



## **Faculty of Mechanical Engineering**

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

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

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**A thesis submitted  
in fulfillment of the requirements for the degree of Master of Science in Mechanical  
Engineering**

**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2018**

## 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.

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## 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.

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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  $137.39 \text{ S/cm}^3$ ,  $34.04 \text{ MPa}$ ,  $1.582 \text{ g/cm}^3$ ,  $53.14$  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<sup>3</sup>, 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 saluran dengan V bentuk boleh direka melalui kaedah pengacuan mampatan panas dengan ketepatan yang tinggi.*

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## TABLE OF CONTENTS

|  | <b>PAGE</b> |
|--|-------------|
| <b>DECLARATION</b>                                 |             |
| <b>APPROVAL</b>                                    |             |
| <b>DEDICATION</b>                                  |             |
| <b>ABSTRACT</b>                                    | <b>i</b>    |
| <b>ABSTRAK</b>                                     | <b>ii</b>   |
| <b>ACKNOWLEDGEMENTS</b>                            | <b>iii</b>  |
| <b>TABLE OF CONTENTS</b>                           | <b>iv</b>   |
| <b>LIST OF TABLES</b>                              | <b>vii</b>  |
| <b>LIST OF FIGURES</b>                             | <b>ix</b>   |
| <b>LIST OF APPENDICES</b>                          | <b>xiii</b> |
| <b>LIST OF ABBREVIATIONS AND SYMBOLS</b>           | <b>xiv</b>  |
| <b>LIST OF PUBLICATIONS</b>                        | <b>xvii</b> |
| <br>   |             |
| <b>CHAPTER</b>                                     |             |
| <b>1. INTRODUCTION</b>                             | <b>1</b>    |
| 1.1 Background                                     | 1           |
| 1.2 Problem Statement                              | 5           |
| 1.3 Objectives                                     | 7           |
| 1.4 Scope  | 7           |
| 1.5 Thesis Layout                                  | 8           |
| <br>   |             |
| <b>2. LITERATURE REVIEW</b>                        | <b>10</b>   |
| 2.1 Overview of Fuel Cell                          | 10          |
| 2.2 Types of Fuel Cells                            | 11          |
| 2.3 Proton Exchange Membrane Fuel Cell (PEMFC)     | 13          |
| 2.4 PEMFC Fuel Cell Component                      | 15          |
| 2.4.1 Ionomer Membrane (MEA)                       | 15          |
| 2.4.2 Electrode                                    | 17          |
| 2.4.3 Gas Diffusion Layer (Porous Transport Layer) | 20          |
| 2.4.4 Bipolar Plates                               | 22          |
| 2.5 Types of Bipolar Plates                        | 24          |
| 2.5.1 Metallic Bipolar Plates                      | 24          |
| 2.5.2 Pure Graphite Bipolar Plates                 | 25          |
| 2.5.3 Conducting Polymer Composite (CPC)           | 25          |
| 2.6 Percolation Theory                             | 27          |

|           |   |           |
|-----------|---|-----------|
| 2.7       | Flow Channel                                  | 29        |
| 2.7.1     | Pin Type Flow channel                         | 30        |
| 2.7.2     | Parallel Type Flow channel                    | 30        |
| 2.7.3     | Interdigitated Type Flow channel              | 31        |
| 2.7.4     | Serpentine Type Flow channel                  | 32        |
| 2.8       | Shape of Flow Channel                         | 34        |
| 2.9       | Cooling Channel                               | 35        |
| 2.10      | Fabrication Method of Flow Channel            | 36        |
| 2.10.1    | Machining                                     | 36        |
| 2.10.2    | Injection Molding                             | 38        |
| 2.10.3    | Hot Compression Molding                       | 40        |
| 2.11      | Factors Affecting Flow Channel                | 41        |
| 2.12      | Recent Development on Composite Bipolar Plate | 42        |
| 2.13      | Research Focus                                | 43        |
| <b>3.</b> | <b>METHODOLOGY</b>                            | <b>45</b> |
| 3.1       | Flow Chart of Fabrication Method              | 46        |
| 3.2       | Material Selection                            | 47        |
| 3.3       | Raw Materials of Bipolar Plate                | 48        |
| 3.3.1     | Natural Graphite                              | 48        |
| 3.3.2     | Carbon Black (CB)                             | 50        |
| 3.3.3     | Iron Powder                                   | 52        |
| 3.3.4     | Electrical Conductive Thermoplastic Composite | 53        |
| 3.4       | Electrical Conductive Thermosetting Composite | 55        |
| 3.5       | Process of Fabrication Bipolar Plate          | 55        |
| 3.5.1     | Pre-Mixing of Raw Materials                   | 56        |
| 3.5.2     | Compounding                                   | 56        |
| 3.5.3     | Pulverizing                                   | 57        |
| 3.5.4     | Compression Molding                           | 58        |
| 3.6       | Flow and Cooling Channel Fabrication          | 60        |
| 3.6.1     | Flow Channel                                  | 61        |
| 3.6.2     | Cooling Channel                               | 63        |
| 3.7       | Properties Testing and Analysis               | 65        |
| 3.7.1     | Electrical Conductivity                       | 65        |
| 3.7.2     | Density Testing                               | 66        |
| 3.7.3     | Flexural Strength                             | 67        |
| 3.7.4     | Shore Hardness                                | 68        |
| 3.7.5     | Coordinate Measurement Test                   | 69        |
| 3.7.6     | Permeability Test                             | 69        |

