UNIVERSITI PUTRA MALAYSIA

PERFORMANCE OF ANIMAL FAT-BASED BIODIESEL ON MICRO-GAS TURBINE

NASER A Z S ALRASHIDI

FK 2019 74

PERFORMANCE OF ANIMAL FAT-BASED BIODIESEL ON MICRO-GAS TURBINE

By

NASER A Z S ALRASHIDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

February 2019

DEDICATIONS

This work is dedicated to my Father and my late Mother and my wifes and my kids

My dear Brothers, Sisters and Family, for all their support

Dr. Abdul Aziz Bin Hairuddin and Prof. Ir. Dr. Nor Mariah bt. Adam, for their guidance and relentless support during this journey

My friends who standed with me throughout this journey

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

PERFORMANCE OF ANIMAL FAT-BASED BIODIESEL ON MICRO-GAS TURBINE

By

NASER A Z S ALRASHIDI

February 2019

Chairman: Abdul Aziz Bin Hairuddin, PhD
Faculty: Engineering

Biodiesel is a fuel that produced from several bio-materials such as waste cooking oil, vegetarian oil, animal fats (tallow's) etc. The present study is about using a biodiesel that produced from animal tallow's to operate a small jet engine. The jet engine has been specially designed to test and investigate the effect of biodiesel from animal tallow on the thermal efficiency of the jet engine. Measure the power of engine in all of the situations and the amount of emissions extracted from turbine using fossil diesel, kerosene, B20, B50, B75 and B100 respectively. These biodiesel fuel properties were analysis based on the international standard. Also, the amount of emissions and the operating performance (temperature and pressure) of micro gas turbine were conducted. A control unit has been designed to ensure a stable operation. The jet engine was tested under 3 levels of load (low, medium, high). A primary and secondary fuel cycle is used to change from using fossil fuel to biodiesel.

The results of the biodiesel fuel were found that they are within the acceptable range of the international standard. Also, the results showed that the amount of oxygen emission changes between 16.4% and 16.8%, and carbon monoxide (CO) emissions in the biodiesel blends (B20, B50, B75 and B100) change between 0.04% and 0.18%. The emission of carbon dioxide in B100 and diesel fuel is the same and the kerosene fuel is the lowest in all stages of operation in the production of carbon dioxide (CO_2) emission changes from 2.7% to 3.0%, reduction in nitrogen oxides (NO_x) compared to fossil fuels. Nitrogen dioxide (NO_2) is low in operation high load of B50, B20, B75 but in B100 it is too high emission changes between 4 ppm to 15 ppm. The performance of micro gas turbine based on the biodiesel fuel was found better than the fossil fuel in general. The results found in this study indicated that the biodiesel blends used is applicable and demonstrated great potential to be used as an alternative fuel to operate small engine with B20 was economically and less polluting the environment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PRESTASI BIODIESEL BERBASIS HATI PADA TURBINE MICRO-GAS

Oleh

NASER A Z S ALRASHIDI

Februari 2019

Pengerusi: Abdul Aziz Bin Hairuddin, PhD
Fakulti: Kejuruteraan

Biodiesel adalah bahan bakar yang dihasilkan daripada beberapa bahan bio seperti minyak masak sisa, minyak vegetarian, lemak haiwan (tallow's) dan lain-lain. Kajian ini adalah mengenai penggunaan biodiesel yang dihasilkan dari tallow haiwan untuk mengendalikan enjin jet kecil. Enjin jet telah direka khas untuk menguji dan menyiasat kesan biodiesel dari hewan hewan pada kecekapan terma enjin jet. Ukur kuasa enjin dalam semua situasi dan jumlah pelepasan yang diekstrak dari turbin menggunakan fosil diesel, minyak tanah, B20, B50, B75 dan B100 masing-masing. Ciri-ciri bahan api biodiesel ini berdasarkan analisis standard antarabangsa. Juga, jumlah pelepasan dan prestasi operasi (suhu dan tekanan) turbin gas mikro telah dijalankan. Unit kawalan telah direka untuk memastikan operasi yang stabil. Enjin jet diuji di bawah 3 tahap beban (rendah, sederhana, tinggi). Kitaran bahan api primer dan sekunder digunakan untuk menukar penggunaan bahan api fosil kepada biodiesel.

Hasil bahan bakar biodiesel didapati bahawa mereka berada dalam lingkungan standard yang dapat diterima. Juga, keputusan menunjukkan bahawa jumlah pelepasan oksigen antara 16.4% dan 16.8%, dan pelepasan karbon monoksida (CO) dalam campuran biodiesel (B20, B50, B75 dan B100) berubah antara 0.04% dan 0.18%. Pembebasan karbon dioksida di B100 dan bahan api diesel adalah sama dan bahan api minyak tanah adalah yang paling rendah dalam semua peringkat operasi dalam pengeluaran perubahan pancaran karbon dioksida (CO_2) dari 2.7% hingga 3.0%, pengurangan nitrogen oksida (NO_x) berbanding dengan bahan api fosil. Nitrogen dioksida (NO_2) adalah rendah beroperasi beban tinggi B50, B20, B75 tetapi dalam B100 ia adalah perubahan pancaran yang terlalu tinggi antara 4 ppm hingga 15 ppm. Prestasi turbin gas mikro berdasarkan bahan bakar biodiesel didapati lebih baik daripada bahan bakar fosil secara umum. Keputusan yang terdapat dalam kajian ini menunjukkan bahawa campuran biodiesel yang digunakan adalah sesuai dan menunjukkan potensi yang besar untuk digunakan sebagai bahan

bakar alternatif untuk mengendalikan enjin kecil dengan B20 secara ekonomi dan kurang mencemarkan alam sekitar.

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest gratitude to God almighty for giving me the opportunity, strengths and blessing in completing this project. I would like to show my appreciation and warmest regard to the amiable chairman of my supervisory committee, Dr. Abdul Aziz Bin Hairuddin for all his professional guidance, constant motivation, moral and financial support throughout the research period. With all humility, i also want to extend my sincere appreciation to other supervisory committee member, Professor. Ir. Dr. Nor Mariah bt. Adam for her advice, motivation and willingness to always assist throughout the research period.

