RANOTOR

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Marine Hybrids of ICE and Steam Engines

(Bottoming cycles for lower fuel consumption, reduced emissions, and auxiliary power)

Background

RANOTOR R & D Company is working on a modern high performance steam engine for mobile as well as stationary applications. The current project, “RAN”, originates from the SAAB SCANIA’s steam power project of the 70’s. The modern high performance steam engine could offer attractive performance as well as very low environmental impact.

The modern high performance steam engine can operate as a self-contained unit, with a broad range of fuels including solar energy. It can also be used as a bottoming-cycle, harnessing the waste heat in the exhaust gas stream from a conventional internal combustion engine (ICE). Such a bottoming-cycle concept, common when it comes to stationary electric generation, has also been suggested in truck applications. However, the steam engine systems studied so far for harnessing the truck exhaust gas energy have been too heavy and bulky to be considered as a cost effective way to reduce fuel consumption.

With modern high performance steam engine technology, the situation is different. RANOTOR, together with Volvo trucks and SCANIA, has conducted a comprehensive study of bottoming cycles for heavy-duty trucks.

The study indicates that there is considerable potential for fuel consumption reduction. The economics depends on operating hours and load profiles on the diesel engine. If the diesel engine is operated most of the time at high loads, the diesel will reject high temperature waste heat, which in turn implies high efficiency of the steam engine system (the bottoming-cycle).

Because the economics strongly depends on operating hours for a bottoming-cycle system, there are some applications of particular importance, such as commercial boats and heavy-duty trucks.

Why a modern steam engine system in marine applications.

The modern high performance steam engine offers several attractive qualities of interest for most kinds of propulsion systems, marine applications in particular. These qualities are: high specific power (kW/kg), silent operation, fuel flexibility, very low exhaust gas emissions, attractive torque characteristics, low fuel consumption, and low cost per kW. These qualities are considered to be attainable with a modest amount of R&D effort. However, some applications will call for considerably more investment efforts than others. Road applications pose more stumbling blocks to advanced engine development than do marine applications. The most notable impediment for road-based transportation is that the power system is cooled by air instead of water as in the marine applications. Furthermore, the firm connection with the road (instead of the slip in the water) will call for a more advanced mechanical design.

The self-contained steam engine propulsion system will offer superior qualities when it comes to noise and exhaust gas emissions over the conventional diesel. However, it will be

hard to compete when it comes to fuel consumption in some cases. From a physical point of view it is possible to reach the same or maybe higher efficiency than a diesel engine, but it will require high pressure (300 bar) and high temperature (900-1000 C). Such a “supercritical” small-scale steam power system is not a far-fetched idea, because the high specific power ratio (1200 kW/kg) can justify the more expensive material that is needed with such a high admission requirements.

Thus, considering the necessary R&D investment cost and time to reach a first commercial product, the most interesting concept is a marine bottoming-cycle, or a ***Hybrid of ICE and Steam Engines.***

Such a concept is similar to some extent to the hybrid concept launched by the auto industry for passenger cars involving an electric battery and electric motor instead of a steam engine system. The idea of such an electric hybrid system is that the internal combustion is allowed to operate at more steady state condition at high loads and the electric battery is used to smooth the highly fluctuating power demand in a typical driving environment. The more constant and higher the load, at which the internal combustion engine is allowed to operate, the higher the average efficiency. At very low loads the efficiency is very low for the internal combustion engine. It is even disconnected completely at the lowest loads and only the electric battery and the electric motor propel the passenger car.

However, compared to the hybrid system consisting on a ICE and electric motor, the hybrid of a ICE and Steam Engines will offer several more attractive qualities, such as: more fuel efficiency, higher performance expressed in terms of kW/kg, kW/litre, lower cost per kW, and a sustained Auxiliary Power Unit (APU) function.

The reason to the lower fuel consumption is explained by the utilization of the waste heat in the exhaust gas, which is partly converted to useful work in the steam engine. The higher performance is obtained due to higher specific power density of the steam engine system compared to an electric battery and the electric motor. A marine ***Hybrid of ICE and Steam Engine*** will also offer the possibility to operate only the steam engine as a silent and environmental friendly APU in harbours and other places where it is of particular importance to offer low harmful environmental impact. Furthermore, a steam engine system has the capability to make use of solar energy (collected by thin film solar cells), as a compliment to fossil fuel, to further reinforce the environmental qualities.

The bottoming cycle constituted by a modern high performance steam engine system will also produce more efficient cooling of the heavy loaded diesel (or gasoline engine) and provide so-called “cooled EGR”, which is a technology to reduce NOx formation. Last but not least the RANOTOR company has developed a “Steam Buffer”, which is a kind of heat energy storage device, that makes it possible to operate without any emissions at all. The Steam Buffer also provides high peak power capability for extra power and storing of solar energy.

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