Cyprus University of Technology

Faculty of Engineering and Technology

Engineering and Informatics

A probability control and statistical modeling study for the feasibility of large-scale implementation of Seebeck-Peltier modules in ship cladding

DOCTORAL DISSERTATION

PhD Candidate: **Ioannis P. Armenakis**

Academic Supervisor: **Prof. Sotirios Chatzis**

Academic Committee:
Prof. Sot. Chatzis CUT
Prof. Chr. Damianou CUT
Prof. Ioannis Prousalidis NTUA

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To my father,
who taught me that every ship has a soul,
to my mother
for making me what I am,
to my daughters
for giving me a reason to live,
and to Despina
for making my life worth living.

«Λίθος, ὃν ἀπεδοκίμασαν οἱ οἰκοδομοῦντες, οὗτος ἐγενήθη εἰς κεφαλὴν γωνίας»

Ψαλμός 117:22

«The stone the builders rejected, has become the cornerstone»

Psalm 117:22

List of relevant publications by the Author et al.

- **Armenakis Yiannis P., Chatzis Sotirios**, "Waste heat recovery and electrical power production on vessels by means of TEG arrays attached on the hull plates below the waterline" As presented in the ESTS 2019 International Conference, Washington USA, 15/08/2019.
- **Armenakis Yiannis P.,** "Exploitation of Waste Heat of Marine Diesel Engines using Seebeck Elements", International Journal of Innovative Research in Science, Engineering and Technology, Volume 11, Issue 7, July 2022, DOI:10.15680/IJIRSET.2022.1107002

Table of Contents

ABSTRACT

Regaining a part of the heat lost during industrial or commercial activities has become a modern Holy Grail quest ever since the 1st Industrial Revolution. Since energy in general and heat in particular, are both the strategic and financial support beam of modern society, a continuous scientific and technical struggle is constantly running towards the rationalization of energy usage and the minimization of its losses. To achieve the above, several technologies have been and are being developed. In this research, the installation of large-scale Thermoelectric (TEG) elements arrays onboard ships was be examined. This venture was attempted several times in the past with limited success due to the immense need of cooling the elements. The goal of this research was the investigation whether or not the recovery of waste heat would be possible by TEG, if effective cooling was possible by attaching them on the inner side of the vessel's hull plates. Towards this, several design approaches have been attempted, numerus simulations have been run, the international bibliography was thoroughly investigated, whilst architectural, structural, mechanical, and electrical data from an actual modern real, large vessel have been evaluated. What was proven to be extremely important was the statistical investigation of the impact of the vessel's routing during its regular voyages on the effectiveness of the system due to the seawater temperature alterations. Although a thorough study of the thermoelectric theory was the cornerstone of this research, it was proven to be a rather interdisciplinary task.

During the research, the need for extensive knowledge of thermodynamics, electrical power management, 2D and 3D CAD drawing, FEA and CFD analyses, MATLAB® SIMULINK®, PLC and SCADA as well as of several statistics software has been proven necessary.

The conclusions of this research indicated that the installation and effective operation of a system of TEG arrays cooled by their attachment on the inner side of the vessel's hull plates, is feasible. The simulations run, have shown that the amount of energy that can be recovered is quite significant and its financial benefit for the ship's operators is indeed impressive. The amount of energy recovered per square meter of arrays was calculated to be 92KWh per 24hrs, thus saving some 17,5 Kg of Diesel Oil which otherwise would have been burned in the vessel's Generator sets. This would save some 68 Kg of CO_2 let alone other GHGs otherwise diffused in the environment.

The conclusions of this research can hardly be considered as a fulfillment of the whole task. In the author's opinion, they are rather the starting point of further discussion and investigation regarding the technical approaches to be followed for the completion of the final goal which was from the very beginning the improvement of the effectiveness and the reduction of the eco-footprint of Marine transportation.

Keywords and Phrases: Seebeck, TEG, Hull plates, Exhaust gas, Waste Heat, Eco Footprint, Back-pressure,