I would also express my profound gratitude to my wifes for their help, encouragement and patience during my study. Also, my deepest thanks to my lovely kids for giving me the inspiration to do well in my study. In addition, my special thanks to my parents, siblings and relatives for their continued love, support and encouragement. They always cheer me up and make my life much easier.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Abdul Aziz Bin Hairuddin, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Nor Mariah bt. Adam, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ROBIAH BINTIYUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ____________________ Date: __________________

Name and Matric No.: Naser A Z S Alrashidi, GS36436

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________________
Name of Chairman of Supervisory Committee: ______________________________

Signature: ______________________________
Name of Member of Supervisory Committee: ______________________________

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/NOMENCLATURES

ANOVA	Analysis of variance
B100	Pure biodiesel
B25	25% biodiesel and 80% fossil kerosene
B50	50% biodiesel and 50% fossil kerosene
B75	75% biodiesel and 25% fossil kerosene
CH_4	Methane
CHP	Combined heat and power
CN	Cetane Number
CO	Carbon monoxide
CO_2	Carbon dioxide
CP	Cloud Point
DMRT	Duncan's multiple range test
FFAs	Free fatty acids
FP	Flash Point
H_2	Hydrogen
H_2O	Water
HC	Unburned hydrocarbons
ICE	Internal combustion engines
KISR	Kuwait Institute for Scientific Research
KOH	Potassium hydroxide
MPOC	Malaysian Palm oil Council
MS	Mean square
N_2	Nitrogen
$NaOCH_3$	Alkali catalyst
NaOH	Sodium hydroxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxide
O_2	Oxygen
PKO	Palm kernel oil
PM	Particulate matter
PP	Pour Point
TMAH	Tetramethylammonium hydroxide

CHAPTER 1

INTRODUCTION

1.1 Background

Smaller gas turbines have a capacity of about 20 kVA to 750 kV, and can be as small as a standard refrigerator. Usually, Natural gas or diesel is used as fuel with fuel efficiency of approximately 32%. The usual interval between main maintenance is Two years. DC power supply is usually used, with an inverter to produce AC power. AC synchronous generation is not suitable for these turbines since the speed of the turbine is very high, usually about 70,000 rpm. Use the AC synchronous generator will require either a gearbox (which reduces efficiency) or specially designed high-speed generator (which would be unreasonably high). The DG unit costs almost as much as $ 700 per kilowatt (Smith *et al*., 2016).

Microturbines integrated packages consisting of multiple microturbine generators are available up to 1,000 kW, and such multiple units are commonly installed at sites to achieve larger power outputs. Microturbines are able to operate on a variety of fuels, including natural gas, sour gas (high sulfur, low Btu content), and liquid petroleum fuels (e.g., gasoline, kerosene, diesel fuel, and heating oil), Design life is estimated to be 40,000 to 80,000 hours with overhaul. Low NO_x combustion when operating on natural gas; capable of meeting stringent California standards with carbon monoxide, Compact and light weight, 2.3-2.7 cubic feet and 40-50 pounds per kW (Darrow *et al*., 2015).

Air quality regulation agencies need to account for this technological innovation. Emission control technologies and regulations for distributed generation system are not yet precisely defined. However, control technologies that could reduce emissions from fossil-fueled components of a distributed generation system to levels similar to other traditional fossil-fueled generation equipment are already available. A typical micro-gas-turbine works with diesel fuel. The main components of diesel emissions are carbon monoxide (CO), unburned hydrocarbons (HC), NO_x and particulate matter (PM). The concentration of these gases varies with speed of engine, rate of fuel combustion and composition of air fuel mixture. An ideal combustion of diesel fuel (Figure 1.1) produces water (H_2O) and carbon dioxide (CO_2) as it is a mixture of hydrocarbons (HC). Thus for an ideal case the volumetric concentration of diesel combustion is as follows.

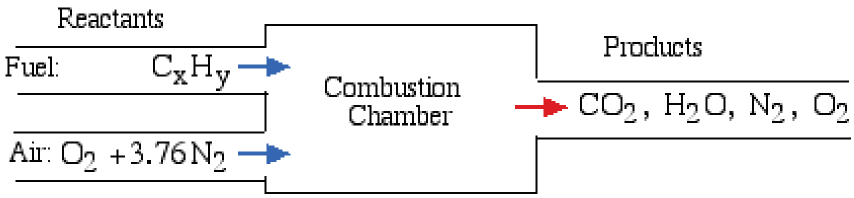

Figure 1.1: Ideal diesel combustion

Variation of these compositions can take place according to the change in engine load. The volumetric concentration of oxygen (O_2) may decrease and H_2O, CO_2 will increase. Any of the components or change in compositions is not causing an adverse effect in human or environment. When the process becomes non-ideal the pollutions are formed. A non-ideal process can be the following:

- Incomplete combustion
- Combustion of engine lubricating oil
- Combustion of oil additives
- Combustion of non- hydrocarbon components of diesel
- Reactions of fuel mixture and components
- Presence of impurities in the diesel fuel.

One of these reasons can cause the formation of HC, NOx, CO and PM. The volumetric concentration of these components in a non-ideal combustion is illustrated in Figure 1.2.

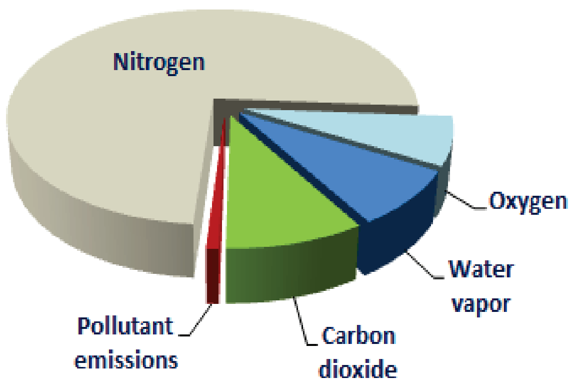

Figure 1.2: Volumetric concentration of pollutants in diesel emission
(Balat, 2011; Bankovic-Ilic et al., 2014; Feddern, 2011)

Furthermore, the presence of catalytic converter in micro-gas-turbine running by diesel fuel can also cause toxic pollutions usually in a small concentration.

In some cases, the presence of metals is also formed due to the wear or by volatilization of solid at high temperature. Carbon monoxide (CO), aldehydes and hydrocarbons (HC) are formed in the diesel emissions due to the presence of incomplete combustion. All these limits the usage of diesel fuels in the operation of micro-gas-turbines.

