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Experimental Investigation of Heat Recovery from Engine Exhausts Gas and Its Application in Electrolux Refrigeration System : Areview

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Abstract

Efficiency of diesel engine is about 35-40 % remaining energy go waste. Maximum energy wastes in exhaust. In diesel engine 30-32% energy go waste in exhaust. So it is important to recover energy from exhaust.

Approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air conditioning system. During recent years research aimed at the development of technologies that can offer reductions in energy consumption, peak electrical demand and energy costs without lowering the desired level of comfort conditions has intensified. By reason that absorption refrigeration technologies have the advantage that the peaks of requirements with the availability of the waste heat. My aim is to recover heat from exhaust gas and use it for absorption refrigeration system (Electrolux refrigeration system).

IndexTerms—heat recovery, absorption refrigeration system, electrolux refrigeration.

1. Introduction

It is well known that energy shortage and environmental pollution have become global issues of common concern. As the most widely used source of primary power for machinery critical to the transportation, construction and agricultural sectors, engine has consumed more than 60% of fossil oil. On the other hand, the amount of CO2 gas released from engine, just for transportation applications, makes up 25% of all human activity related CO2 emissions. Thus, energy conservation on engine is one of best ways to deal with these problems since it can improve the energy utilization efficiency of engine and reduces emissions [1].

Given the importance of increasing energy conversion efficiency for reducing both the fuel consumption and CO2 gas emissions of engine, scientists and engineers have done lots of successful research aimed to improve engine thermal efficiency, including supercharge, lean mixture combustion, etc. However, in all the energy saving technologies studied, engine exhaust heat recovery (EHR) is considered to be one of the most effective means and it has become a research hotspot recently [1].

1.1 Diesel engine

A diesel engine is an internal combustion engine which operates using the diesel cycle. Diesel engines have the highest thermal efficiency of any internal or external combustion engine, because of their compression ratio. The diesel internal combustion engine differs from the gasoline powered Otto cycle by using a higher compression of the air to ignite the fuel rather than using a spark plug for this reason it is known as compression ignition and the petrol engine is referred as spark ignition engine. In the diesel engine, only air is introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15 and 22 resulting into a 40 bar pressure compared to 14 bar in the gasoline engine. This high compression heats the air to 550 °C. At about this moment , fuel is injected directly into the compressed air in the combustion chamber.

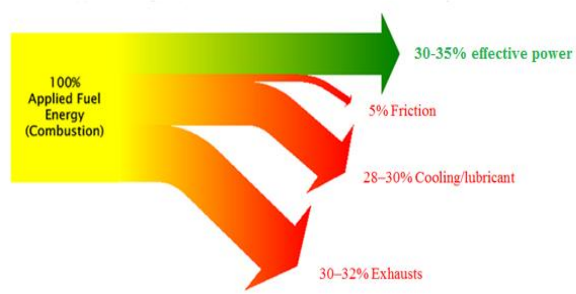

Figure ***Error! No text of specified style in document.*** *sankey diagram of diesel engines*

The efficiency of such an IC engine is 35–40%, meaning that only about one-third of the energy in the fuel used is converted to useful work. This means that the remaining 60–65% of the primary energy is rejected to the environment by cooling water/lubricant losses of approximately 28–30%, exhaust gas losses of approximately

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30–32%, and the remainder by radiation, etc. The same is true for the considerably more powerful main propulsion engines of the road vehicle.

1.2 Refrigeration

The production of cold has applications in a considerable number of fields of human life, for example the food processing field, the air-conditioning sector, and the conservation of pharmaceutical products, etc. The conventional refrigeration cycles driven by traditional vapor compression in general contribute significantly in an opposite way to the concept of sustainable development. Two major problems have yet to be addressed:

- *The global increasing consumption of limited primary energy*: The traditional refrigeration cycles are driven by electricity or heat, which strongly increases the consumption of electricity and fossil energy. The International Institute of Refrigeration in Paris (IIF/ IIR) has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes of various kinds, and the energy consumption forAir-conditioning systems has recently been estimated to 45% of the whole households and commercial buildings. Moreover, peak electricity demand during summer is being re-enforced by the propagation of air conditioning appliances.
- *The refrigerants used cause serious environmental problems*: The traditional commercial, non-natural working fluids, like the chlorofluorocarbon (CFCs), the hydro chlorofluorocarbon (HCFCs) and the hydrofluorocarbon (HFCs) result in both ozone depletion and/or global warming. Since the protocol of Montreal in 1987, international agreements have been signed to reduce the emissions of these refrigerants. European Commission Regulation 2037/2000, which has been implemented on 1 October 2000, treats the whole spectrum of control and phase-out schedule of all the ozone depleting substances. It is indicated that till 2015 all HCFCs will be banned for servicing and maintaining existing systems.

