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# AN EXPERIMENTAL AND NUMERICAL INVESTIGATION OF A GAS TURBINE RESEARCH COMBUSTOR

by

**Reuben Montresor Morris**

Dissertation presented in partial fulfilment
of the requirements for the degree of

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Promoter: Prof. J.A. Visser

Department: Mechanical and Aeronautical Engineering

Degree: Master of Engineering

## SUMMARY

Gas turbine engineering faces many challenges in the constant strive to increase not only the efficiency of engines but also the various stages of development and design. Development of combustors have primarily consisted of empirical or semi-empirical modelling combined with experimental investigations. Due to the associated costs and development time a need exists for an alternative method of development. Although experimental investigations can never be substituted completely, mathematical models incorporating numerical methods have shown to be an attractive alternative to conventional combustor design methods.

The purpose of this study is twofold: firstly, to experimentally investigate the physical properties associated with a research combustor that is geometrically representative of practical combustors; and secondly, to use the experimental measurements for the validation of a computational fluids dynamic model that was developed to simulate the research combustor using a commercial code.

The combustor was tested at atmospheric conditions and is representative of practical combustors that are characterized by a turbulent, three-dimensional flow field. The single can combustor is divided into a primary, secondary and dilution zone, incorporating film-cooling air through stacked rings and an axial swirler centred around the fuel atomizer. Measurements at different air/fuel ratios captured the thermal field during operating conditions and consisted of inside gas, liner wall and exit gas temperatures.

An investigation of the different combustion models available, led to the implementation of the presumed-PDF model of unpremixed turbulent reaction. The computational grid included the external and internal flow field with velocity boundary conditions prescribed at the various inlets. Two-phase flow was not accounted for with the assumption made that the liquid fuel is introduced into the combustion chamber in a gas phase.

Experimental results showed that incomplete combustion occurs in the primary zone, thereby reducing the overall efficiency. Also evident from the results obtained are the incorrect flow splits at the various inlets. Evaluation of the numerical model showed that gas temperatures inside the combustor are overpredicted. However, the numerical model is capable of capturing the correct distributions of temperatures and trends obtained experimentally.

This study is successful in capturing detail temperature measurements that will be used for validation purposes to assist the development of a numerical model that can accurately predict combustion properties.

**Keywords:**

Gas turbine combustion
Liner wall temperatures
Exit gas temperatures
Presumed-PDF model
Swirling air
Computational fluids dynamics
Inside gas temperatures
Test rig
Boundary conditions
Flow splits

# 'N EKSPERIMENTELE EN NUMERIESE ONDERSOEK VAN 'N GAS TURBINE NAVORSINGS VERBRANDER

deur

**Reuben Montresor Morris**

Promotor: Prof. J.A. Visser

Departement: Meganiese en Lugvaartkundige Ingenieurswese

Graad: Magister in Ingenieurswese

## OPSOMMING

Gas turbine ingenieurswese trotseer voortdurend uitdagings om die effektiwiteit van turbinestraalmotors sowel as die verskillende fases van ontwerp en ontwikkeling te verbeter. Ontwikkeling het hoofsaaklik berus op empiriese of semi-empiriese modellering gekoppel aan eksperimentele ondersoeke. As gevolg van die hoë kostes en ontwikkelings tyd verbonde aan eksperimentele ondersoeke bestaan daar 'n behoefte aan 'n alternatiewe manier van ontwikkeling. 'n Alternatiewe manier wat baie potensiaal wys is die gebruik van wiskundige modelle wat numeriese metodes implementeer.

Die doel van die studie is tweeledig: eerstens, om eksperimenteel die fisiese eienskappe van 'n navorsings verbrandingsruim wat geometries verteenwoordigend is van praktiese verbranders te ondersoek, en tweedens, om die eksperimentele resultate te vergelyk met die resultate van 'n berekeningsvloeidinamika model wat ontwikkel is om die navorsings verbrander te simuleer. Die numeriese model is ontwikkel deur gebruik te maak van 'n kommersieël beskikbare kode.

Eksperimente is uitgevoer by atmosferiese toestande en die verbrander is verteenwoordigend van praktiese verbranders wat gekenmerk word deur 'n driedimensionele, turbulente vloeiveld. Die verbrandingsruim is verdeel in 'n primêre, sekondêre en tersiêre sone en film verkoelingslug word geimplimenteer deur gebruik te maak van stapel ringe. 'n Aksiale werwelaar gesentreer rondom die brandstof inspuiter verhoog die turbulensie intensiteit.

'n Ondersoek na die verskillende verbrandingsmodelle het gelei tot die implementering van die PPDF-model van ongemengde turbulente reaksie. Die berekenings rooster het die interne en eksterne vloeiveld ingesluit en snelhede is gespesifiseer as grens voorwaardes by die verskillende inlate. Tweefase vloei is nie in ag geneem nie, en die aaname is gemaak dat die brandstof in 'n gasfase vrygestel word in die verbrandingsruim.

Die eksperimentele resultate het gewys dat die verbrandings effektiwiteit word verlaag as gevolg van onvolledige verbranding in die primêre sone. Ook voor die hand liggend is dat die verkeerde vloei verdelings bestaan by die afsonderlike inlate. Evaluering van die numeriese model wys dat die resultate oorbereken die gas temperature binne die verbrander. Ten spyte hiervan is die numeriese model in staat om die korrekte temperatuur verspreidings en tendense wat verkry is eksperimenteel te voorspel.

Die studie is suksesvol in die sin dat detail temperatuur metings verkry is wat gebruik sal word vir evaluerings doeleindes en om bystand te lewer in die ontwikkeling van 'n model wat die fisiese eienskappe van 'n gas turbine verbrander akkuraat kan voorspel.

**Sleutelterme:**

Gas turbine verbrander
Wand temperature
Uitlaatgas temperature
PPDF-model
Werwelings lug
Berekiningsvloeidinamika
Binne gas temperature
Toets opstelling
Grens voorwaardes
Vloei verdelings

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