Nowadays, energy is a very important factor for human endeavors and it is needed for economic growth and basic human needs such as food and health (Medina, 2013). In recent years, the world is faced with energy crisis due to increased population growth, increased in the consumption of energy and depletion of energy resources (Budzianowski, 2016; Bankovic-Ilic *et al*., 2014). Biomass is one of the most common and important renewable sources of energy that can be obtained from wood, animal waste, plants, and municipal waste (Budzianowski, 2016). Therefore, there is a strong need to replace fossil fuels with more sustainable and readily available renewable energy such as biodiesel.

Recently, biodiesels have been used in the operation of micro gas turbines. Among the most commonly used biodiesels is animal fats. Commonly used animal fats include tallow, choice white grease or lard, and chicken fat (Balat, 2011; Bankovic-Ilic et al., 2014; Feddern, 2011). Compared to plant crops, these fats frequently offer an economic advantage because they are often priced favorably for conversion into biodiesel (Balat and Balat, 2010; Balat, 2011). Animal fat methyl ester has some advantages such as high cetane number, non-corrosive, clean and renewable properties, this fat tend to be low in free fatty acids (FFAs) and water (Balat and Balat, 2010; Abbasi et al., 2012). Thus, the use of animal fat in the operation of micro-gas-turbines becomes a potential viable substitute for petrol or diesel fuels.

1.2 Problem Statement

When operating a micro turbine using diesel fuel, CO particles are formed and are accumulated in the air. The presence of CO in the air causes headache, lethargy and dizziness. Besides that, diesel fuel has high levels of CO_2 emissions (Alshehry and Belloumi, 2015). The presence of hydro carbons causes irritations and chocking sensations to human eye. When the temperature and pressure in the combustion process are high, NO_x are formed. This mainly composed of NO_x and small fraction of nitrogen dioxide (NO_2). The presence of NO_x in the atmosphere causes smog. Sulfur dioxide is formed in the diesel exhaust because the presence of sulfur content in the fuel. Sulfur content of a fuel has an effect on engine wear and deposits. Sulfur in the fuels is harmful for environmental and human health, and it also affects emission values. Sulfur content must be maximum 10 ppm for EN 14214 and it has two standard values as S15 and S500 for ASTM D6751. S15 sulfur content standard allows maximum to be 15 ppm, whereas S500 sulfur content standard allows maximum to be 500 ppm. The oxidation of sulfur dioxide causes the formation of sulfur trioxide and the chances of acid rain are high. Sulfur oxides have more impact on atmosphere by being the major reason of acid rain.

Particulate matter is a solid waste or soot formed after the emission. It causes hear or respirator dieses in human beings. Particulate matter is the primary reason for black smoke from the diesel engine.

Basically, the effects of diesel emissions on human beings are acute and chronic. Acute exposures can cause itching and irritations to the eye. In chronic cases mostly, the duration a person is in contact with diesel emissions are more. Since the diesel emissions are part of air particles, these particles goes deep in to the lungs while breathing and may cause lung cancer. In addition to the effect on human, diesel emissions causes global warming and also increases the temperature of atmosphere, which is an important fact to be considered for sustainable environmental future. Generally, studies show that the after effect of biodiesel is much lesser than the effects caused by diesel emissions (Palash *et al*., 2013; Özener *et al*., 2014).

Since many animal meat processes facilities, rendering companies collecting and processing of animal mortalities, large food processing and service facilities create large amount of animal fats, it can be a great opportunity to obtain biodiesel from these very cheap raw materials. The use of animal fats in the operation of micro turbines eliminates the need of their disposal, besides contributing to the supply of biodiesel (Bankovic-Ilic *et al*., 2014). Generally, a comparison costs of traditional transesterification of vegetable oils (are around US$ 0.6–0.8 per liter) and animal fats (about US$ 0.4–0.5 per liter) (Centrec Consulting Group, 2014). Currently, the cheapest option is biodiesel production from animal fats. Though the use of animal fats for biodiesel production has helped to reduce the biodiesel price, yet more investigations and technological development is still required.

Studies relating with biodiesel production from animal fats have been published by many authors. Most of these works are focused on the production of biodiesel on the laboratory scale (Adewale *et al*., 2015; Banković-Ilić *et al*., 2014; Alptekin *et al*., 2014; Awad *et al*., 2013). However, only a few papers described the production of biodiesel in larger scales. In their pilot-plant study, Alptekin et al (2014) used chicken fat and fleshing oil as animal fats to produce methyl ester in a biodiesel. In their study, sulfuric acid was used as catalyst and methanol was used as alcohol in the pretreatment reactions. Cunha Jr *et al*. (2013) studied biodiesel production from a pilot plant using beef tallow and methanol (1:6), and potassium hydroxide (KOH) (1.5.00% w/w) as an alkali catalyst. From the results, it is clear that they produced high-quality biodiesel with a good conversion rate. The acid number of the feedstock ranged from 1.2 to 1.8 mg KOH. Torres *et al*. (2013) compared the results obtained in the laboratory with the results from the pilot-scale experiments in their article. However, to the best of currently, there is limited study on the use of animal fats in the operation of micro-gas-turbine. This knowledge back is a serious setback for the advancement of micro-turbine operations and sustainable climate and environmental conservation.

1.3 Objectives

The main objective of this study is to investigate the biodiesel produced from animal fat and applied them to operate micro turbines. Thus, in order to achieve this main objective, the following specific objectives were set:

1. To analyses the properties of fuel types used in this study based on the international standard.
2. To analyses the amount of emissions extracted from turbine using fossil diesel and biodiesel from animal fat.
3. To determine the effect of operating performance (temperature and pressure) at different part of gas turbine such combustion chamber, inlet turbine as using fossil diesel and biodiesel from animal fat.

1.4 Scope and Limitations

The study was conducted in the Public Authority for Applied Education and Training – Kuwait. In this study, the design and fabrication of micro-turbine operating with biodiesel from Animal fats Produced from animal fat for sheep and camels from domestic slaughterhouses in Kuwait. The study will also be limited to the performance of the micro turbine based on power, pressure and temperature of the engine. Besides that, the types of fuels will be used here are including kerosene, diesel and biodiesel (B20, B50, B75 and B100).

