Analysis of Heat Recovery from Engine Exhausts Gas Using in Electrolux Refrigeration System: A review

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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. 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).

Index Terms—*heat recovery, absorption refrigeration system, Electrolux refrigeration.*

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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 CO_2 gas released from engine, just for transportation applications, makes up 25% of all human activity related CO_2 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].

Waste heat recovery technologies in engines: In this section, a short review of the technologies for heat transfer from engines is presented. In the current status of the world the requirement of energy is increasing especially for transportation applications, so the usage of fossil fuels and consequently harmful green house gases (GHG) will increase. Researchers attempt to reduce the need of fossils fuels by using the waste heat recovery from engines. Also now, six technologies are presented for engines waste heat recovery of which Saidur et al. [2] have performed a complete review of four of them. These six technologies are thermoelectric generators (TEG), Organic Rankine Cycle (ORC), six stroke engines, turbo charging, exhaust gas recirculation (EGR) and exhaust heat exchangers (HEXs).

Given the importance of increasing energy conversion efficiency for reducing both the fuel consumption and CO_2 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.

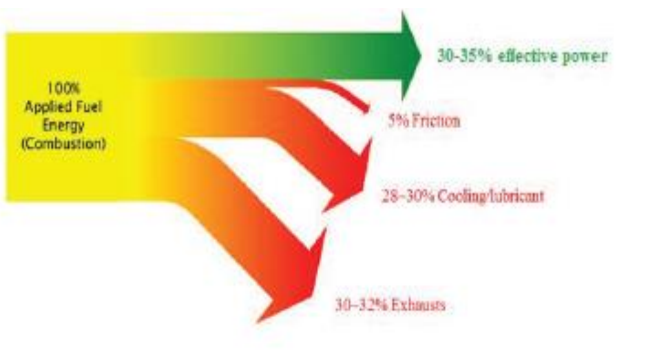

Fig.1 sankey diagram of diesel engine

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.

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 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.

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

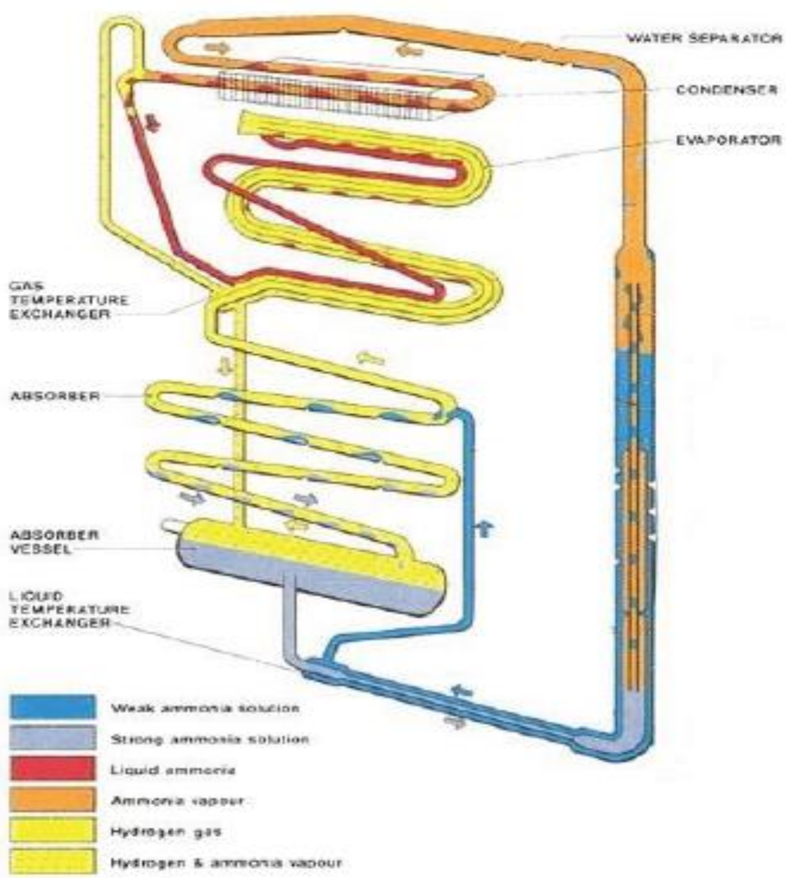

Figure 2 Electrolux Refrigeration system

In the system shown in figure 2 Model of NH3-H2O single effect refrigeration is shown. In this system evaporator and absorber is maintained at lower pressure level and generator and condenser at higher pressure level. Let's start from absorber, saturated vapour of pure NH3 at state 5 enters into absorber where ammonia which is working as refrigerant absorbed by solution and refrigerant releases the heat absorbed inside evaporator which is removed by continuous circulation of cooling water and comes out at state 7 then strong solution at state 7 is passed through pump and pumped to generator pressure at state 9 through liquid-liquid heat exchanger. Inside generator solution absorb heat from the waste heat coming out of diesel engine's exhaust, causing refrigerant to vaporize and separate refrigerant from absorbent solution and solution having less concentration of refrigerant returns back to absorber through liquid-liquid heat exchanger. As in case of NH3-H2O system vaporize refrigerant contains water along with it so it passes through dephlagmator ,After dephlagmator pure ammonia comes out at state 1 and then it enters into condenser where it rejects heat and condenses and comes out at state 2 then through expansion valve it comes to evaporator at state 4 where it absorbs heat i.e. called refrigerating effect then its converts into vapour and exits at state 5 lower pressure and enters into absorber this process repeats again and again in absorption refrigeration cycle .

