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Cost to benefit ratio of an exhaust heat recovery system on a long haul truck

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Abstract

Nearly 30 percent of the fuel energy in an internal combustion engine is lost as waste heat in the form of hot exhaust gases. Nowadays it seems clear that the heavy duty manufacturers will implement bottoming Rankine cycles to recover the exhaust heat on their long haul trucks in the 2020s as an answer to future stringent regulations and the still increasing customer pressure for reductions in operating costs. Though the potential of exhaust heat recovery is clear, the technology has to prove the business, durability and safety cases to be widely spread in the next decade. This paper focuses on the business case of such a technology.

Keywords: "Heavy duty trucks, exhaust heat recovery, piston expander, fuel saving, cost, business case"

1. Introduction

To date, emission regulations focusing on local pollutants have not focused on the efficiency of internal combustion engines (ICE). However, future regulations will focus on CO_2 emissions, requiring high efficiency increase of the whole drivetrain. The best efficiency of a modern ICE will remain below 42% and research projects tend to increase it up to 50 or 55%. Electrification of ancillaries and hybridization seem to lead to little fuel savings on Heavy Commercial Vehicles (HCVs) and, at least, would be too expensive to reach future CO_2 emissions regulation compared to air drag reduction and waste heat recovery (WHR). While HCVs aerodynamic is mostly constrained by regulation and also depends on trailer manufacturers, WHR appears as essential in the future innovation panel for HCVs. Though the potential of WHR is clear, the technology has to prove the business,

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durability and safety cases to be launched in mass production. This paper is dedicated to assess the business case of such a system through the calculation of the cost of the system and of its payback time. We try to go deeper in details than previous papers did [1].

Nomenclature

EAT	Exhaust After Treatment
HCV	Heavy Commercial Vehicle
ICE	Internal Combustion Engine
ORC	Organic Rankine Cycle
SCR	Selective Catalytic Reduction
WHR	Waste Heat Recovery

2. ORC architecture

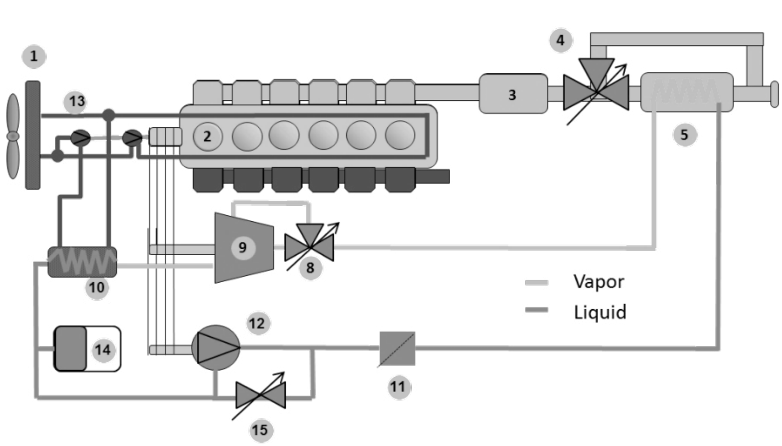

Fig. 1. ORC system considered for this business case (turbocharger is not shown)

The truck engine architecture chosen is a so-called “SCR- only” exhaust after-treatment system. Though it is not the best configuration for WHR [2], it has been chosen based on our current development of a demonstration truck. The waste heat is only recovered from the tailpipe as there is no EGR on this engine. The Organic Rankine Cycle (ORC) recovers the heat from the exhaust gases to convert it into mechanical power re-injected on the driveline. In the scheme considered (Fig. 1), there is no electric component: only pneumatic valves for the three of them and mechanical coupling for the two pumps and the expander. The working fluid, which is a mixture containing mostly ethanol, is moved to an evaporator (5) by means of a pump (12). The pump is assumed to be a gear pump. The flow is controlled by means of a liquid bypass valve (15) that re-circulates part of the liquid to achieve the desire superheating at the evaporator outlet. The vapor circulates from the evaporator to the expander (9) that will expand it and will re-inject torque. The expander considered is based on a swashplate architecture counting three pistons cumulating around 240 cm^3. This device is coupled to the ICE though the gear of an engine PTO. We assume a simple passive freewheel and a damping system between the expander shaft and the PTO gear. A vapor bypass valve (8) may help the warm-up the expander or the stop of the ORC. The vapor at low pressure goes to a condenser (10) that is cooled in parallel of the existing engine cooling loop. The additional cooling pump is mechanically linked to the engine. The working fluid which has been condensed is pumped back to the evaporator. The evaporator and the condenser are assumed to be plate heat exchanger in stainless steel for temperature and corrosion issues. A gas