



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**AUTOMOTIVE EXHAUST THERMOELECTRIC GENERATOR**

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology Mechanical (Automotive Technology) (Hons.)

by

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TAJUK: **AUTOMOTIVE EXHAUST THERMOELECTRIC GENERATOR**

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## DECLARATION

I hereby, declared this report entitled Automotive Exhaust Thermoelectric Generator is the results of my own research except as cited in references.

**Signature** :.....

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## **APPROVAL**

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology Mechanical Automotive (Hons.). The member of the supervisory is as follow:

.....

(Project Supervisor)

## ABSTRACT

Automotive Exhaust Thermoelectric Generator is a green technology project. It generates electrical energy from wasted heat energy. The wasted heat energy harvested from automotive exhaust system. A thermoelectric module that been applied to an automotive exhaust system to harvest the wasted heat energy from the automotive engine. The size of the module is 900mm square and 4mm in height. The maximum voltage generated by the module is approximately 2.2v at temperature difference 190<sup>0</sup>C between hot and cold side of the module. A thermoelectric generator has been using 4 units of the present module which is connected in series circuit to each other. The modules are arranged parallel to each other at the highest temperature at the exhaust manifold cover facing the hot side of the module. A heat sink fin has take place at the cold side of the thermoelectric generator module. At the end of this project, generated voltage of the present thermoelectric generator was 9.7v when the exhaust gases produce by the engine at 6000rpm with static condition of 2000cc V6 gasoline engine.

## ABSTRAK

'Automotive Exhaust Thermoelectric Generator' adalah satu projek teknologi bertenaga hijau. Ia menjana kuasa elektrik daripada tenaga haba yang terbazir. Tenaga haba yang terbazir dituai daripada sistem ekzos automotif. Pengaplikasian modul 'thermoelectric' pada sistem ekzos automotif untuk menuai tenaga haba yang terbazir dan menukarkan tenaga haba tersebut kepada tenaga elektrik. Modul yang digunakan bersaiz 90mm persegi dan 4mm tinggi. Kuasa voltan tertinggi yang dapat dijana oleh penjanakuasa ini ialah 2.2 voltan pada pembezaan suhu  $190^{\circ}\text{C}$  diantara permukaan sebelah panas dan permukaan sebelah sejuk. Jumlah modul yang digunakan adalah empat (4) buah dan disambung secara sesiri untuk setiap modul. Modul-modul berkenaan disusun dan dipasang secara selari di permukaan yang telah dikenalpasti sebagai kawasan paling tinggi suhunya dan permukaan sebelah panas dipadankan dengan bahagian panas ekzos berkenaan. Sesirip pembebas haba digunakan dan dipasang pada permukaan sebelah sejuk modul berkenaan. Pada akhir projek ini, hasil penjanaan kuasa elektrik oleh penjana kuasa ialah 9.7v apabila haba gas ekzos terhasil pada kelajuan 6000 rpm oleh enjin petrol V6 berkuasa 2000sp.

## **DEDICATIONS**

For facing the tough works and tasks need high self motivation and efforts besides guidance from the professionals and well experienced person. As my humble effort in completing this thesis, I dedicate it to my beloved father, who taught me that the best kind of knowledge to have is that which is learned for its own sake besides always praying for my success and honour. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time which is highly motivate me all the time. Not forget to all teachers, lecturers, technician and staff who involved in this project.

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## LIST OF SYMBOLS AND ABBREVIATIONS

|                    |   |  |
|--------------------|---|--|
| TE                 | = | Thermoelectric   |
| TEG                | = | ThermoElectric Generator                               |
| TEM                | = | ThermoElectric Module                                  |
| CATIA              | = | Computer Aided Three Dimension Interactive Application |
| T                  | = | Temperature  |
| $\Delta T$         | = | Temperature Different                                  |
| Tmin               | = | Temperature Minimum                                    |
| Tmax               | = | Temperature Maximum                                    |
| Tavg               | = | Temperature Average                                    |
| CAD                | = | Computer Aided Design                                  |
| CAM                | = | Computer Aided Machine                                 |
| CAE                | = | Computer Aided Engineering                             |
| CPD                | = | CATIA composite design                                 |
| 2D                 | = | Two Dimension  |
| 3D                 | = | Three Dimension  |
| FEA                | = | Fernite Element Analysis                               |
| DC                 | = | Direct Current   |
| V                  | = | Voltage  |
| Vavg               | = | Average Voltage  |
| Vc                 | = | Circuit Voltage  |
| Vo                 | = | Initial Voltage  |
| $^{\circ}\text{C}$ | = | Degree Celcius   |
| Ic                 | = | Circuit Current  |

