Overview of the Activities on Heavy Duty Diesel Engines Waste Heat Recovery with Organic Rankine Cycles (ORC) in the Frame of the ECCO-MATE EU FP7 Project

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Abstract

The ECCO-MATE Project is a European Union funded project aimed to develop a synergistic framework for cutting edge research on novel engine technologies for higher energy efficiency and lower emissions. The project partners, Ricardo plc, an engineering consulting company, and the University of Trieste, focus the research attention on waste heat recovery systems, such as Organic Rankine Cycles (ORC), which are gaining increasing interest by engine manufacturers, vehicles and ships fleet operators, because of their potential for further increasing engine efficiency and decreasing fuel consumption. In particular, in the frame of the developed research activity, the 1-D Ricardo engine simulation software WAVE has been used in order to assess novel engine concepts, both in the commercial vehicles and marine sectors. A combined engine-ORC system First and Second Law of Thermodynamics analysis has been proposed in order to study where system inefficiencies are concentrated and propose improvements, with particular focus on commercial vehicle heavy duty diesel engines. A thermo-economic analysis has been also considered. Furthermore, in collaboration with the project partners National Technical University of Athens (NTUA) and Winterthur Gas & Diesel (WinGD), an innovative low pressure Exhaust Gas Recirculation (EGR) configuration for low speed 2-stroke ship propulsion units has also been studied with the aim of reducing NO\textsubscript{x} in order to meet IMO Tier III emissions limits. ORC systems are, in this application also, a promising technology that can be used, in synergy with emission reduction systems, to recover, in particular, low temperature heat sources such as engine coolant and scavenging air, always with the aim of improving overall system efficiency while respecting new stringent emission reduction targets. The first results of the research activity show that a fuel consumption improvement up to 10\% could be achieved both for commercial vehicles off-highway applications and in the marine sector, depending on the type of ORC and waste heat recovery architecture chosen and the engine considered.

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1. Introduction

This paper is meant to be a short overview to the work carried out, about waste heat recovery in marine and commercial vehicles heavy duty diesel engines, in the frame of the EU funded FP7 (Framework Package 7) ECCO-MATE Project (Experimental and Computational Tools for Combustion Optimization in Marine and Automotive Engines).

The main goal of the project is the study of cutting edge combustion strategies to be applied in heavy duty engines used for vehicles and ships propulsion. In parallel to these topics, Ricardo and the University of Trieste, in collaboration with the National Technical University of Athens (NTUA) and Winterthur Gas & Diesel (WinGD), focused the research activities on the analysis of different waste heat recovery concepts, such as, in particular, Organic Rankine Cycles (ORC), in order to exploit the engine waste heat with the final objective of decreasing fuel consumption, increasing overall powertrain efficiency, and reducing environmental pollution.

In the last decades, several institutions, such the EU, the American EPA (Environmental Protection Agency) and the IMO (International Maritime Organization), are introducing new stringent emissions limits in order to control pollutants and reduce the impact of transportation technologies on the environment. Some of these regulations are, for example, the Euro and Tier, in the on-off highway sectors, and the IMO Tier in the large ships marine sector [1]. Several methods are currently applied by engine manufactures and fleet owners in order to reduce pollutants, such as aftertreatment systems, new engine air management technologies, such as Exhaust Gas Recirculation (EGR), fleet operating strategies, and advanced technologies such as waste heat recovery systems.

In both commercial vehicles and marine heavy duty diesel engines, only around 40 - 50% of the energy introduced with the fuel is converted into mechanical energy at the brake, while the rest is usually wasted to the cooling and lubrication oil circuits, through friction processes, and to the environment through radiation, convection and exhaust gases. In Fig. 1, two typical heat balances, for full load conditions, have been reported: in Fig. 1(a) a 200 kW four stroke, single stage turbocharged, charge air cooled (CAC), direct injection, 6 cylinders engine for commercial vehicles applications, obtained from Ricardo WAVE calculations [2], while in Fig. 1(b) a 13.6 MW two-stroke, 6 cylinders, single stage turbocharged, scavenge air cooled (SAC), IMO Tier II compliant ship propulsion unit, calculated from the data obtained from the WinGD GTD software [3]. Actual technologies can reach slightly higher efficiencies compared to what reported for the two engines.

Fig. 1. Heat balances examples: (a) 200 kW commercial vehicle engine heat balance, (b) 13.6 MW ship propulsion engine
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