Biodiesel is most commonly used as a blend with petroleum diesel. At concentrations of up to 5% (B5) in conventional diesel fuel, the mixture will meet ASTM D975 diesel fuel specification at concentrations of 6% to 20% (B6 to B20), biodiesel blends can be used in many applications that use diesel fuel. Commonly used blends are limited to B20 in the USA because this level provides a good balance between material compatibility, cold weather operability, performance, and emission benefits. B20 is also the minimum blend level allowed for compliance with the Energy Policy Act of 1992 (EPAct). Higher blend levels such as B50, and B100 require special handling and may require equipment modifications (Alleman *et al*., 2016). Therefore, in this study, biodiesel with B20, B50, B75 and B100 were used in order to study the effect of operating performance in the micro-turbine based on these fuel types.

1.5 Significance

Micro gas turbine represents the leading energy system through which electric power generation has currently being deployed. In 2014, Alptekin *et al*. stated that animal fat is a low cost feedstock for biodiesel production compared to high-grade vegetable oils. The huge animal fats wastes can be producing biodiesel, for example, in 2013 the number of chicken consumption was about 1200 million in Turkey. If it is assumed that 25% of chicken amount are sent to rendering process and the fat contents of rendering products are 10–12%, there will be about 100 million kg of chicken fat per year. This present study explores the feasibility of utilising biodiesel produced from animal fats in operating micro gas turbine. Therefore, the findings from this study could be useful as input in the development of micro-turbine operations and sustainable climate and environmental conservation.

1.6 Organization of the Study

The thesis consists of five chapters, and each chapter was divided into several sub-sections. Chapter one gave information about the background of the research, problem statement, specific objectives and the scope of the study. The first part of chapter two covered the literature review of micro-gas-turbine. This chapter discussed the principle, types, efficiency and limitation of micro-gas-turbine. Also, chapter two discussed the different biodiesel plants and animals with more focused on animal fats. Chapter three focused on methodology used in the investigation of the operation performance and emission gasses of micro-gas-turbine. The methodology of micro-gas-turbine was used fossil diesel and biodiesel, including samples preparation, laboratory analysis, and statistical methods. Meanwhile, chapter four presented the findings of the research with some discussion explaining the results. Finally, the conclusions and recommendations are presented in chapter five.

REFERENCES

Abdullah, A. Z., Salamatinia, B., Mootabadi, H., & Bhatia, S. (2009). Current status and policies on biodiesel industry in Malaysia as the world's leading producer of palm oil. *Energy Policy*, *37*(12), 5440–5448.

Abdullah, S., & Tiong, E. C. (2008). Prediction of Palm Oil Properties using Artificial Neural Network. *Journal of Computer Science*, *8*(8), 101–106.

Adewale, P., Dumont, M. J., & Ngadi, M. (2015). Recent trends of biodiesel production from animal fat wastes and associated production techniques. *Renewable and Sustainable Energy Reviews*, 45, 574-588.

Ajanovic, A. (2011). Biofuels versus food production: Does biofuels production increase food prices? *Energy*, *36*(4), 2070–2076.

Ali, N., Sebzali, M., Safar, A., & Al-khatib, F. (2015). A Feasibility Study of Using Waste Cooking Oil as a Form of Energy in Kuwait. *IEEE-Nternational Conference on Sustainable Mobility Applications, Renewables and Technology (SMART)*, 3–7.

Alleman, T. L., McCormick, R. L., Christensen, E. D., Fioroni, G., Moriarty, K., & Yanowitz, J. (2016). Biodiesel handling and use guide (No. NREL/BK-5400-66521; DOE/GO-102016-4875). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Alptekin, E., & Canakci, M. (2011). Optimization of transesterification for methyl ester production from chicken fat. *Fuel*, *90*(8), 2630–2638.

Alptekin, E., Canakci, M., & Sanli, H. (2012). Evaluation of leather industry wastes as a feedstock for biodiesel production. *Fuel*, *95*, 214–220.

Alptekin, E., Canakci, M., & Sanli, H. (2014). Biodiesel production from vegetable oil and waste animal fats in a pilot plant. *Waste Management*, *34*(11), 2146–2154.

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. r*enewable and Sustainable energy reviews*, 41, 237-247.

Al-Sood, M. M. A., Matrawy, K. K., & Abdel-Rahim, Y. M. (2014). Optimum operating parameters of an irreversible gas turbine cycle. *Journal of Engineering Sciences, Assiut University*, 40(6), 1695-1714.

Antoine, H., & Prieels, L. (2002, January). The ACTE spiral recuperator for gas turbine engines. In ASME Turbo Expo 2002: Power for Land, Sea, and Air (pp. 1025-1031). *American Society of Mechanical Engineers*.

Ashraful, A. M., Masjuki, H. H., Kalam, M. A., Fattah, I. R., Imtenan, S., Shahir, S. A., & Mobarak, H. M. (2014). Production and comparison of fuel properties, engine performance, and emission characteristics of biodiesel from various non-edible vegetable oils: *A review. Energy conversion and management*, 80, 202-228.

Asgari, H., Chen, X., Menhaj, M. B., & Sainudiin, R. (2013). Artificial neural network–based system identification for a single-shaft gas turbine. *Journal of Engineering for Gas Turbines and Power*, 135(9), 092601.

Awad, S., Paraschiv, M., Varuvel, E. G., & Tazerout, M. (2013). Optimization of biodiesel production from animal fat residue in wastewater using response surface methodology. *Bioresource technology*, 129, 315-320.

Azad, A. K., Uddin, S. A., & Alam, M. M. (2013). Experimental study of DI diesel engine performance using biodiesel blends with kerosene. *International Journal of Energy and Environment*, 4(2), 265-278.

Balat, M. (2009). Prospects for worldwide biodiesel market development. *Energy Sources, Part B*, *4*(1), 48–58.

Balat, M. (2011). Potential alternatives to edible oils for biodiesel production – A review of current work. *Energy Conversion and Management*, *52*(2), 1479–1492.

Balat, M., & Balat, H. (2010). Progress in biodiesel processing. *Applied Energy*, *87*(6), 1815–1835.

Bankovic-Ilic, I. B., Stojkovic, I. J., Stamenkovic, O. S., Veljkovic, V. B., & Hung, Y. T. (2014). Waste animal fats as feedstocks for biodiesel production. *Renewable and Sustainable Energy Reviews*, *32*, 238–254.

