

Non Intrusive Exhaust Gas Heat Recovery System for an Automobile: A Preliminary Investigation

David Neihguk

Aravindh Rajaram

Samir Rawte

ABSTRACT

A parallel flow concentric tube heat exchanger is designed to recover exhaust heat by using the exhaust pipe as the tube side and the concentric tube as the shell side. The heat exchanger which is also called the primary heat exchanger is welded concentrically to the intermediate exhaust pipe forming a double pipe heat exchanger. The shell side pipe consists of Cold Water inlet and Hot Water outlet, while the tube side pipe carries the hot exhaust gases. The water flowing in the shell side gets heated due to conduction and convection and is circulated through the Hot Water outlet to produce Hot Water on demand. The same Hot Water is simultaneously circulated to the annular chamber of the secondary heat exchanger, thereby transferring the heat to the Hot Box.

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INTRODUCTION

Amid the economic uncertainties and a declining sales, a demand for new technologies and innovative features that will enhance the pleasure of driving to the customer is inevitable. As the expectations of the conscious consumption customer increases, there is an increasing emphasis on value for money [1]. In other words, a car with luxurious features at a competitive cost is the key to woo customers in this highly competitive automotive industry.

Increasingly, customers are being given the opportunity to customize their purchase, while the automakers are becoming more adroit at understanding which customers create the most value for them. Another dimension is the fact that cars are evolving into electric appliances. Today, 22 percent of a car is electronic content. In ten years, that will be 40 percent. Connectivity will promote extended relationships with auto owners fostering a greater customer-centric focus [2].

One way to enhance relationship of a car with its owners is by providing features that will augment the pleasure of driving at no additional or minimal cost. In this context, this can be best done by making use of the sunk energy of the vehicle that get wasted otherwise. For example, the heat

energy from the heated coolant and the exhaust gases. Extraction of heat energy from the former will mean higher pumping requirement to drive the flow of the coolant in the annular chamber of the Hot Box and a reduced cooling efficiency of the cooling system, whereas the later can be done in a non-intrusive manner and without any adverse impact on the back pressure of the exhaust system. Moreover, the coolant oil used in the cooling system may lead to contamination of the Hot Box [3].

A well known technology to recover exhaust heat is the Thermo Electric Generator (TEG). TEG produces electric power to supplement charging system in an automobile [6]. One of the objectives of TEG is improvement of fuel economy without increased emission and in a cost effective way. This is done by reducing the electric accessory loads on the alternator by using the TEG generated power. The excess energy, if any, can be used for propulsion in hybrid vehicles [7]. This gain in fuel economy comes at the cost of increasing back pressure of the exhaust system because of the changes in cross section at the inlet and outlet of TEG, in addition to the viscous drag caused by the fin surfaces [8].

Unlike TEG, Non Intrusive Exhaust Gas Heat Recovery System (NEHRS) consumes electric energy from the 12 V

battery for pumping work. A 12 V DC brushless pump is used for this purpose. The objective of NEHRS is to provide seamless hot water on demand and a heating space called Hot Box, [figure 7](#). NEHRS recovers heat without creating perturbation in the exhaust flow and hence, no additional back pressure is developed.

The exhaust gas heat recovery system discussed in this paper harnessed the thermal energy of the exhaust gases, and used it for heating water to provide Hot Water on demand. The same Hot Water is used for heating a closed container called Hot Box. The unique feature of this system is that, the heat exchange process takes place without the need for bypassing the exhaust gases and thereby without increasing the exhaust back pressure. Hence, without any adverse impact on the volumetric efficiency of the engine.

Therefore, heat recovery from the exhaust system with water as the heat exchanger medium is found to be a more pragmatic and hygienic proposition.

THERMAL LOSSES FROM EXHAUST SYSTEM

The laws of thermodynamics indicate that with the Carnot cycle, an ideal engine could achieve a maximum efficiency of about 85% for typical heat generation and rejection temperatures. The low heat rejection and the high thermal efficiency cannot be achieved in practice for a number of reasons [4-5]. However, the typical thermal efficiencies of actual Diesel Internal Combustion Engines are in the range of 32-33 per cent in which the thermal losses from exhaust system alone contributes to about 30 - 33 per cent as shown in [figure 1](#). Therefore, a mechanism for effective recuperation of the heat loss from exhaust system is an important aspect of efficient energy recovery system.

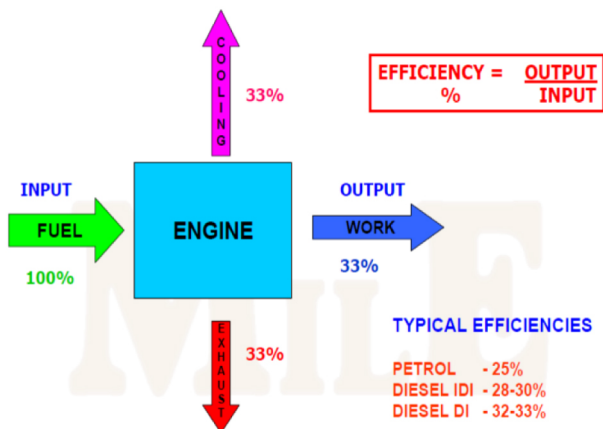


Figure 1. Thermal losses from Exhaust System

COMPONENTS OF NON INTRUSIVE EXHAUST GAS HEAT RECOVERY SYSTEM

The heat recovery system consists of the following components, [figure 3](#) and [figure 4](#):

1. Primary Heat Exchanger
2. Connectors
3. Hot Water Pump
4. Cold Water Inlet
5. Hot Water Outlet
6. Hot Box or Secondary Heat Exchanger
7. Exhaust Pipe
8. Control Valve
9. Electrical switch
10. Hoses

Primary Heat Exchanger

A recuperative indirect-contact-type of heat exchanger where the heat transfer occurs through a separating wall, in which the Cold water recovers some of the heat from the Hot exhaust gas is found to be the most appropriate type of heat exchanger for this type of application. The double pipe heat exchanger is a parallel flow concentric tube heat exchanger because the Cold Water and the Hot Exhaust Gas flow in the same direction. The heat exchanger medium flows in the shell side tube and the exhaust gas flows in the tube side tube [9] [10], [figure 2](#).

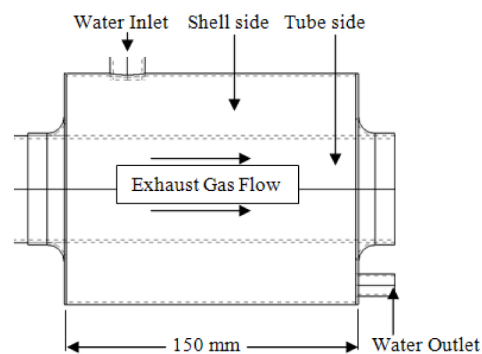


Figure 2. Parallel flow Double Pipe Heat Exchanger

Location

The Primary Heat Exchanger is a retrofitted part that is adapted into the existing exhaust system of the vehicle. The functions of various components of the exhaust system like the Catalytic converter and muffler cannot be compromised. Hence, determination of the position of the Primary Heat