During recent years research aimed at the development of technologies that can offer reductions in energy consumption, peak electrical demand and energy costs without lowering the desired level of comfort conditions has intensified. By reason that absorption refrigeration technologies have the advantage of removing the majority of harmful effects of traditional refrigeration machines and that the peaks of requirements in cold coincide most of the time with the availability of the waste heat, the development of absorption refrigeration technologies became the worldwide focal point for concern again. Waste heat energy can be transformed either to electricity or to heat to power a refrigeration cycle.

1.3 Electrolux refrigeration system

A single-pressure absorption refrigerator uses three substances: ammonia, hydrogen gas, and water. At standard atmospheric conditions, ammonia is a gas with a boiling point of -33°C. The system is pressurized to the point where the ammonia is liquid. The cycle is closed, with all hydrogen, water and ammonia collected and endlessly reused.

The cooling cycle starts with liquefied ammonia entering the evaporator at room temperature. The evaporated ammonia is mixed with hydrogen. The partial pressure of the hydrogen is used to regulate the total pressure, which in turn regulates the vapor pressure and thus the boiling point of the ammonia. As the ammonia boils in the evaporator, it pulls heat from the refrigerators interior and provides the cooling required.

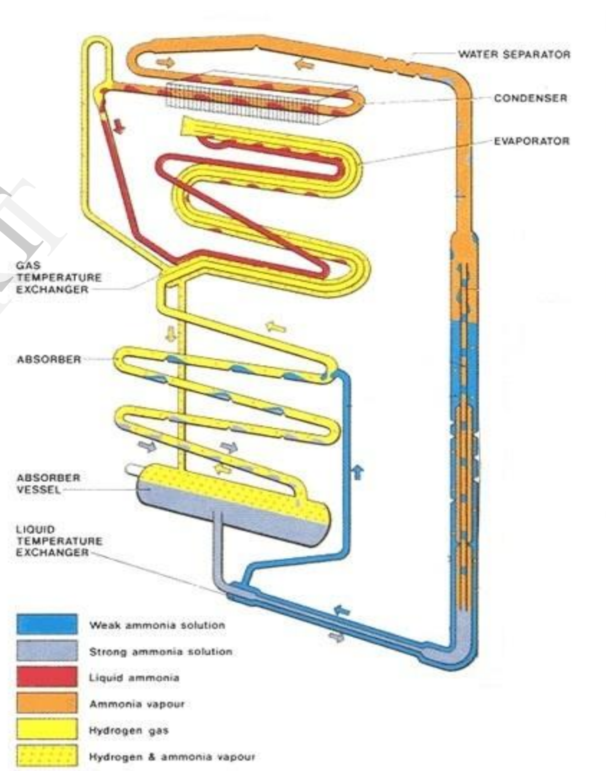

Figure 2 Electrolux Refrigeration system

The next three steps exist to separate the gaseous ammonia and the hydrogen:

1. In the absorber, the mixture of gases enters the bottom of an uphill series of tubes, into which water is added at the top. The ammonia dissolves in the water, producing a mixture of liquid ammonia solution and hydrogen. The gaseous

hydrogen collects at the top of the absorber, while the liquid ammonia solution flows to the bottom.

2. The next step separates the ammonia and water. In the generator, heat is applied to the solution to distill the ammonia from the water. Some water vapor and bubbles remain mixed with the ammonia. This water is dried out in the final separation step, by passing it through the separator, an uphill series of twisted pipes with minor obstacles to pop the bubbles, allowing the collected water to drain back to the generator.
3. Finally, the pure ammonia gas enters the condenser. In this heat exchanger, the hot ammonia gas is cooled to room temperature and hence condenses to a liquid, allowing the cycle to restart.

2. Parametric study of heat recovery from exhaust gas and its application

Khaled S. AlQdah[5] in this paper, the system using the exhaust waste heat of an internal combustion diesel engine as energy source. The energy availability that can be used in the generator and the effect of the system on engine performance, exhaust emissions, auto air conditioning performance and fuel economy are evaluated. Because automotive air conditioning is one the most equipment that heavily uses CFC compounds and the leakage of CFCs from such air conditioners impact on the environment. The main purpose of this investigation to explore the feasibility of using waste energy to design the absorber and generation since these components are the most important components of absorption and they are directly influence the performance of the whole system. It has been found that the aqua -ammonia concentration effect the cooling capacity. The estimated cooling load for the automobile found to be within acceptable ranges which are about 1.37 ton refrigeration. The obtained results show that the coefficient of performancevalues directly proportional with increasing generator and evaporator temperatures but decrease with increasing condenser and absorber temperatures. Measured values for generator, absorber, and evaporator and condenser temperature were recorded and the coefficient of performance of the system varied between 0.85 and 1.04.

The aqua-ammonia vapour absorption automobile air conditioner is an economically attractive concept for utilizing exhaust waste heat because most of the energy input comes from the heat available in the exhaust gases, with only small electric power used to operate the pump. The engine exhaust gas was confirmed as a potential power source for absorption automobile air conditioner system. In other words, the absorption refrigeration system may be able to take advantage of the exhaust gas power availability and provide the cooling capacity required for automotive air conditioning.