|                  |   |                                |
|------------------|---|--------------------------------|
| P <sub>max</sub> | = | Maximum Power                  |
| R <sub>in</sub>  | = | Resistance of Module           |
| MIGW             | = | Metal Inert Gas Welding        |
| TIGW             | = | Tungsten Inert Gas Welding     |
| AMM              | = | Analogue Multi-meter           |
| DMM              | = | Digital Multi-meter            |
| VOM              | = | Voltage ohm mille ampere meter |
| ATM              | = | Atmospheric                    |
| H <sub>s</sub>   |   | Hot Side                       |
| C <sub>s</sub>   |   | Cold Side                      |



# Chapter 1

## INTRODUCTION

### 1.1. Project Background

In the era of advance technology, automobile became a necessity to everyone in their daily life. It also used as transportation either to travel for a long or short journey. Therefore, automobile technology became advance according to the new investment of the technology. In this competitive field, automobile must be improved from the aspect of performance and the fuel consumption.

In every automobile were fulfilling by the electrics and electronics parts. The major electrical power source for the electric and electronic parts was the car battery. The car battery provides an electric charge to consume all the electronic components. To maintain the battery power due to long time usage need a charger that called an alternator to charge the battery. In fact, the alternator will take over the electrical power source when the automobile engine was running. The alternator was powered by belting that connected to the crankshaft pulley. It will give some load to the engine that reduces the engine performance in fact it also will increase the fuel consumption.

This innovation focuses on the generative of electrical power which is converting the wasted heat energy by the automotive exhaust system to electrical energy by using Thermo Electric Generator so that it will reduce the load of alternator to powered up the electrics and electronics part so that the engine performance are not affected due to alternator load.

## **1.2. Problem Statement**

In the advance technology era, all electronic devices of the vehicle system were depending on the engine capacity of the existing system. The engine needs to produce more power when the load from the alternator increased. Because of that, the fuel consumption will be increased due to the load of alternator to generate necessary current to the electronic parts. Nowadays, basically vehicles user demanded on low fuel consumption and high performance.

Therefore, this study is helping the alternator to generate the current that needed by electronic parts and components in fact of reducing the load and usage of the alternator on the engine.

## **1.3. Objective**

The aim of this research is stated below:

1. To determine the position of highest temperature at the automotive exhaust system by using Dasault Systemes SolidWork analysis and experiment.
2. To design and fabricate a thermal electric generator on the automotive exhaust system.
3. Identify the maximum voltage that can be generated by thermo electric generator at the automotive exhaust system.

## **1.4. Scope**

This project will limited to this aspects:

1. The CATIA and Solidwork analysis learning.
2. Potential of wasted heat from automotive exhaust to be consume.
3. Potential of thermoelectric generator installed to generates maximum voltage.

## Chapter 2

### LITERATURE REVIEW

#### 2.1 Introduction

A literature review are studies that been made before starting to proceed with the project development. In this chapter there will be the literature review of this project to guide for further process of this project. This chapter consist briefly the heat transfer process, thermal energy harvesting, designing process, SolidWork Analysis on heat flow and basically in properties of Thermoelectric Generator (TEG). A few researches had been done to ensure that this project will achieve the objective of this project.

#### 2.2 Designing Process

##### 2.2.1 Catia V5R21

CATIA is named as the short form of Computer Aided Three dimensional Interactive Application which is multi functioning for CAD, CAM and CAE software. This software was invented by the French company known as Dassault Systemes.