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

Jianbo Li, et al [3] 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

- **The performance of absorption compression hybrid refrigeration driven by waste heat and power from coach engine.**

- Engine:- Bore/stroke (mm) 126 /130
- power (kW) 247/1900

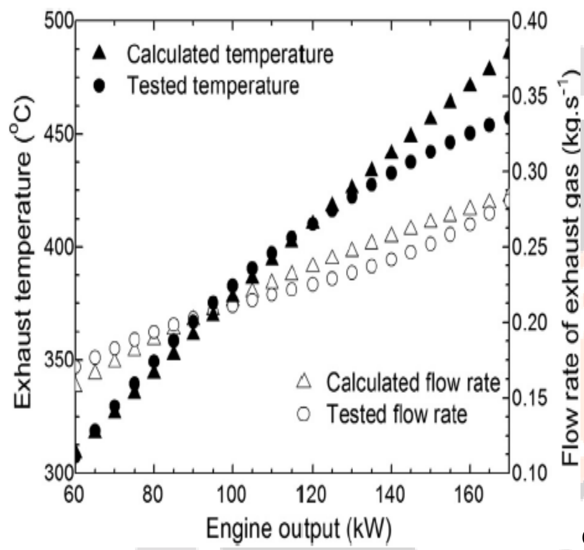

Chart.1

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 unit

3) 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[4] in this paper,fig4 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.

Performance of the different configurations at an ambient temperature 35 °C

Engine configuration	No charge air cooling	With pre-cooler only	With inter-cooler	With pre- and inter-cooler
Engine speed (RPM)	2000	2000	2000	2000
Inlet manifold temperature (K)	434	414	334	329
Power (kW)	154.8	159.6	165	167.4
Exhaust temperature (K)	1000	951	890	860
BSFC (g/kW h)	211.4	207.4	200.7	198.2
Air entering system (kg/s)	0.09135	0.09607	0.09834	0.1023
Air leaving system (kg/s)	0.0958	0.101	0.103	0.107
Brake thermal efficiency (%)	38.51	39.25	40.56	41.0
Energy to exhaust (%)	38.35	38.48	36.49	34.05
Energy to coolant (%)	18.15	17.37	14.96	14.71

Table.1

I.Horuz, et al [5] An experimental investigation of the performance of a commercially available vapor absorption refrigeration (VAR) system is described. The natural gas-fired VAR system uses aqua-ammonia solution with ammonia as the refrigerant and water as the absorbent and has a rated cooling capacity of 10 kW. The unit was extensively modified to allow fluid pressures and temperatures to be measured at strategic points in the system. The mass flow rates of refrigerant, weak solution, and strong solution were also measured. The system as supplied incorporates air-cooled condenser and absorber units. Water-cooled absorber and condenser units were fitted to extend the VAR unit's range of operating conditions by varying the cooling water inlet temperature and/or flow rates to these units. The response of the refrigeration system to variations in chilled water inlet temperature, chilled water level in the evaporator drum, chilled water flow rate, and variable heat input are presented.
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.

Thermal desalination using diesel engine exhaust waste heat — An experimental analysis K.S. Maheswari et al [6]
The aim of this work is to utilize the heat energy wasted in exhaust gas of an internal combustion engine of low capacity for desalination using a submerged horizontal tube straight pass evaporator and a condensing unit, without the aid of any external energy used for pumping system. In this work a horizontal tube straight pass evaporator and water cooled condenser for condensing the evaporated steam were designed and fabricated.
The experiments were conducted in a 5 hp diesel engine to analyze the performance of the submerged horizontal tube straight pass evaporator (SHTE) under various load conditions. It is evident that 3.0 l/h of saline water can be desalinated from the engine exhaust gas, without affecting the performance of the engine. More over nearly 24 l of water is heated, up to 60 °C in the condenser unit. By utilizing the heat energy in condenser water in addition to waste exhaust gas heat energy the overall efficiency of the system is enhanced and thermal pollution is also reduced considerably.

Khaled S. AlQdah,et el[9] Performance and Evaluation of Aqua Ammonia Auto Air Conditioner System Using Exhaust Waste Energy.