|           |  |            |
|-----------|--|------------|
| 3.7.7     | Surface Morphology (EDX and SEM)   | 70         |
| <b>4.</b> | <b>RESULTAND DISCUSSION</b>  | <b>73</b>  |
| 4.1       | Fabrication of Blank Bipolar Plate Composites                                    | 74         |
| 4.1.1     | Electrical Conductivity  | 74         |
| 4.1.2     | 3-Point Bending (Flexural Test)  | 77         |
| 4.1.3     | Density Test   | 78         |
| 4.1.4     | Shore Hardness Test (Shore-D)  | 79         |
| 4.1.5     | EDX Result and Analysis  | 80         |
| 4.1.6     | Surface Morphology Analysis  | 81         |
| 4.1.7     | Summary Process  | 85         |
| 4.2       | Permeability Test  | 86         |
| 4.3       | Preliminary Study Flow Channel Fabrication                                       | 87         |
| 4.3.1     | Drawing and Mold Fabrication of U and V Shapes                                   | 87         |
| 4.3.2     | U and V Shapes of Flow Channel Fabrication                                       | 91         |
| 4.3.2.1   | Polypropylene (PP)   | 91         |
| 4.3.2.2   | Gr/CB/Fe/PP Composite  | 92         |
| 4.4       | Fabrication of Mold for Flow Channel (50mm x 50mm)                               | 94         |
| 4.4.1     | Observation through Nick Eye   | 94         |
| 4.4.2     | Coordination Mesurement between Drawing and Actual Spacer                        | 96         |
| 4.4.3     | Coordinate Measurement between Mold and Sample                                   | 97         |
| 4.5       | Fabrication of Mold for Flow and Cooling Channel (100mm x 100mm).                | 98         |
| 4.5.1     | Coordination Measurement Drawing and 100mm x 100mm Mold                          | 100        |
| 4.5.2     | Fabrication V Shape Flow and Cooling Channel                                     | 100        |
| 4.5.3     | Coordinate Flow Channel Sample   | 101        |
| 4.5.4     | Cooling Channel Sample   | 102        |
| 4.6       | Final Result 100mm x 100mm from the Best Fabrication Mold, Sample and<br>Drawing | 103        |
| 4.7       | Summary of Process Fabrication   | 105        |
| 4.8       | Comparison with others Research Finding  | 106        |
| <b>5.</b> | <b>CONCLUSION AND RECOMMENDATIONS</b>  | <b>107</b> |
| 5.1       | Conclusion   | 107        |
| 5.2       | Recommendations  | 108        |
|           | <b>REFERENCES</b>  | <b>109</b> |
|           | <b>APPENDICES</b>  | <b>119</b> |

