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Effect of Exhaust Gases Temperature on the Performance of a Hybrid Heat Recovery System

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Abstract

The reuse or reduction of wasted heat supplies an excellent opportunity for cost saving in industrial and residential application. This paper deals with a Hybrid heat recovery system that reuses the thermal energy captured by exhaust gases to produce domestic hot water and generate electric power using thermoelectric generators (TEG). The heat recovery process is mainly affected by the temperature of exhaust gases. The effect of gases temperature on the performance of the system – water temperature and power generated – is studied including different residential applications. It shows that as the exhaust gases temperature increase the heat rate, water temperature, and power generated increases.

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Keywords: Heat recovery; Thermoelectric generators; cogeneration; Thermal modeling; Domestic hot water;

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1. Introduction

Due to the rapid increase in demand and consumption of energy, scientists are forced to find solutions of what is called “Energy crisis”. Fossil fuel remains still the main energy resource that feeds most industrial and residential applications. Renewable energy and energy management are certainly the most effective solutions of Energy crisis

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[1]. Renewable energy which is an alternative source of energy is mainly generated from solar, wind, biomass, geothermal, and hydropower [2-11].

Energy recovery consists in the reuse of energy dumped to the environment without taking advantage of it [12-17]. Because of the high dependence of fossil fuel which is burned to generate thermal energy, high amount of exhaust gases are generated which could be the highest energy loss in the system. Recovering heat from exhaust gases can be done directly or indirectly by a mean of heat exchanger or any energy transformation process. Jaber et al. [18] did a short review on heat recovery, classifying it into different configurations. The authors classified exhaust gas heat recovery systems within three classifications that are exhaust gas temperature, utilized equipment and proposed a new classification according to recovery purposes.

This paper deals with heat recovery from exhaust gases. A hybrid heat recovery system proposed is utilized to recover exhaust gases to produce simultaneously domestic hot water and generate electricity using thermoelectric generators (TEG). The concept of study is discussed in section 2. Section 3 presents the thermal modeling of the system, and section 4 studies the effect of changing exhaust gases temperature on the performance of the system. Finally a conclusion about the whole study is carried.

Nomenclature

A	Area [m^2]
h	Convection heat transfer coefficient [$W/m^2.K$]
HHRS	Hybrid heat recovery system
q	Heat transfer rate [W]
L	Length of the tank [m]
N	Number of items
P	Power produced [W]
r	Radius [m]
T_a	Temperature [°C]
k	Thermal conductivity [W/m.K]
R	Thermal resistance [K/W]
e	Thickness of the TEG [m]

2. Heat recovery concept

The relatively high amount of thermal energy lost through exhaust gases forced scientists to investigate how to get benefit of this energy. Variety of studies were made in the field of heat recovery including single or hybrid heat recovery systems. This paper proposes a hybrid heat recovery system in which hot water is produced and electric power is generated. The system is composed of water tank with a pipe passing through it. At the inner wall of the pipe a thermoelectric generators layer is attached allowing a direct contact of exhaust gases with TEGs. Part of the thermal energy hold by exhaust gases transfer through the TEGs layer in which this TEG layer dissipate heat to the water at the tank. The TEGs layer is sandwiched between the exhaust gases (heat source) and the inner wall of the tube (heat sink) [19]. As the TEGs are subjected to a temperature difference an electric power is generated. Figure 1 shows a schematic of the proposed hybrid heat recovery system. It shows a pipe crosses the tank in which exhaust gases passes through the pipe with a direct contact with the TEG layer (Red layer). TEG in its turn convert part of the absorbed thermal energy to electrical energy and dissipate the other part to water. The quantity and quality of exhaust gases plays a crucial role in the recovery process. The effect of exhaust gases temperature on water temperature and power generated is examined in this paper. To proceed, a thermal modelling of the system will be carried in order to obtain the behaviour of the hybrid heat recovery system while changing the temperature of