UNIVERSITI PUTRA MALAYSIA

EXPERIMENTAL AND SIMULATED PERFORMANCE STUDY OF A SMALL-SCALE GAS TURBINE ENGINE USING JET A-1 AND PALM OIL BIODIESEL BLENDS

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By

EZANEE BIN GIRES

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Chair: Abd Rahim Abu Talib, PhD
Faculty: Engineering

The experimental and simulated performance of an Armfield CM4 turbojet engine was investigated for conventional Jet A-1 fuel as well as its blends with palm oil biodiesel (PME), a form of fatty acid methyl ester (FAME). The volumetric blends of PME with Jet A-1 are 20, 50, 70 and 100% (B20, B50, B70 and B100). Fuel heating values (FHV) of each fuel mixture were obtained by calometric analysis and were used to estimate changes in CM4 performance which were verified experimentally. The experimental tests included performance tests for Jet A-1 and B20, while the performances of B50 to B100 were simulated using GasTurb 11 analytical software after verification of simulated and experimental results for Jet A-1 and B20. Values of thrust, fuel flow, temperature and pressure distribution along the engine and engine speed were available from experimental measurements, whereas other values of merit were calculated using parametric cycle analysis and one-dimensional flow assumptions. In terms of maximum measured thrust, Jet A-1 yielded the highest value of 216 N, decreasing by 0.77%, 4%, 8% and 12% with B20, B50, B70 and

B100 based on experimental and simulated results. It was found that B20 produced comparable results compared to the benchmark Jet A-1 tests, particularly with thrust and thermal efficiency. Slight performance penalties occurred due to the lower energy content of the biodiesel blend. The efficiency of the combustor improved with the addition of biodiesel while the other component efficiencies remained collectively consistent. The performance parameters of the CM4 engine were found to deteriorate with increased PME content in the simulations, particularly for volumetric blends of over 50% palm oil biodiesel. This research shows that for gas turbines, PME is suitable for use as an additive to Jet A-1, but not as a complete replacement fuel.

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

KAJIAN PRESTASI EKSPERIMEN DAN SIMULASI ENJIN TURBIN GAS SKALA KECIL MENGGUNAKAN JET A-1 DAN CAMPURAN BIODIESEL MINYAK SAWIT

Oleh

EZANEE BIN GIRES

Januari 2013

Pengerusi: Abd Rahim Abu Talib, PhD

Fakulti: Kejuruteraan

Prestasi sebuah enjin turbojet Armfield CM4 telah dikaji secara eksperimen dan simulasi untuk bahan api pesawat udara konvensional Jet A-1 serta campurannya dengan biodiesel minyak kelapa sawit (PME), sejenis metil ester asid lemak (FAME). Isipadu campuran PME dengan Jet A-1 adalah dalam nisbah campuran isipadu 20, 50, 70 dan 100% (B20, B50, B70 dan B100). Kandungan tenaga bahan api (FHV) bagi setiap campuran minyak telah diperolehi melalui analisis kalorimetrik dan nilainya digunakan dalam anggaran perubahan prestasi CM4 yang telah disahkan melalui eksperimen. Kajian eksperimental merangkumi ujian prestasi bagi minyak Jet A-1 dan B20, manakala prestasi bagi B50, B70 dan B100 disimulasi dengan menggunakan perisian analisis GasTurb 11 selepas pengesahan keputusan simulasi B20 dan Jet A-1 dengan keputusan daripada eksperimen. Nilai-nilai tujahan, aliran bahan api, taburan suhu dan tekanan dalam enjin, serta pusingan per minit (rpm) enjin diperolehi daripada pengukuran eksperimen, manakala nilai-nilai merit yang lain dikira melalui analisis kitaran parametrik dan andaian aliran satu dimensi. Dari segi tujahan maksimum, Jet A-1 menghasilkan nilai tertinggi iaitu 216 N, dengan

nilai yang menurun sebanyak 0.77%, 4%, 8% dan 12% dengan B20, B50, B70 dan B100 berdasarkan keputusan eksperimen dan simulasi. Didapati bahawa B20 menghasilkan keputusan setanding dengan keputusan kajian menggunakan Jet A-1, terutamanya dalam tujahan dan kecekapan terma. Penalti prestasi yang kecil diakibatkan oleh kandungan tenaga B20 yang lebih rendah daripada Jet A-1. kecekapan seksyen pembakar enjin dipertingkatkan dengan pembakaran campuran biodiesel, manakala kecekapan komponen yang lain kekal konsisten. Parameter prestasi enjin CM4 didapati merosot dengan peningkatan kandungan PME dalam simulasi, terutamanya bagi campuran isipadu lebih daripada 50% biodiesel minyak sawit. Kajian ini menunjukkan bahawa bagi turbin gas, PME adalah sesuai untuk digunakan sebagai bahan tambahan kepada Jet A-1, tetapi bukan sebagai bahan api gantian yang lengkap.

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I certify that a Thesis Examination Committee has met on 29 January 2013 to conduct the final examination of Ezanee bin Gires on his thesis entitled "**Title of thesis**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

Members of the Thesis Examination Committee were as follows:

Harijono Djojodihardjo, PhD
Professor Ir
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Kamarul Arifin Ahmad, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Surjatin Wiriadidjaja, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohammad Nazri Mohd Ja'afar, PhD
Professor
Faculty of Mechanical Engineering
Universiti Teknologi Malaysia
Malaysia
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 March 2013

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:

Abd Rahim Abu Talib, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohamed Tarmizi Ahmad
Associate Professor Lt. Col. (R)
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

EZANEE BIN GIRES

Date: 29 January 2013

TABLE OF CONTENTS

APPENDICES