CATIA enables the creation of three dimensional parts from three dimensional sketches. It also consist the sheet-metal, composites, molded-part, forged and also tooling parts up to the definition of mechanical assemblies. The software provides advance technologies for mechanical surfacing process and also for Body in White (BIW). It providing the tools to complete the product definition including functional tolerances as well as kinematics definitions. CATIA will provides a wide range of applications for tooling, mold

and die. This software also provide a solution to shape a design, styling, surfacing workflow and visualize to create, modify and validate a complex innovative shape from the industry design to Class A surfacing with the ICEM surfacing technologies according to M.Iqbal et-al, 2012. There were many automotive companies used CATIA to varying degrees including Toyota Motor Corporation Japan said Joann Muller, 2010.



Figure 2.1.1: CATIA start up logo

The advantages of CATIA are;

- a) This program is truly collaborative engineering application. This software is the only solution capable of addressing the complete product development process, from product concept specification through product-in-service, in a fully integrated and associative manner. Based on an open, scalable architecture, it facilitates true collaborative engineering across the multidisciplinary extended enterprise, including style and form design, mechanical design and equipment and systems engineering, managing digital mock-ups, machining, analysis, and simulation. By enabling enterprises to reuse product

design knowledge and accelerate development cycles, CATIA helps companies to speed-up their responses to market needs.

- b) **This program will save up time and costing.** The CATIA V5 relational design change management capabilities use automatic updates, lessening the impact of changes to the design-to-manufacturing process through automatic updates in the engineering design phase. It does not need to restart the full design process all over again and allowing user to achieve considerable savings in time and money.
- c) **Its provide geometrical configurations.** The geometrical configuration of composite parts can make designing these parts fairly complicated, increasing the risk of errors in design accuracy. Although, CATIA Composites Design 3 (CPD) supports the design of numerous composite configurations. CATIA CPD 3 enables you to manage multi-part geometries including core-stiffened parts better than you would with standard composites design solutions.
- d) **Productibility checks** are available with CATIA. In depth productibility checking allows users to predict the behavior of composites across complex surfaces. For example, users can predict manufacturing problems such as wrinkles and can take action to correct any issues and generate flat patterns. This is important when trying to produce high quality parts while keeping costs down and avoiding wasting time.

## 2.3 Heat Flow Analysis

### 2.3.1 Dassault Systemes SolidWork

SolidWorks which is a solid modeling CAD and CAE software that invented for computer program that runs on Microsoft Windows operation system. SolidWorks is published by Dassault Systemes. These applications of software parameters refer to constraints whose values determine the shape or geometry of the model or assembly. The parameters can be either numeric parameter. For example, the line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical. The numeric parameters can be assigned with each other through the use of relations, which allow them to capture design.

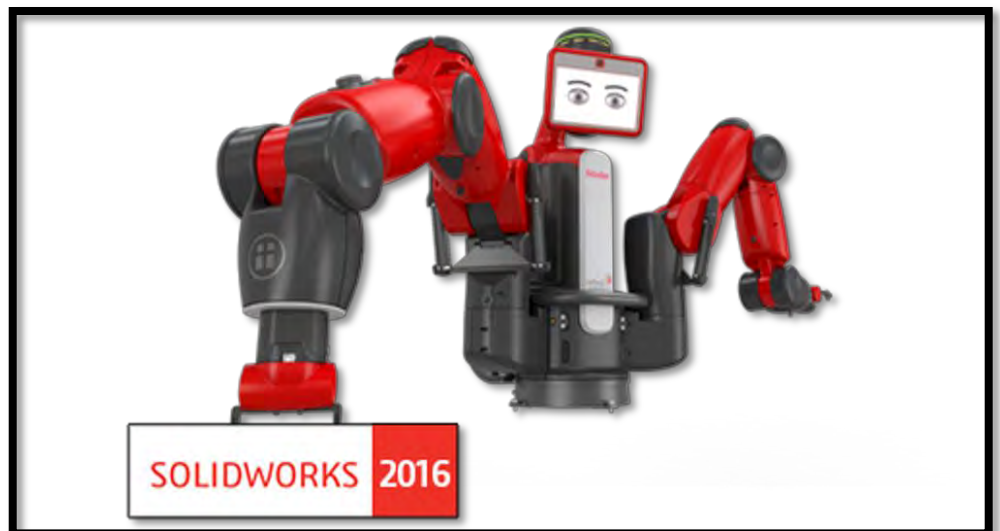


Figure 2.1.2: SolidWork (2016 version)

Design intent is how the designer of the part wants it to respond to changes and also updates purpose. This software allow the designer to specifically change the parameter without affecting the drawing.