- In this paper, the effect of the system on engine performance, exhaust emissions, auto air conditioning performance and re evaluated.
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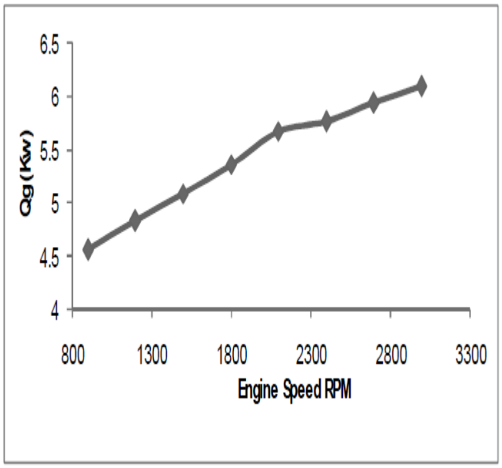

Chart. 2

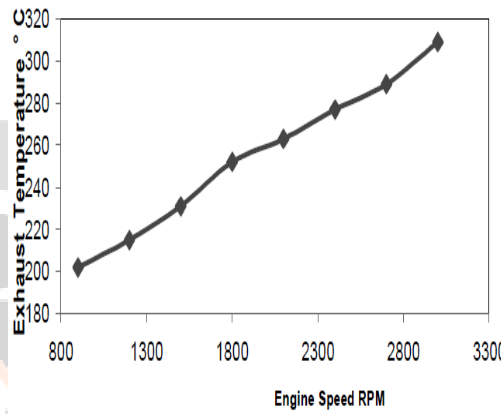

Chart.3

- Engine speed vs. Exhaust Temp. and COP vs. Heat(Chart.3)

V. Pandiyarajan, M. Chinna Pandian, E. Malan a, R. Velraj, R.V. Seeniraj, et al[10] Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal storage system.

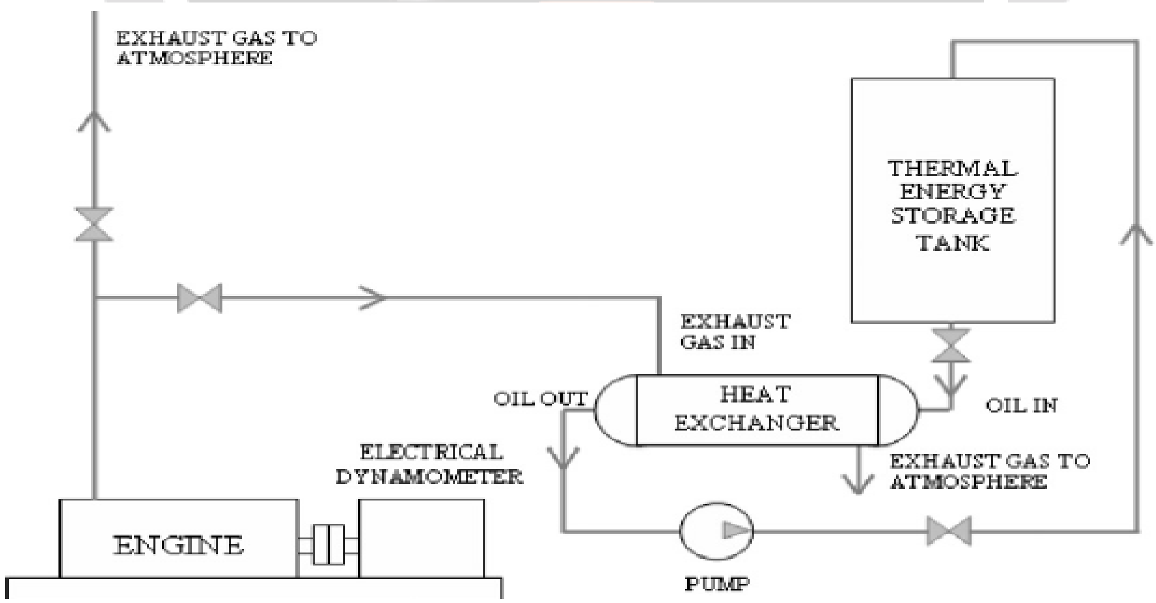

Fig.3

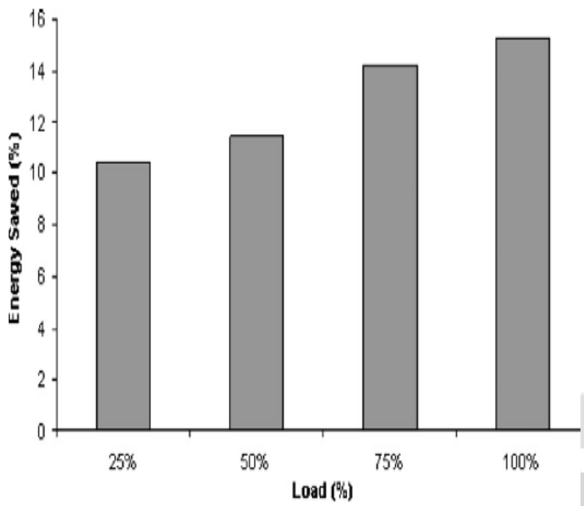

Chart.4

- Nearly 10–15% of total heat (that would otherwise be gone as waste) is recovered with this system.
- Both the charging rate and charging efficiency are very high at higher load and they decrease with respect to load.

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 systemor Electrolux refrigeration.

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