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REMNANT HEAT EXPLOITATION FOR POWER ENGENDERMENT BY USING ORGANIC RANKINE CYCLE

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Abstract-The increasing interest in emission reduction, ship operating costs reduction and the newly adopted IMO EEDI rules calls for measures that ensure optimal utilisation of the fuel used for main engines on board ships. Main engine exhaust gas energy is by far the most attractive among the waste heat sources of a ship because of the heat flow and temperature. It is possible to generate an electrical output of up to 11% of the main engine power by utilising this exhaust gas energy in a waste heat recovery system. This paper deals with an innovative concept of utilizing residual heat from main engine for producing electric power using Residual heat generator.

Keywords: Residual heat generator (RHG), Waste heat recovery system (WHRS), Energy efficiency design index (EEDI), Exhaust Gas Boiler (EGB).

1. INTRODUCTION

Over the past decade, several reports have outlined exhaust emissions from the growing marine transport sector as a significant air pollution source (Lloyd's Register Engineering Services, 1995; Corbett et al., 1999; European Commission, 2002a). The European shipping fleet, using fuels with an average sulphur content of 2.7% m/m, emitted approximately 2578 thousand tons of SO2 for the year 2000 within the European monitoring and evaluation program (EMEP) domain (European Commission, 2002a). This can be compared to 5750 thousand tons arising from European Community land-based sources. It is estimated that shipping emissions accounts from2-4% of CO_2global emission, 10-20% of global NOxemission and 4-8% of global Sox emission. Shipping industry is looking for the possibilities of reducing these emissions and fuel consumption. Utilizing residual heat from main engine exhaust gas is one such possibility of reducing the fuel consumption as well as the emissions. The common existing methods of utilizing waste heat from main engine exhaust are EGB (Exhaust Gas Boiler) and Exhaust Gas turbine or Steam turbine driving alternator for power generation. Latest researches have proved that a system using both exhaust gas turbine and steam turbine is more efficient. But by using Residual heat generator which uses an organic fluid as a driving fluid with magnetic bearing in the alternator will increase the efficiency of the waste heat recovery system to a great extent. This paper will give a detailed explanation of the residual heat generator.

2. RESIDUE HEAT GENERATOR:

Residue heat generator is similar to a waste heat recovery system. Basic waste heat recovery system is often compared to the system with the exhaust gas boiler and steam turbine driving the generator. The Residue Heat Generator is similar to WHRS with a difference that it uses an organic fluid whose boiling point is about 50^{o}C. RHG improves the efficiency but also reduces the chances of corrosion because of using organic fluid.

2.1 Working of RHG

The Organic Rankine Cycle has been generating power for decades. The concept is very simple, the organic fluid captures heat in an evaporator and gets boiled, producing vapour, the vapour expands and spins the turbine which drives a generator and produces electricity. Then the vapour is cooled back to a liquid and pumped back to the evaporator to repeat the process. It is possible to adjust the heat input without affecting the industrial process or the engines only bypassing part of the thermal fluid flowing in the loop.

The above Fig.2.1 indicates a model operating system of RHG. Organic Rankine Cycle technology has generated reliable power for decades in large-scale applications all over the world. The Organic Rankine Cycle is used in waste Heat Generator to electricity upto 110kw per plant.

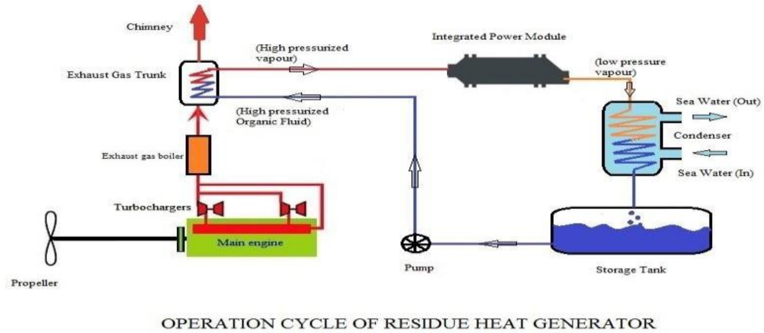

Fig. 2.1 A Model Operating System of RHG

2.1.1 Evaporator

Evaporator of the RHG is placed above the EGB in the exhaust gas trunk. This acts like a heat exchanger where the heat from the exhaust gas is absorbed by the organic fluid which evaporates and becomes a superheated vapour.

