Analysis and Experimentation of a Single Stage Travelling-wave Thermoacoustic Engine

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Master of Science (Major Component Research)

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DECLARATION

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 06/03/2025

The above candidate has carried out research for the PhD/MPhil/Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor	Signature of the Supervisor	Date
Dr. MMID Manthilake		07/03/2025
Dr. MA Wijewardane		07/03/2025
Dr. RACP Ranasinghe		08/03/2025

DEDICATION

This thesis is humbly dedicated to the most important people in my life, my cherished parents who have guided me throughout this journey. Your guidance and unwavering support have been my motivation.

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I deeply thank my beloved parents for their unwavering support, encouragement, and sacrifices throughout this journey. Your belief in my abilities and constant motivation has been my guiding light, inspiring me to strive for excellence in every endeavor.

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ABSTRACT

Clean and sustainable energy has become the most significant necessity in the modern world due to the growth of the population and the scarcity of conventional energy sources. Moreover, using fossil fuels hurts the environment, biodiversity, and the health and well-being of both present and future generations. Currently, 30–50% of waste heat is produced by fossil fuels, and the emission of greenhouse gases and fuel consumption can be mitigated by recovering waste heat by using heat recovery techniques such as organic Rankine cycles, regenerators, and plate heat exchangers.

Thermoacoustic technology harnesses the waste heat from low-grade waste heat sources by converting it into acoustic energy and then into electricity. Still, it remains a relatively nascent field, and ongoing research is being done to develop conversion efficiency. The impact of the design parameters of the device on conversion efficiency was studied. According to the study, the working fluid temperature and the stack length are crucial to energy conversion efficiency. Based on the results, as the working fluid temperature increases, there is a noticeable rise in both pressure amplitude and volume flowrate amplitude, along with an improvement in efficiency, all while maintaining a constant regenerator length.

Similarly, efficiency increases with longer regenerator lengths when the working fluid temperature is held constant. If the working fluid temperature increases by 1 degree Celsius while maintaining the regenerator length constant, the pressure amplitude is increased by 6.2%. Higher efficiencies can be achieved by increasing the stack length, yet an upper limit exists. The efficiency is limited after a certain regenerator length because the expected acoustic behavior vanishes. These findings suggest the importance of both working fluid temperature and regenerator length in optimizing the efficiency of thermoacoustic energy conversion systems.

Keywords: Thermoacoustic, Acoustic, Travelling wave, Regenerator, DeltaEC

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γ - specific heat ratio

δ_k - thermal penetration depth

δ_v - viscous penetration depth

ε_s - correction factor for finite solid capacity

λ - wavelength

μ - dynamic viscosity

ρ_m - mean density

τ - temperature ratio

ω - angular velocity

Δ - difference

$\varnothing$ - porosity

a - speed of sound

f - frequency

f_k - spatially averaged thermal function

f_v - spatially averaged viscous function

k_{gas} - thermal conductivity of gas

k_{solid} - thermal conductivity of solid

r_h - hydraulic radius

A - area

A_{gas} - cross sectional area of the gas channel

A_{solid} - solid cross-sectional area

C - acoustic compliance

C_p - specific heat at constant pressure

D_{wire} - wire diameter

H - energy flow

I - current

L - inertance

P_1 - pressure amplitude

P_r - Prandtl number

Q - heat

Re - real component

T_c - temperature of regenerator cold face

T_h - temperature of regenerator hot face

T_m - mean temperature

U_a - velocity amplitude

U_1 - volumetric velocity amplitude

V - voltage

$\dot{W}$ - acoustic power flow

X_a - displacement amplitude

Z - acoustic impedance