Overall, carbon monoxide emission was decreased when the absorption refrigeration system was installed in the exhaust gas. So, changes in exhaust components concentration were a consequence of the major modifications in the exhaust system. The absorption cycle has the economic advantage of having few high precision components, thus reducing manufacturing costs. The low efficiency, however, is a negative economic factor. Ammonia Absorption cycle, should be considered as a viable alternative to mechanical vapor compression cycle. Appreciable cooling load reduction can be realized by modification on the automobile body and the door and windows design.

With flexibility in operation, absence of compressor noise, very low maintenance and high reliability. The waste heat energy available in exhaust gas is directly proportional to the engine speed and exhaust gas flow rates.

Jianbo Li, et al[4] in this paper, through quantitatively analyzing the waste heat from a vehicle engine under different running conditions and calculating the heat load of devices in the absorption compression hybrid refrigeration cycle, the heat transfer area and structure of the main unit are determined. The research results show that the absorption refrigeration sub-cycle can completely meet the space cooling demand (30 kW) for the coach when it runs over 100 km/h. The compression refrigeration sub-cycle fully supplies the cooling load for the coach when speed is lower than 40 km/h. Both the sub-cycles work together to supply the space cooling for the coach when speed is between 40 km/h and 100 km/h

Conclusions

1) The exhausted waste heat from the running coach engine is well-established by simulation calculation. The calculative results have fine coincidence with the tested data.

2) On the basis of the quantitative analysis of the exhausted gas parameters, the main devices are determined in the absorption compression hybrid cycle driven respectively by the waste heat of exhaust gases and power from the coach engine. One dimensional steady distribution parameter model in the generator and lumped parameters model in the other heat exchangers are established, for coupling heat transfer in the unit3) The ARSC can completely meet the demand of coach space cooling, when the running speed (u) is greater than 100 km/h; the ARSC together with the CRSC supplies the cooling capacity for the coach, when u is between 40 and 100 km/h; When u is lower than 40 km/h, the ARSC has no cooling effect, and the cooling demand for the coach is fully supplied by the CRSC. The characteristics of the ARSC are analyzed under different ambient temperatures. The performance of the ARSC drops with the rise in ambient temperature.

4) The ACHRC have advantages of meeting coach cooling demands by recovering the waste heat from engine and consuming less fuel oil. The compact and light weight structures are considered to apply into the key devices in the ACHRC.

M. Talbi, et al [7] in this paper, the utilization of exhaust waste heat is now well known and the forms the basis of many combined power installations. The exhaust gases from such installations represent a significant amount of thermal energy that traditionally has been used for combined heat and power applications.

Research in thermodynamic power cycles over the past two decades has shown improvements in thermal power plant efficiencies. Many combined cycles have been suggested as alternative to the conventional power cycles for improving the overall energy conversion efficiency. These systems that produced space heating have the additional advantage that the heating and electrical loads do not occur simultaneously.

Reducing energy consumption a combined cooling and power system was the main idea of this paper. It will not only produce power but also provide a certain amount of cooling. An absorption refrigeration unit interfaced with a Caterpillar diesel engine has been used for cooling the charge air prior to ingestion to the engine cylinder or for other cooling purposes such as air conditioning and it was demonstrated that a diesel absorption unit combination is a practical possibility.

By I. Horuz[12] in this paper, this includes an experimental investigation into the use of vapor absorption refrigeration (VAR) systems in road transport vehicles using the waste heat in the exhaust gases of the main propulsion unit as the energy source. This would provide an alternative to the conventional vapor compression refrigeration system and its associated internal combustion engine. The performance of a VAR system fired by natural gas is compared with that of the same system driven by engine exhaust gases. This showed that the exhaust-gas-driven system produced the same performance characteristics as the gas-fired system. It also suggested that, with careful design, inserting the VAR system generator into the main engine exhaust system need not impair the performance of the vehicle propulsion unit. A comparison of the capital and running costs of the conventional and proposed alternative system is made. Suggestions are also made regarding operation of the VAR system during off-road/slow running conditions.

Experimental results proved that it is possible to drive a VAR system using the exhaust gases from a diesel engine. This suggests that such a system could be used in road transport vehicles. However, further consideration is required with respect to the following:

- Design of a heat exchanger capable of extracting the maximum waste heat with minimum pressure loss in the exhaust systems
- Effect of increased back pressure on engine performance
- Corrosion effect of the exhaust gases on the heat exchanger material
- Fluctuations in the cooling capacity caused by variations in vehicle speed
- Alternative energy input while vehicle is stationary
- Effect of varying ambient conditions on system performance

The writer believes that this study is worth pursuing in terms of energy and cost savings and suggests that a prototype design study be undertaken.

3. Conclusion

Nearly one-third of the energy in the fuel used is go to waste in exhaust gas so, it is necessary to hear recover from exhaust gas. Absorption refrigeration system is good way to utilization of waste heat of engine.

From above study it comes clear that exhaust gas heat is use for absorption refrigeration system or electrolux refrigeration.

4. Acknowledgment

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