Shape of the based features typically begins with a 2D or 3D sketching of shapes. For example the shape is bosses, slots and holes.

The sketching then can be extruded or cut to add or remove material from the part easily. In other word, this system did not sketch based include features such as chamfer, shells, fillet that applied to the face of the parts drafted.

This software basically starts with 2D sketching. Besides, the modeling started with 3D also provided for advance user. The 3D modeling not really difficult because it freely can be sketch and extrude easily. The dimension also directly provided in the sketch and modeling stage. It makes the user become more easy in order to draft and sketch. In an assembly, the sketch relations define condition. For example, the tangency, parallelism, and concentricity with respect to sketch geometry will define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. This software also provide an advanced features such as gear and cam follower mates, which allow modeled gear assemblies to produce a kinematic analysis for motion accurately.

Lastly, the drawings can be designed either in the form parts or assemblies product. The views will automatically generate from the solid model for the notes, dimensions and tolerances, it can be easily implement to the drawing as needed. The drawing module also include in standard size of paper and most of the paper size available for printing purpose.

The advantages of using SolidWork in analysis process are;

- a) SolidWork design model in solid form. It can be 2D and 3D drawing. It was the common friendly program to user.
- b) The modeling can be detailed and can be linked to another program include CAD/CAM.
- c) The simple platform that is easy to be conduct by the user to explore the function.
- d) It can do the CAE analysis in heat flow, aerodynamic, internal flow, FEA and many more.

Somehow, this program also had some disadvantages which are;

- a) This program was very high cost in pricing, platform and training.
- b) SolidWork need a specialist training in order to master the features in order to do a complicated modeling.

## 2.4 Heat Transfer

Heat can be transferred in three ways which are by having conduction, through the radiation and by the convection process. The heat is transferred in solid matter by conduction by touching directly to each other. The heat will transfer in liquid by conduction and convection. Then, in open space the heat will be transferred by radiation. In practice, the three type of heat transfer may occur together in one situation as shown in figure 2.3.

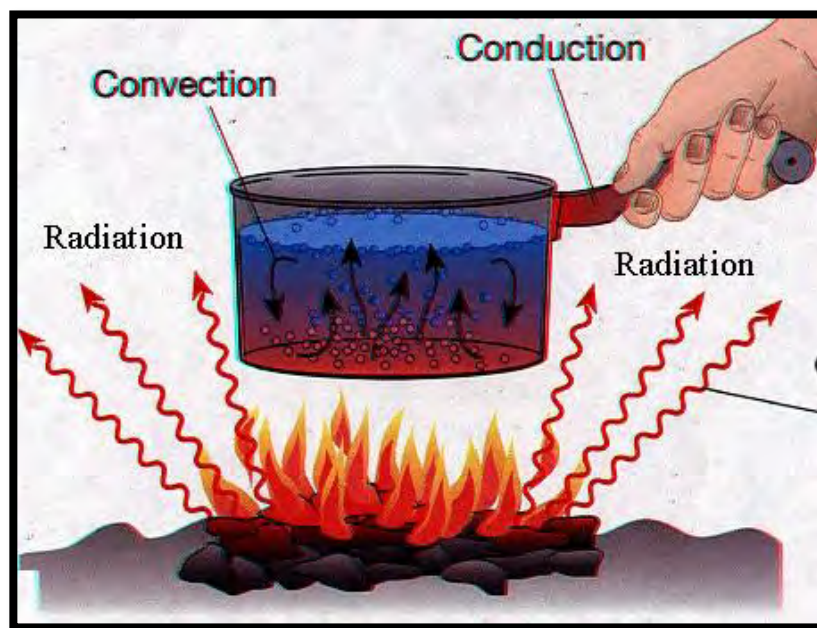


Figure 2.1.3: Heat transfer in one situation

(Source: <http://www.g9toengineering.com/resources/heattransfer.htm>)

### 2.4.1 Heat Conduction Transfer

In heat transfer, conduction is the transfer of heat between near molecules in a substance due to a different temperature of the substance. It always occurs from a spot of high temperature to a spot