## LIST OF TABLES

| <b>TABLE</b> | <b>TITLE</b>   | <b>PAGE</b> |
|--------------|--|-------------|
| 2.1          | Type of fuel cell  | 12          |
| 2.2          | Properties for bipolar plates  | 24          |
| 2.3          | Comparison all fabrication to produce bipolar plate                        | 41          |
| 3.1          | Properties of filler materials   | 47          |
| 3.2          | Table of composition G/CB/Fe/PP  | 48          |
| 3.3          | The physical properties of PP  | 54          |
| 3.4          | Parameters of compression molding  | 58          |
| 3.5          | Parameters of flow channel design for flow channel mold                    | 62          |
| 3.6          | Parameters of cooling channel design for flow channel mold                 | 64          |
| 4.1          | Percentage weight% and atomic% sport by EDX                                | 81          |
| 4.2          | SEM for all composition G/CB/Fe/PP   | 84          |
| 4.3          | Summary properties for 5 compositions Fe wt%                               | 86          |
| 4.4          | Gauge pressure reading of permeability G/CB/Fe/PP composite                | 86          |
| 4.5          | Comparison of drawing and actual mold using coordinate measurement machine | 90          |
| 4.6          | Comparison of spacer and samples using coordinate measurement machine      | 93          |
| 4.7          | Comparison of drawing and actual mold                                      | 97          |
| 4.8          | Difference mold and sample dimensions                                      | 98          |

|      |  |     |
|------|--|-----|
| 4.9  | Comparison drawing and mold  | 100 |
| 4.10 | Comparison between mold and flow channel sample                    | 101 |
| 4.11 | Comparison between mold and cooling channel sample                 | 103 |
| 4.12 | Illustration of measurement drawing, mold and sample 100mm x 100mm | 105 |

## LIST OF FIGURES

| <b>FIGURE</b> | <b>TITLE</b>  | <b>PAGE</b> |
|---------------|---|-------------|
| 2.1           | Operating principle of proton exchange membrane fuel cell   | 14          |
| 2.2           | PEM fuel cell membrane-electrode assembly (MEA) with ionomer membrane in the electrodes and in the membrane separator (S. Lee, Jeong, Ahn, Lim, & Son, 2008). | 17          |
| 2.3           | Cross section of PEM fuel cell electrode  | 19          |
| 2.4           | Gas diffusion layer schematic for a PEM fuel cell   | 21          |
| 2.5           | Illustration of single filler and multifiller   | 27          |
| 2.6           | Schematics of percolation pathway   | 28          |
| 2.7           | Percolation S-Curve   | 29          |
| 2.8           | Pin type flow channel: shown is the concentration of oxygen in Gas Diffusion Layer  | 30          |
| 2.9           | Parallel type flow channel: shown is the concentration of oxygen in Gas Diffusion Layer   | 31          |
| 2.10          | Interdigitated type flow channel: shown is the concentration of oxygen in Gas Diffusion Layer   | 32          |
| 2.11          | Serpentine type flow channel: shown is the concentration of oxygen in Gas Diffusion Layer   | 33          |
| 2.12          | Geometry of difference draft angle  | 34          |
| 2.13          | Geometry of difference type with same area  | 35          |
| 2.14          | Machining Process   | 37          |
| 2.15          | Injection Molding Process   | 39          |
| 3.1           | Flow chart the sequence of the process  | 46          |

|      |  |    |
|------|--|----|
| 3.2  | From left Graphite, carbon black, iron ferum, and polypropylene              | 48 |
| 3.3  | Particle size of graphite using SEM.   | 50 |
| 3.4  | Particle size of carbon black using SEM                                      | 52 |
| 3.5  | Particle size of Ferum using SEM   | 53 |
| 3.6  | Ball milling machine   | 56 |
| 3.7  | Shows the internal mixer   | 57 |
| 3.8  | Filler with polypropylene  | 57 |
| 3.9  | The output of melt compounding process                                       | 57 |
| 3.10 | The pulverizer and ring sieve hole   | 58 |
| 3.11 | Mold of sample composite   | 59 |
| 3.12 | Hot press machine  | 59 |
| 3.13 | Bipolar plates made of G/CB/Fe/PP compositions                               | 60 |
| 3.14 | Illustration name of measurement   | 61 |
| 3.15 | Drawing spacer U-long Parallel & V-long Parallel                             | 62 |
| 3.16 | Body and spacer mold flow channel serpentine (50mm x 50mm) & (100mm x 100mm) | 63 |
| 3.17 | (a) Draft angle 0° and (b) Draft angle 30°                                   | 63 |
| 3.18 | Drawing Cad for cooling channel.   | 64 |
| 3.19 | Mold already fabricate for cooling channel.                                  | 65 |
| 3.20 | Jandel Multiheight Microposition Probe                                       | 66 |
| 3.21 | Electronic Densimeter  | 67 |
| 3.22 | INSTRON Universal Testing Machine  | 68 |
| 3.23 | Analogue TECLOCK GS -702G Shore-D Durometer.                                 | 68 |
| 3.24 | Coordinate Measuring Machine (CMM)   | 69 |
| 3.25 | Equipment of permeability test   | 70 |
| 3.26 | Equipment of Scanning Electron Microscopy (SEM)                              | 72 |

