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Design of a Thermoelectric Energy Harvesting Module for a Wireless Pressure Measurement in Vehicles

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Abstract

A thermoelectric energy harvesting module for the pressure measurement of air induction system of heavy duty vehicles is designed. A positive contribution for cable complexity, fuel consumption and vehicle performance is intended by creating a sensor node after the air filter. A sensor node basically measures the pressure drop before the compressor inlet through air filter of a vehicle and transmits the pressure wirelessly to the engine control unit (ECU). System is capable of generating electrical energy by means of a thermoelectric generator to the sensor node for its life time with a 1 Hz sampling frequency.

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Keywords: Thermoelectric energy harvesting, fuel consumption, pressure drop

1. Introduction

Sensor usage in automotive industry increased dramatically in the last twenty years because of the significant government regulations and increasing trend on customer expectations regarding to the power consumption and engine performance [1]. Therefore, automotive manufacturers have to phase in new sensors to control the electronic systems. This situation causes cable complexity and maintenance issues for the life time of the vehicle. Moreover, original Equipment Manufacturers (OEM) have to handle fuel consumption and performance characteristics of the vehicle, which is the supreme problem in automotive industry. The increasing number of sensors also leads to the wiring

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complexity and maintenance in the vehicle's physical on-board power systems and adds additional weight to the vehicle. Also, fuel consumption and acceleration performance of the vehicle is affected directly by air filter and its clogging percentage [2].

This study, which proposes a self-powered wireless pressure monitoring system (WPMS) for air induction pressure measurement in heavy duty vehicles, presents a positive contribution for vehicle performance and cable complexity. The system basically measure the pressure drop before the compressor inlet through the air filter of a vehicle and transmit the pressure value wirelessly to the engine control unit (ECU). Thus, the ECU have the chance to regulate the mass air flow to the compressor when the inlet pressure is continuously monitored. The air induction system consists of an air snorkel, an air filter, a mass air flow sensor, a pressure sensor and the compressor inlet pipe. During the operation of the internal combustion engine (ICE), the power of the system is supplied from a thermoelectric based energy harvesting system where the waste heat from the ICE exhaust manifold is utilized.

2. System Overview and Simulations

The computer aided design of the WPMS is given in Fig. 1.a where it basically consists of a pressure measurement sensor node, an energy harvesting module and a wireless communication module. In addition to them, a microcontroller that is based on an ultra-low power management (MSP 430) architecture is embedded to the system for the power management and sensor node control. The energy harvesting module is based on thermoelectric generator (TEG) and the waste energy is recovered from the exhaust pipe.

The thermoelectric devices generate an electrical energy when there is a temperature difference between the two faces. When the TEG is used for a thermoelectric power generation, the usual and efficient setting is to put the hot side of the TEG to the heat source where the cold side is exposed to mostly a chiller. Moreover, the amplitude of the substantial temperature difference may change during the operation and is needed to be maintained sufficiently at all the time for both side of the thermoelectric generator (TEG) for adequate power output. The first option is to place the TEG to the exhaust pipe which behaves as a constant heat source whereas the volume between the inlet and exhaust pipe acts as a heat sink as seen in Fig.1.b.1. Although this type of configuration seems to be an efficient design in terms of the temperature difference available between the two sides, there are some constructional and operational difficulties. Firstly, the exhaust pipe temperatures reach up to 700 °C depending on the drive conditions which limit the use of commercially available TEG's and results in stability problems over time. Secondly, since there is an enormous temperature difference between the air space volume and exhaust pipe, the temperature of the two sides of the thermoelectric generator eventually becomes equal in the steady state regime that produces zero power output. Therefore, the cold side of generator is consistently needed to be cooled by utilizing an external chiller which is not feasible for our case. The second option is to use the hot surrounding between the inlet and exhaust pipe inside the ICE as a heat source where the air flow inside the inlet pipe would behave as an effective chiller. Therefore, it is possible to create efficient heat sink and sources of the TEG that is available inherently during the operation of the ICE.

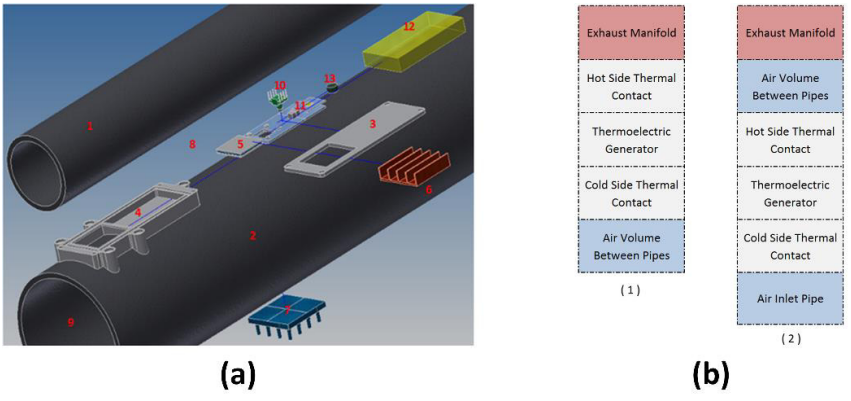

Fig. 1. (a) Computer aided design (CAD) of the system: 1-Exhaust manifold, 2- Air inlet pipe, 3- Top cover, 4- Bottom Cover, 5- Thermoelectric generator, 6-Hot side fin, 7- Cold side fin, 8- Air volume between pipes, 9- Inlet of air inlet pipe, 10- Pressure sensor, 11-Electronic circuit board, 12- Protection gel, 13- Battery. (b) 1- Inefficient design, 2- Efficient design.

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