2.1.2 Integrated Power Module

The superheated vapour from the evaporator goes to the power production unit where it expands to drive a turbine. This turbine in turn drives the rotor of an alternator which produces electric current which can be utilized for ship's power requirements. The alternator of RHG is similar to common alternators used in ship with a difference that it uses magnetic bearings. A magnetic bearing is a bearing that supports a load using magnetic leviation. Magnetic bearings support moving parts without physical contact. For instance, they are able to leviate a rotating shaft and permit relative motion with very low friction and no mechanical wear. Magnetic bearings support the highest speeds of all kinds of bearing and have no maximum relative speed. Magnetic bearing advantages include very low and predictable friction, and the ability to run without lubrication.
The IPM, different from the axial and radial inflow configurations, is capable of converting the energy contained in the fluid into mechanical power with higher efficiency than competing technology on the market (over 80%). In IPM the fluid enters axially and is deviated by 90 degrees with a nose cone. The fluid expands radially through a series of stages arranged on a single disk. At the end the fluid is discharged in a radial diffuser to recover the kinetic energy and then is conveyed to the condenser.

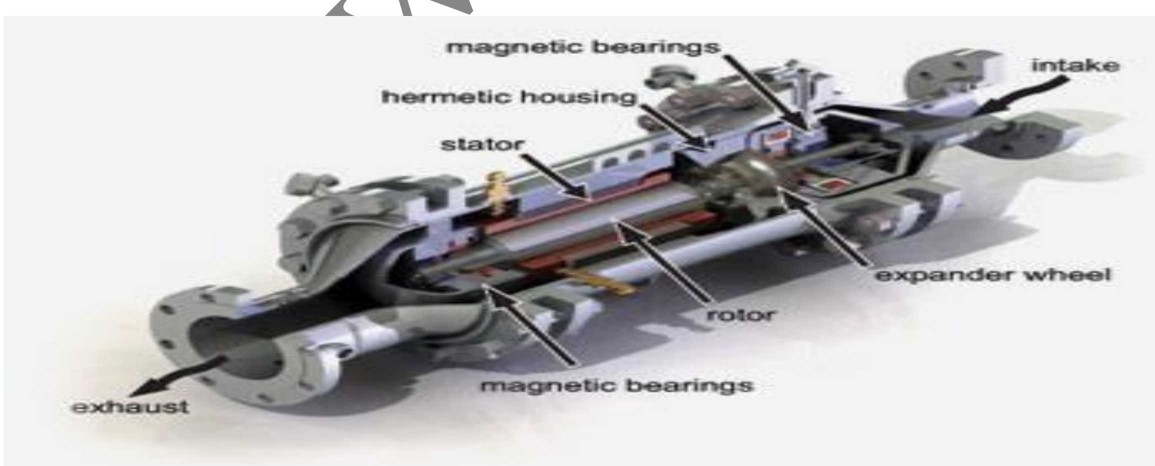

Fig.2.2 Constructional View of RHG

2.1.3 Magnetic bearings in IPM

The concern is the inability to remove heat generated by eddy current losses in the stator core and resistance heating in the electromagnetic coils. No bearing or squeeze film damper system exists that can handle a blade loss event, to this effect, magnetic bearings have no disadvantage. But, of the various damper technologies, the dynamic characteristics of the magnetic bearing make it the most adaptable for unplanned events. As for high-g maneuvers and landing events, total load capacity is the main factor. Though magnetic bearings and foil bearings alike are inferior to rolling element bearings in this regard, magnetic bearing load capacities have clearly increased beyond expectation. Recent work at NASA GRC demonstrated continuous operation of a magnetic bearing flywheel at 60,000 rpm. The necessary electric current from the control circuit to the magnetic bearing is determined based on the position of the rotor (it is the electric current magnitude that will determine the position of the shaft inside of the bearing). The position of the rotor is related to the disturbance or control current by the equation (using Laplace transform),

$$I_p(s) = G(s)\, x(s) \qquad 2.1$$

Where G(s) is the global transfer function. This complex transfer function is composed by the multiplication the position sensor, low pass filter, PID controller and power amplifier. The most important parameters of the control circuit are the total, derivative, proportional and integral gains of the PID controller (K_T, K_D, K_P e K_I respectively) and the gain of the power amplifier (Ka) (Guiráo and Nascimento, 2004b). They will be later regarded on the rotor modeling.

2.1.4 Condenser

The Condenser of the RHG uses sea water to cool and condense the organic fluid which comes to the condenser after driving the turbine. Condensed organic fluid is again pumped back to the evaporator to repeat the process.

