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HD Diesel engine equipped with a bottoming Rankine cycle as a waste heat recovery system. Part 1: Study and analysis of the waste heat energy

V. Dolz, R. Novella*, A. García, J. Sánchez

CMT – Motores Térmicos, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

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A B S T R A C T

This paper describes the study of different bottoming Rankine cycles with water-steam and/or ORC configurations in classical and innovative setups such as a waste heat recovery system in a Heavy Duty Diesel (HDD) Engine. This work has been divided in two parts. This first part describes the model of the studied HDD engine and the available waste energy sources in this HDD Engine. The waste energy sources are studied from the standpoint of energy analysis to determine which are the most appropriate for their application in bottoming cycles attending to minimizing external irreversibilities. Finally, two configurations are chosen as the most appropriate, in a balance between external irreversibilities and technological complexity, and they have been analyzed to determine global efficiencies, power increments and necessary modifications to implement these cycles in the HDD engine. The second part of this article will analyze additional innovative setups in the HDD engine to fit this engine with ORC cycles.

1. Introduction

The increasing fuel costs and diminishing petroleum supplies are forcing governments and industries to increase the power efficiency of engines. A cursory look at the internal combustion engine heat balance indicates that the input energy is divided into roughly three equal parts: energy converted to useful work, energy transferred to coolant and energy lost with the exhaust gases. There are several technologies for recovering this energy on a Heavy Duty Diesel (HDD) engine, whereas the dominating ones are:

- Mechanical turbocompounding. The Diesel engine is equipped with an additional power turbine [1,2]. The power turbine is placed in the exhaust line and is mechanically coupled to the engine crankshaft via a gear train.
- Electrical turbocompounding. The system consists of an electric motor/generator coupled by means of a turbocharger [3,4]. The generator extracts surplus power from the turbine, and the electricity produced is used to run a motor assembled/fitted to the engine crankshaft.
- Thermoelectric materials. The exhaust pipe contains a block with thermoelectric materials that generates a direct current, thus providing for at least some of the electric power requirements [5,6].
- Rankine cycle. The system is based on the steam generation in a secondary circuit using the exhaust gas thermal energy to produce additional power by means of a steam expander. A special case of low temperature energy generation systems is the use of certain organic fluids instead of water in so-called Organic Rankine Cycle (ORC). This technique has the advantage compared with turbocompounding that does not have so an important impact on the engine pumping losses and with respect to thermoelectric materials that provides higher efficiency in the use of the residual thermal energy sources [1].

ORC is considered a way of converting different kinds of low temperature energies such as solar, geothermal, biomass and thermal energy of exhaust gases into electrical energy [7]. Several studies have examined Rankine cycles for exhaust gas heat recovery in vehicle applications [8,9]. For instance, Thermo Electron Corporation tested a Diesel-Organic Rankine compound engine on Class 8 trucks [10]. The application in a specific vehicle requires a redesigned system to fit all system components [11]. The additional vehicle mass and system cost need to be determined to show its economic feasibility.

This paper presents a study on different bottoming Rankine cycle configurations for application in Diesel engines. The second part of this article analyzes new and more complex configurations to improve the global efficiency of the engine.

* Corresponding author.
E-mail address: rinoro@mot.upv.es (R. Novella).

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