Basrawi, F., Yamada, T., & Obara, S. Y. (2014). Economic and environmental based operation strategies of a hybrid photovoltaic–microgas turbine trigeneration system. *Applied Energy*, 121, 174-183.

Bernotat, K., & Sandberg, T. (2004). Biomass fired small-scale CHP in Sweden and the Baltic States: A case study on the potential of clustered dwellings. *Biomass and Bioenergy*, *27*(6), 521–530.

Bianchi, M., De Pascale, A., Melino, F., & Peretto, A. (2014). Performance prediction of micro-CHP systems using simple virtual operating cycles. *Applied Thermal Engineering*, 71(2), 771-779.

Blanco-Marigorta, A. M., Suárez-Medina, J., & Vera-Castellano, A. (2013). Exergetic analysis of a biodiesel production process from Jatropha curcas. *Applied Energy*, *101*, 218–225.

Budzianowski, W. M. (2016). A review of potential innovations for production, conditioning and utilization of biogas with multiple-criteria assessment. *Renewable and Sustainable Energy Reviews*, 54, 1148–1171.

Canakci, M. (2007). The potential of restaurant waste lipids as biodiesel feedstocks. *Bioresource Technology*, *98*(1), 183–190.

Canakci, M., & Sanli, H. (2008). Biodiesel production from various feedstocks and their effects on the fuel properties. *Journal of Industrial Microbiology and Biotechnology*, *35*(5), 431–441. http://doi.org/10.1007/s10295-008-0337-6

Canakci, M., & Van Gerpen, J. H. (2003). Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel, and soybean oil biodiesel. *Transactions of the ASAE*, *46*(4), 937.

Cao, P., Dubé, M. A., & Tremblay, A. Y. (2008). High-purity fatty acid methyl ester production from canola, soybean, palm, and yellow grease lipids by means of a membrane reactor. *Biomass and Bioenergy*, *32*(11), 1028–1036.

Cao, Y., Wang, Y., Riley, J. T., & Pan, W. P. (2006). A novel biomass air gasification process for producing tar-free higher heating value fuel gas. *Fuel Processing Technology*, *87*(4), 343–353.

Carlini, M., Castellucci, S., & Cocchi, S. (2014). A pilot-scale study of waste vegetable oil transesterification with alkaline and acidic catalysts. *Energy Procedia*, *45*, 198–206.

Centrec Consulting Group, LLC for the National Biodiesel Board. (2014). Biodiesel demand for animal fats and tallow generates an additional revenue stream for the livestock i ndustry. Retrive: https://biodiesel.org/docs/default-source/news---supporting-files/animal-fats-and-tallow-bd-demand-impact-report.pdf?sfvrsn=2

Čerc?e, T., Peter, S., & Weidner, E. (2005). Biodiesel-transesterification of biological oils with liquid catalysts: Thermodynamic properties of oil-methanol- amine mixtures. *Industrial & Engineering Chemistry Research*, *44*(25), 9535–9541.

Chitra, P., Venkatachalam, P., & Sampathrajan, A. (2005). Optimisation of experimental conditions for biodiesel production from alkali-catalysed transesterification of Jatropha curcus oil. *Energy for Sustainable Development*, *9*(3), 13–18.

Chiong, M. C., Chong, C. T., Ng, J. H., Lam, S. S., Tran, M. V., Chong, W. W. F., ... & Valera-Medina, A. (2018). Liquid biofuels production and emissions performance in gas turbines: A review. *Energy Conversion and Management,* 173, 640-658.

Choudhury, A., Chandra, H., & Arora, A. (2013). Application of solid oxide fuel cell technology for power generation—A review. *Renewable and Sustainable Energy Reviews*, 20, 430-442.

Chuah, L. F., Yusup, S., Aziz, A. R. A., Klemeš, J. J., Bokhari, A., & Abdullah, M. Z. (2016). Influence of fatty acids content in non-edible oil for biodiesel properties. *Clean Technologies and Environmental Policy*, 18(2), 473-482.

Comodi, G., Renzi, M., Caresana, F., & Pelagalli, L. (2015). Enhancing micro gas turbine performance in hot climates through inlet air cooling vapour compression technique. *Applied Energy*, *147*, 40–48.

Cunha Jr, A., Feddern, V., Marina, C., Higarashi, M. M., de Abreu, P. G., & Coldebella, A. (2013). Synthesis and characterization of ethylic biodiesel from animal fat wastes. *Fuel*, 105, 228-234.

Da Cunha, M. E., Krause, L. C., Moraes, M. S. A., Faccini, C. S., Jacques, R. A., Almeida, S. R., … Caramão, E. B. (2009). Beef tallow biodiesel produced in a pilot scale. *Fuel Processing Technology*, *90*(4), 570–575.

Darrow, K. et al., 2015. Catalog of CHP Technologies, US: U.S. Environmental Protection Agency Combined Heat and Power Partnership.

Dharma, S., Ong, H. C., Masjuki, H. H., Sebayang, A. H., & Silitonga, A. S. (2016). An overview of engine durability and compatibility using biodiesel–bioethanol–diesel blends in compression-ignition engines. *Energy Conversion and Management*, *128*, 66–81.

Di, Y., Cheung, C. S., & Huang, Z. (2009). Comparison of the effect of biodiesel-diesel and ethanol-diesel on the gaseous emission of a direct-injection diesel engine. *Atmospheric Environment*, *43*(17), 2721–2730.

Dias, J. M., Alvim-Ferraz, M. C. M., & Almeida, M. F. (2009). Production of biodiesel from acid waste lard. *Bioresource Technology*, *100*(24), 6355–6361.

Diakostefanis, M., Nikolaidis, T., Sampath, S., & Triantafyllou, T. (2017). Remote operation and monitoring of a micro aero gas turbine. *The Aeronautical Journal*, 121(1242), 1051-1065.

Dias, J. M., Alvim-Ferraz, M. C. M., Almeida, M. F., M??ndez D??az, J. D., Polo, M. S., & Utrilla, J. R. (2012). Selection of heterogeneous catalysts for biodiesel production from animal fat. *Fuel*, *94*, 418–425.

Dong, L., Liu, H., & Riffat, S. (2009). Development of small-scale and micro-scale biomass-fuelled CHP systems - A literature review. *Applied Thermal Engineering*, *29*(11-12), 2119–2126.