|      |  |    |
|------|--|----|
| 4.1  | Nine different points the measurement was taken.   | 75 |
| 4.2  | Graph of Electrical Conductivity   | 76 |
| 4.3  | Graph of Flexural Strength   | 77 |
| 4.4  | Graph of Bulk Density  | 78 |
| 4.5  | Indication of points of which the measurement was taken  | 79 |
| 4.6  | Graph of shore hardness  | 79 |
| 4.7  | Spectrum 1 sport using EDX analysis  | 80 |
| 4.8  | Analysis of EDX prove Fe content   | 81 |
| 4.9  | Fracture surface at 5000 magnification of 5% Fe.   | 82 |
| 4.10 | Fracture surface at 5000 magnification of 25% Fe   | 83 |
| 4.11 | Complete drawing mold assembly with flow and cooling channel using CAD software                          | 88 |
| 4.12 | Spacer drawing using CAD solid work software   | 89 |
| 4.13 | Actual mold after fabricated   | 89 |
| 4.14 | Front view measurement mold  | 90 |
| 4.15 | (a) Spacer (b) PP samples with flow channel U shape with draft angle of 0° and 30° parallel flow channel | 91 |
| 4.16 | U shape sample after fabrication   | 92 |
| 4.17 | V shape sample after fabrication   | 92 |
| 4.18 | G/CB/Fe/PP composite sample for flow channel of U shape with draft angle 0° and 90° has broken and crack | 94 |
| 4.19 | CAD drawing for center part mold serpentine 30°.   | 95 |
| 4.20 | Actual spacer after fabricated   | 96 |
| 4.21 | Fabricate dimensions and indication of points where the measurement was taken and their respective pair  | 97 |
| 4.22 | Drawing mold 100mm x 100mm   | 99 |
| 4.23 | Comparison measurement drawing and mold 100mm x 100mm  | 99 |



|      |   |     |
|------|---|-----|
| 4.24 | Comparison measurement mold and sample 100mm x 100mm                              | 101 |
| 4.25 | Sample flow and cooling channel after fabrication through hot compression molding | 102 |
| 4.26 | Drawing of cooling channel mold 100mm x 100mm                                     | 102 |
| 4.27 | Measurement coordinate cooling channel sample                                     | 103 |
| 4.28 | Measurement taken from mold and sample 100mm x 100mm                              | 104 |

## LIST OF APPENDICES

| APPENDIX | TITLE            | PAGE |
|----------|------------------|------|
| A        | EDX Full Results | 119  |

## 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 terephthalate         |
| DSC   | - | Differential Scanning Calorimetry  |
| TGA   | - | Thermo-Gravimetry Analysis         |
| MWNTs | - | Multi-walled Nanotubes             |
| SWNTs | - | Single-walled Nanotubes            |
| MA    | - | Maleic anhydride                   |
| EG    | - | Exfoliated graphite                |

|                   |   |                                    |
|-------------------|---|------------------------------------|
| xGnP <sub>s</sub> | - | 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 <sub>2</sub>    | - | Hydrogen                           |
| O <sub>2</sub>    | - | Oxygen                             |
| e <sup>-</sup>    | - | Electron                           |
| wt. %             | - | Weight percentage                  |
| Scm <sup>-1</sup> | - | Siemen/centimeter                  |
| cm                | - | centimeter                         |
| μA                | - | micron Ampere                      |
| MPa               | - | Mega Pascal                        |
| mK                | - | mili Kelvin                        |
| °C                | - | Degree Celcius                     |
| g/cm <sup>3</sup> | - | gram/centimeter <sup>3</sup>       |
| ~                 | - | is equivalent to                   |
| <                 | - | is less than                       |
| >                 | - | is greater than                    |
| Φ <sub>c</sub>    | - | percolation threshold              |
| σ <sub>m</sub>    | - | maximum electrical conductivity    |
| F                 | - | filler                             |
| σ <sub>p</sub>    | - | 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

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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>
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DOI: <https://doi.org/10.1063/1.4943465>

# 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 et al., 2007).