of the crucial piece of PEMFC which supplies hydrogen (reactant) and oxygen (oxidant) to responsive region, evacuate water, gather delivered momentum and gives mechanical support to Membrane Electrode Assembly (MEA) in power device stack (Aiyejina et al., 2012). Bipolar plate serves as one of the main components in PEMFC. It serves many functions such as connecting cells, separating reactants and oxidants in adjoining cells, providing mechanical strength to the fuel cell and housing the flow channel for the pathways of gases. (Heinzel, et al, 2009)

The fuel cell performance heavily depends on the design of the fuel stack and choice of materials. The components of the fuel stack such as the catalyst, gas diffusion layer (GDL), Membrane Electrode Assembly (MEA) and bipolar plates affect the performance of the fuel cell (Antunes et al., 2011). Developing and producing these components consume time. Additionally, they are expensive. Thus, using other variation such as stack compression, flow channel geometry, manifold design and operating protocol give better result as compared to varying the main components (Kim etal., 2007).