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Prospects of waste heat recovery and power generation using thermoelectric generators

Bradley Orr*, Aliakbar Akbarzadeh

School of Engineering, RMIT University, Melbourne 3000, Australia

Abstract

Thermoelectric generators (TEGs) are small solid state devices that generate electricity directly from heat. They have the potential to be applied in waste heat recovery systems and be used as a primary heat engine as a generator. Two case studies are discussed showing the potential power generation from the exhaust gases of a car engine and an open loop gas turbine power plant. It was determined that it is possible to generate 1.4 kW of electricity from a car exhaust heat recovery system if the engine produces 150 kW. It was also determined that it is possible to generate 5.9 MW of electricity from a 500 MW gas turbine power plant waste heat recovery system. A design is proposed to show how TEGs could be used as a primary power source but TEGs must improve their power per unit cost before they become a viable alternative to petrol generators.

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Keywords: Thermoelectric generators; heat pipes; exhaust heat; car engine; gas turbine.

1. Introduction

Thermoelectric generators are small tile shaped devices that operate as a heat engine by directly converting heat into electricity. An image of a TEG can be seen in figure 1. These devices make use of the Seebeck effect. They are made up of many N and P type elements that are connected electrically in series but thermally in parallel as demonstrated in figure 2. When there is a temperature difference over these elements, a small voltage is generated. As all the elements are connected in series, these small voltages add up to generate usable voltages. The difference

* Corresponding author. Tel.: +61 3 99256079.
E-mail address: s3236808@student.rmit.edu.au

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between the N and P type elements is that the voltages generated are opposite. The amount of voltage generated by the TEG is proportional to the temperature difference and the amount of electrical power produced is proportional to the temperature difference squared. The most common thermoelectric material is Bismuth Telluride (BiTe) but other thermoelectric materials are available. Their thermal efficiency typically peaks at around 5% [1]. This paper looks at the prospects of TEGs being used to produce power from waste heat sources and as a primary power source.

Nomenclature

P_{eng}	Engine power
P_{TEG}	TEG power
$\dot{Q}_{exh}$	Rate of heat energy in exhaust gases
$\dot{Q}_{rec}$	Rate of heat recovery
$\dot{Q}_{tot}$	Total rate of energy input from the fuel
η_{eng}	Engine efficiency
η_{exh}	Percentage of fuel energy in exhaust
η_{HX}	Heat exchanger effectiveness
η_{TEG}	TEG thermal efficiency

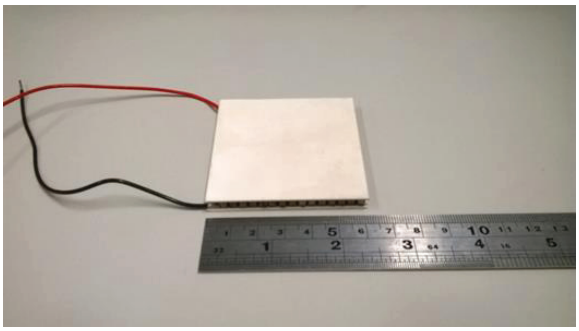

Fig. 1. Thermoelectric generator.

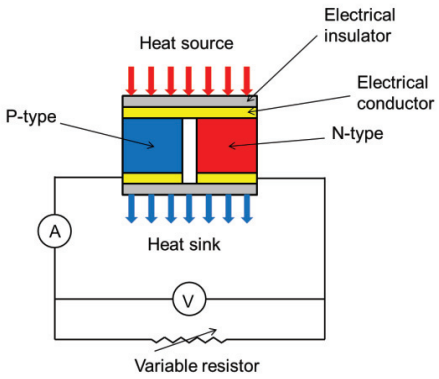

Fig. 2. Schematic of a TEG.