3. WORKING FLUID

An Internal Combustion Engine only converts about one third of the fuel energy into mechanical power. For instance, for a typical 1.4 liter Spark Ignition ICE, with a thermal efficiency ranging from 15 to 32%, 1.7 to 45 kW are released through the radiator (at a temperature close to 80 - 100°C) and 4.6 to 120 kW through the exhaust gas (400 - 900°C). The heat recovery Rankine cycle system is an efficient means for recovering heat (in comparison with other technologies such as thermo-electricity and absorption cycle air-conditioning). The idea of associating a Rankine cycle to an ICE is not new and the first technical developments followed the 70's energy crisis. For instance, Mack Trucks (Patel & Doyle, 1976) designed and built a prototype of such a system operating on the exhaust gas of a 288 HP truck engine.

When optimizing the design of a cycle, it is necessary to list the degrees of freedom available in the system and link them (at least qualitatively) to the operating conditions of the cycle. Since the pump is a positive displacement machine, it imposes the volume flow rate. The fluid being incompressible, the mass flow rate is also determined by the pump. It can be adjusted by modifying the swept volume of the pump or varying its rotational speed. the mass flow rate is imposed by the pump, the vapor density is modulated to maintain continuity at steady state. Modulating the density can be achieved by varying the temperature or the pressure. However, in usual working conditions, the relative variation of the temperature (expressed in Kelvin) is small compared to the relative variation of the pressure. Hydrocarbons such as pentanes or butanes and refrigerants such as R227ea, HCFC-123, HFC-245fa, and HFE7000 are good candidates for moderate and low temperatures (typically lower than 200°C).

3.1 Properties of Working Fluid

They are low in toxicity, nonflammable, non- corrosive, and compatible with other materials. In addition, they have thermodynamic and physical properties. It does not contain chlorine or bromine; therefore, it has an ozone-depletion potential (ODP) of zero.

4. ORGANIC RANKINE CYCLE

The ORC system is similar to steam cycle used in coal fired power plants, except in this case water is replaced as the working fluid that evaporates at lower temperatures and thus possesses more efficient thermodynamic properties than water in order to achieve the greatest possible efficiency, refrigerants are chosen based on the temperature of the heat source. The working fluid also makes it possible to apply an effective steam pressure on the turbine whose rotating shaft is used to generate electricity with waste heat or residual heat at temperatures below 873K The application of the ORC ranges from temperature above 373K and sizes up to 68MW approximately.

4.1 Advantages of ORC

Flexibility to choose the most appropriate working fluid depending on the boundary conditions, environmental requirements and features of the heat source (i.e. heat source release curve, flammable or non-flammable); the solution is completely customizable on client requests.

Fully-automated operation and easy maintenance, resulting in minimal impact on the existing production facility in terms of dedicated personnel or O&M costs. Flexibility of operation and superior off-design performance allowing electricity production at a reduced heat inputs. High reliability and simple maintenance means low cost and high operating hours during the year No need of make-up water for the cycle operation.

CONCLUSION AND RECOMMENDATIONS

It was estimated on an annual basis, ships emitted approximately 1,725 kilotons (kt) of NO, 1,246kt of SO and 147kt of CO and 35kt of hydrocarbons, based on 1990 ship movement data. This was approximately 85.90% of the emission totals for the north-eastern Atlantic region, previously estimated by Lloyd's Register. Total annual emissions estimates for NO and SO were of a similar magnitude to those reported for France in 1990. A strong relationship was evident between ship traffic density and pollution emissions, with the grid squares with the highest emissions lying along the Atlantic/Suez corridor, the Bosporus/Volga transit, the coastal routes around the Gulfs of Valencia and Lion and the Ligurian, Tyrrhenian and Adriatic Seas. With respect to further development of this work, the emission quantification model developed in this study could also be applied to assessing emission reduction strategies.

Heat balance diagrams analysis of marine low speed diesel engines confirms possibility and advisability use of waste heat recovery energy in marine energetic power plants. Marine engine power output, temperature of medium feeding the waste heat recovery system (exhaust gases, cooling water), pressure and flow rate factor determine the quantity of available heat in waste heat recovery system. Residue Heat Generator application takes effect in additional electric energy production, fuel oil savings and limitation of emission toxic substances to the atmosphere. RHG increases systems efficiency especially in direction to enlarge of electric energy production.

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