Enweremadu, C. C., & Mbarawa, M. M. (2009). Technical aspects of production and analysis of biodiesel from used cooking oil-A review. *Renewable and Sustainable Energy Reviews*, *13*(9), 2205–2224. h

Fan, X., & Burton, R. (2009). Recent Development of Biodiesel Feedstocks and the Applications of Glycerol: A Review. *The Open Fuels & Energy Science Journal*, *2*(1), 100–109.

Feddern, V. (2011). Animal Fat Wastes for Biodiesel Production. *Biodiesel - Feedstocks and Processing Technologies*, 45–70.

Fukuda, H., Kondo, A., & Noda, H. (2001). Biodiesel fuel production by transesterification of oils. *Journal of bioscience and bioengineering*, 92(5), 405-416.

Ghaderi, a., Abbasi, S., Motevali, a., & Minaei, S. (2012). Comparison of mathematical models and artificial neural networks for prediction of drying kinetics of mushroom in microwave vacuum dryer. *Chemical Industry and Chemical Engineering Quarterly*, *18*(2), 283–293.

Gillette, S., & Gilbreth, M. (2013). Microturbines. In *Power Electronics for Renewable and Distributed Energy Systems* (pp. 295–331). Springer.

Gomes, M. C. S., Arroyo, P. A., & Pereira, N. C. (2013). Influence of acidified water addition on the biodiesel and glycerol separation through membrane technology. *Journal of membrane science*, 431, 28-36.

Gui, M. M., Lee, K. T., & Bhatia, S. (2008). Feasibility of edible oil vs. non-edible oil vs. waste edible oil as biodiesel feedstock. *Energy*, *33*(11), 1646–1653.

Gupta, K. K., Rehman, A., & Sarviya, R. M. (2010). Bio-fuels for the gas turbine: A review. *Renewable and Sustainable Energy Reviews*, *14*(9), 2946–2955.

Hill, J., Nelson, E., Tilman, D., Polasky, S., & Tiffany, D. (2006). Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences*, *103*(30), 11206–11210.

Hoekman, S. K., & Robbins, C. (2012). Review of the effects of biodiesel on NOx emissions. *Fuel Processing Technology*, *96*, 237–249.

Hohloch, M., Zanger, J., Widenhorn, A., & Aigner, M. (2010, October). Experimental characterization of a micro gas turbine test rig. In ASME Turbo Expo 2010: Power for Land, Sea, and Air (pp. 671-681). A*merican Society of Mechanical Engineers*.

Hossain, A. B. M. S., Salleh, A., Boyce, A. N., Chowdhury, P., & Naqiuddin, M. (2008). Biodiesel fuel production from algae as renewable energy. *American Journal of Biochemistry and Biotechnology*, *4*(3), 250–254.

Hou, Z., & Zheng, D. (2009). Solar utility and renewability evaluation for biodiesel production process. *Applied Thermal Engineering*, *29*(14-15), 3169–3174.

Isler, A., Sundu, S., Tüter, M., & Karaosmano\uglu, F. (2010). Transesterification reaction of the fat originated from solid waste of the leather industry. *Waste Management*, *30*(12), 2631–2635.

Jain, S., & Sharma, M. P. (2010). Prospects of biodiesel from Jatropha in India: A review. *Renewable and Sustainable Energy Reviews*, *14*, 763–771.

Jha, S. K., Fernando, S., Columbus, E., & Willcutt, H. (2009). A comparative study of exhaust emissions using diesel-biodiesel-ethanol blends in new and used engines. T*ransactions of the ASABE*, 52(2), 375-381.

Karavalakis, G., Stournas, S., & Karonis, D. (2010). Evaluation of the oxidation stability of diesel/biodiesel blends. *Fuel*, *89*(9), 2483–2489.

Lagerstrom, G., & Xie, M. (2002, January). High performance and cost effective recuperator for micro-gas turbines. In ASME Turbo Expo 2002: Power for Land, Sea, and Air (pp. 1003-1007). *American Society of Mechanical Engineers*.

Leung, D. Y. C., & Guo, Y. (2006). Transesterification of neat and used frying oil: optimization for biodiesel production. *Fuel Processing Technology*, *87*(10), 883–890.

Lin, L., Ying, D., Chaitep, S., & Vittayapadung, S. (2009). Biodiesel production from crude rice bran oil and properties as fuel. *Applied Energy*, *86*(5), 681–688.

Mahmudul, H. M., Hagos, F. Y., Mamat, R., Adam, A. A., Ishak, W. F. W., & Alenezi, R. (2017). Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review. *Renewable and Sustainable Energy Reviews*, *72*(April 2016), 497–509.

Mandotra, S. K., Kumar, P., Suseela, M. R., Nayaka, S., & Ramteke, P. W. (2016). Evaluation of fatty acid profile and biodiesel properties of microalga Scenedesmus abundans under the influence of phosphorus, pH and light intensities. *Bioresource technology*, 201, 222-229.

Marvey, B. B. (2008). Sunflower-based feedstocks in nonfood applications: perspectives from olefin metathesis. *International Journal of Molecular Sciences*, *9*(8), 1393–1406.

Máša, V., Bobák, P., & Vondra, M. (2016). Potential of gas microturbines for integration in commercial laundries. *Operational Research*.

Mata, T. M., Martins, A. A., & Caetano, N. S. (2010). Microalgae for biodiesel production and other applications: A review. *Renewable and Sustainable Energy Reviews*, *14*(1), 217–232.

McDonald, C. F., & Wilson, D. G. (1996). The utilization of recuperated and regenerated engine cycles for high-efficiency gas turbines in the 21st century. *Applied Thermal Engineering*, 16(8-9), 635-653.

Medina Rey, J. M. (2013). Biofuels and food security. *Cuadernos de Estrategia*, (161), 196–224.

Mittelbach, M., & Remschmidt, C. (2004). *Biodiesel: The comprehensive handbook; B{ö}rsedruck GmbH, Wien*.

Mohammadi, E., & Montazeri-Gh, M. (2014). Simulation of full and part-load performance deterioration of industrial two-shaft gas turbine. *Journal of Engineering for Gas Turbines and Power*, 136(9), 092602.

Nabi, M. N., Hoque, S. M. N., & Akhter, M. S. (2009). Karanja (Pongamia Pinnata) biodiesel production in Bangladesh, characterization of karanja biodiesel and its effect on diesel emissions. *Fuel Processing Technology*, *90*(9), 1080–1086.

Nagarhalli, M. V, Nandedkar, V. M., & Mohite, K. C. (2010). Emission and performance characteristics of karanja biodiesel and its blends in a CI engine and its economics. *ARPN Journal of Engineering and Applied Sciences*, *5*(2), 52–56.

Nagasaki, T., Tokue, R., Kashima, S., & Ito, Y. (2003, November). Conceptual design of recuperator for ultramicro gas turbine. *In Proceedings of the International Gas Turbine Congress* (pp. 2-7).

Naik, M., Meher, L. C., Naik, S. N., & Das, L. M. (2008). Production of biodiesel from high free fatty acid Karanja (Pongamia pinnata) oil. *Biomass and Bioenergy*, *32*(4), 354–357.

Nascimento, M. A. R. Do, Rodrigues, L. D. O., E. C. Dos Santos, E. E. B. G., Dias, F. L. G., Velásques, E. I. G., & Carrillo, R. a. M. (2013). Micro Gas Turbine Engine: A Review. *Progress in Gas Turbine Performance*, 108–142.

Nascimento, M. A., Lora, E. S., Correa, P. S., Andrade, R. V., Rendon, M. A., Venturini, O. J., & Ramirez, G. A. (2008). Biodiesel fuel in diesel micro-turbine engines: Modelling and experimental evaluation. *Energy*, 33(2), 233-240.

Nkoi, B., Pilidis, P., & Nikolaidis, T. (2013). Performance assessment of simple and modified cycle turboshaft gas turbines. *Propulsion and Power Research*, 2(2), 96-106.

Ngadi, M., Dirani, K., & Oluka, S. (2006). Mass transfer characteristics of chicken nuggets. *International Journal of Food Engineering*, 2(3).

Ngo, H. L., Zafiropoulos, N. A., Foglia, T. A., Samulski, E. T., & Lin, W. (2008). Efficient two-step synthesis of biodiesel from greases. *Energy and Fuels*, *22*(1), 626–634.

Oswald, J. I., Dawson, D. A., & Clawley, L. A. (1999, June). A new durable gas turbine recuperator. In ASME 1999 International Gas Turbine and Aeroengine Congress and Exhibition (pp. V002T04A010-V002T04A010). A*merican Society of Mechanical Engineers*.

Özener, O., Yüksek, L., Ergenç, A. T., & Özkan, M. (2014). Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics. *Fuel*, 115, 875-883.

Pahl, G. (2008). *Biodiesel: growing a new energy economy*. Chelsea Green Publishing.

Palash, S. M., Kalam, M. A., Masjuki, H. H., Masum, B. M., Fattah, I. M. R., & Mofijur, M. (2013). Impacts of biodiesel combustion on NOx emissions and their reduction approaches. *Renewable and Sustainable Energy Reviews*, *23*, 473–490.

Pang, X., Shi, X., Mu, Y., He, H., Shuai, S., Chen, H., & Li, R. (2006). Characteristics of carbonyl compounds emission from a diesel-engine using biodiesel–ethanol–diesel as fuel. *Atmospheric environment*, 40(36), 7057-7065.

Park, J. B. K., Craggs, R. J., & Shilton, A. N. (2011). Wastewater treatment high rate algal ponds for biofuel production. *Bioresource Technology*, *102*(1), 35–42.

Pilavachi, P. A. (2000). Power generation with gas turbine systems and combined heat and power. *Applied Thermal Engineering*, *20*(15), 1421–1429.

Pilavachi, P. A. (2002). Mini- and micro-gas turbines for combined heat and power. *Applied Thermal Engineering*, *22*(18), 2003–2014.

Pinzi, S., Garcia L., I., Lopez-Gimenez J., F., Castro D.,Luque,de, M., Dorado, G., & Dorado P., M. (2009). The Ideal Vegetable Oil-based Biodiesel Composition: A Review of Social, Economical and Technical Implications. *Energy & Fuels*, *23*(5), 2325–2341.

Plascencia, A., Estrada, M., & Zinn, R. A. (1999). Influence of free fatty acid content on the feeding value of yellow grease in finishing diets for feedlot cattle. *Journal of animal science*, 77(10), 2603-2609.

Rehman, A., Phalke, D. R., & Pandey, R. (2011). Alternative fuel for gas turbine: Esterified jatropha oil–diesel blend. *Renewable energy*, 36(10), 2635-2640.

Rice, B., Fröhlich, A., & Leonard, R. (1998). *Biodiesel production from camelina oil, waste cooking oil and tallow*. Dublin: Teagasc.

Richter, B. (2009). Environmental Challenges and the Controversy about Palm Oil Production--Case Studies from Malaysia, Indonesia and Myanmar. *Singapore: Friedrich-Ebert-Stiftung*.

Rochelle, D., & Najafi, H. (2019). A review of the effect of biodiesel on gas turbine emissions and performance. *Renewable and Sustainable Energy Reviews*, 105, 129-137.

Roessler, P. G., Brown, L. M., Dunahay, T. G., Heacox, D. a, Jarvis, E. E., Schneider, J. C., … Zeiler, K. G. (1994). Genetic Engineering Approaches for Enhanced Production of Biodiesel Fuel from Microalgae. *Enzymatic Conversion of Biomass for Fuels Production*.

Rovira, A., Sánchez, C., & Muñoz, M. (2015). Analysis and optimisation of combined cycles gas turbines working with partial recuperation. *Energy Conversion and Management*, 106, 1097-1108.

Sendzikiene, E., Makareviciene, V., & Janulis, P. (2006). Influence of fuel oxygen content on diesel engine exhaust emissions. *Renewable Energy*, *31*(15), 2505–2512.

Shi, X., Pang, X., Mu, Y., He, H., Shuai, S., Wang, J., … Li, R. (2006). Emission reduction potential of using ethanol--biodiesel--diesel fuel blend on a heavy-duty diesel engine. *Atmospheric Environment*, *40*(14), 2567–2574.

Shih, H. Y., & Huang, Y. C. (2009). Thermal design and model analysis of the Swiss-roll recuperator for an innovative micro gas turbine. *Applied Thermal Engineering*, 29(8-9), 1493-1499.

Smith, C. B., Capehart, B. L., & Rohrer Jr, W. M. (2016). Industrial energy efficiency and energy management. *In Energy Management and Conservation Handbook,* Second Edition (pp. 257-342). CRC Press.

Soares, C. (2007). Chapter 4 - Microturbine economics and market factors. *Microturbines*, 31–36.

Solaimuthu, C., Ganesan, V., Senthilkumar, D., & Ramasamy, K. K. (2015). Emission reductions studies of a biodiesel engine using EGR and SCR for agriculture operations in developing countries. *Applied Energy*, *138*, 91–98. http://doi.org/10.1016/j.apenergy.2014.04.023

Sorate, K. A., & Bhale, P. V. (2015). Biodiesel properties and automotive system compatibility issues. *Renewable and Sustainable Energy Reviews*, 41, 777-798.

Sun, J., Caton, J. A., & Jacobs, T. J. (2010). Oxides of nitrogen emissions from biodiesel-fuelled diesel engines. *Progress in Energy and Combustion Science*, *36*(6), 677–695.

Sureshkumar, K., Velraj, R., & Ganesan, R. (2008). Performance and exhaust emission characteristics of a CI engine fueled with Pongamia pinnata methyl ester (PPME) a

nd its blends with diesel. *Renewable Energy*, *33*(10), 2294–2302.

Teixeira, L. S. G., Assis, J. C. R., Mendonça, D. R., Santos, I. T. V, Guimarães, P. R. B., Pontes, L. A. M., & Teixeira, J. S. R. (2009). Comparison between conventional and ultrasonic preparation of beef tallow biodiesel.

Fuel Processing Technology, *90*(9), 1164–1166.

Thamsiriroj, T., & Murphy, J. D. (2010). How much of the target for biofuels can be met by biodiesel generated from residues in Ireland? *Fuel*, *89*(11), 3579–3589.

van der Velde, M., Bouraoui, F., & Aloe, A. (2009). Pan-European regional-scale modelling of water and N efficiencies of rapeseed cultivation for biodiesel production. *Global Change Biology*, *15*(1), 24–37.

Varatharajan, K., & Cheralathan, M. (2012). Influence of fuel properties and composition on NOx emissions from biodiesel powered diesel engines: A review. *Renewable and Sustainable Energy Reviews*, *16*(6), 3702–3710.

Veljkovic, V. B., Lakicevic, S. H., Stamenkovic, O. S., Todorovic, Z. B., & Lazic, M. L. (2006). Biodiesel production from tobacco (Nicotiana tabacum L.) seed oil with a high content of free fatty acids. *Fuel*, *85*(17-18), 2671–2675.

Walsh, P. P., & Fletcher, P. (2004). Gas turbine performance. John Wiley & Sons.

Wang, Y., Ou, S., Liu, P., & Zhang, Z. (2007). Preparation of biodiesel from waste cooking oil via two-step catalyzed process. *Energy Conversion and Management*, *48*(1), 184–188.

Yilmaz, N., Vigil, F. M., Donaldson, A. B., & Darabseh, T. (2014). Investigation of CI engine emissions in biodiesel–ethanol–diesel blends as a function of ethanol concentration. *Fuel*, 115, 790-793.

Zhang, Z., Guo, Z., Chen, Y., Wu, J., & Hua, J. (2015). Power generation and heating performances of integrated system of ammonia–water Kalina–Rankine cycle. *Energy Conversion and Management*, 92, 517-522.

Xiao, G., Yang, T., Liu, H., Ni, D., Ferrari, M. L., Li, M., ... & Ni, M. (2017). Recuperators for micro gas turbines: A review. *Applied Energy*, 197, 83-99.

BIODATA OF STUDENT

Nasser Abdullah Al-Rashidi Born March 8, 1975 in Al-Jahra, Kuwait I studied at the elementary and middle school in Al-Jahra, Kuwait. He completed his secondary education at Kefan School 1992 in Kefan, Kuwait. Then, he joined The Public Authority for Applied Education and Training College of Technology Studies Received a Diploma in Automotive Technology 1992 to 1995. After that, he worked at the Ministry of Transportation in the main workshop from 1995 to 1999. Following this he joined the military service from 1999 to 2000. He completed his undergraduate studies at Philadelphia University in Jordan and got a Bachelor of Mechanical Engineering from 2000 to 2005. Then, he worked in the Ministry of Electricity in the enterprise sector, Department of Mechanical Works In the project of the Sabia plant for the production of energy and water Supervision of welding works ,hydrostatic test pipelines for strength and leaks. He received his Master of Engineering and Project Management from Coventry University, UK 2005 to 2007. Then, he joined Ministry of Electricity in the enterprise sector Department of Mechanical Works 2008 to 2015. Then, he registered Master of Mechanical Engineering at UPM.

LIST OF PUBLICATIONS

Journals

Al-Rashidi. N, Hairuddin. A. A and Adam. N. M. (2018). Micro gas turbine operation using biodiesel. ***Renewable Energy.*** **In the process of publication.**

Al-Rashidi. N, Hairuddin. A. A and Adam. N. M. (2018). Experimental investigation of the performance of an animal fat-based biodiesel on a micro-gas turbine. **In the process of publication.**

UNIVERSITI PUTRA MALAYSIA

STATUS CONFIRMATION FOR THESIS / PROJECT REPORT AND COPYRIGHT

ACADEMIC SESSION : ____________________

TITLE OF THESIS / PROJECT REPORT :

PERFORMANCE OF ANIMAL FAT-BASED BIODIESEL ON MICRO-GAS TURBINE

NAME OF STUDENT: NASER A Z S ALRASHIDI

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as :

*Please tick (V)

☐	**CONFIDENTIAL**	(Contain confidential information under Official Secret Act 1972).
☐	**RESTRICTED**	(Contains restricted information as specified by the organization/institution where research was done).
☐	**OPEN ACCESS**	I agree that my thesis/project report to be published as hard copy or online open access.

This thesis is submitted for :

☐ **PATENT** Embargo from ____________ (date) until ____________ (date)

Approved by:

(Signature of Student)	(Signature of Chairman of Supervisory Committee)
New IC No/ Passport No.:	Name:
Date :	Date :

[Note : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]