Literature Review on Organic Rankine Cycle and its Application in Heat Recovery on the I.C. Engines

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Abstract— Organic Rankine Cycle is now-a-days rising as a new solution to the heat recovery system. By using this technology to recover the heat from the diesel engine will also help in reducing the use of diesel. Dry or isentropic fluids are used in the organic rankine cycles because of their operating ranges and critical temperature. Diesel crisis, fossil fuels etc. have become some of the major factors affecting the pollution, global warming and many other environmental hazards. Moreover, heat released by such resources is tough to be recovered as the temperature is too low. To improve the use and reuse these released heat some promising technologies are being studied and used. Organic Rankine Cycle is one of such technologies.

Key words: Organic Rankine Cycle, Heat Recovery, Diesel Engine, Dry Fluids, Isentropic Fluids

I. Literature Review

Energy has now-a-days become a crucial factor regarding the environmental safety and economical balance. Diesel crisis, fossil fuels etc. have become some of the major factors affecting the pollution, global warming and many other environmental hazards. Moreover heat released by such resources is tough to be recovered as the temperature is too low. To improve the use and reuse these released heat some promising technologies are being studied and used. Organic Rankine Cycle is one of such technologies.

Organic Rankine Cycle is similar to Steam Rankine Cycle in its operation. The differences here are the working temperature range and the working fluid. In steam Rankine Cycle, Wet fluids with negative slope are used such as water, whereas, in Organic Rankine cycle, dry or isentropic fluids are used. Some of the advantages of Organic Rankine cycle over steam rankine cycle are no superheating, lower turbine inlet temperature, lower evaporating pressure, higher condensing pressure, low temperature heat recovery. Advantages of steam rankine cycle over ORC are higher efficiency, low-cost working fluid, non-flammable, non-toxic working fluid, low pump consumption, high chemical-stability working fluid

II. Organic Rankine Cycle and its Applications

Sylvain Quoilin, Martijn Van Den Broek, Se'bastien Declaye, Pierre Dewallef, Vincent Lemort(2013)[1] studied the Organic Rankine Cycle and its various applications and its market review based on its economical survey, its commercial module and manufacturers. Organic rankine cycle can use Solar energy, biomass, geothermal energy, heat released by the engines etc. as its input energy. Higher capacity plants are already in use in some of the areas like Arizona, Hawaii etc. An Internal Combustion Engine only converts about one-third of the fuel energy into mechanical power on typical driving cycles. A typical 1.4 l Spark Ignition ICE, with a thermal efficiency ranging from 15% to 32%, releases 1.7–45 kW of heat through the radiator at a temperature close to 80–100oC and 4.6–120 kW via the exhaust gas. Scroll expanders were most suitable for the fluid selected.

Organic rankine cycle has an enormous potential for the production of heat for heating, domestic hot water, drying processes in industry, absorption cooling, etc. and for mechanical and electrical energy from a few kW to some MW from renewable energy sources such as biomass, solar and geothermal and waste heat from industrial processes or other technologies. Because of the wide range of power of the ORC, it can also recover the waste heat from other power cycles such as turbines, internal combustion engines, heat pumps etc., according to Fredy Vélez, José J. Segovia, M. Carmen Martín, Gregorio Antolín, Farid Chejne, Ana Quijanoa(2012)[8].

III. Fluid Selection

Some guidelines and indicators are mentioned by Sylvain Quoilin, Martijn Van Den Broek, Se'bastien Declaye, Pierre Dewallef, Vincent Lemort(2013)[1]. Some of them are Thermodynamic performance, Positive or Isentropic saturation vapour curve, High vapor density, low viscosity, high temperature stability, lower melting point that the ambient temperature, high safety level, low ozone depleting potential. Low greenhouse warming potential, good availability and low cost.

For the Selection of the fluids Benzene (C_6H_6), Toluene (C_7H_8), p-Xylene (C_8H_{10}), R113 and R123 were studied by Tzu-Chen Hung(2000)[2]. Among the working fluids under investigation, p-Xylene shows the highest efficiency while Benzene shows the lowest. The study also shows that the irreversibility depends on the type of heat source. Generally speaking, p-Xylene has the lowest irreversibility in recovering a high temperature waste heat, while R113 and R123 have a better performance in recovering a low temperature waste heat.

Jie Zhu and Hulin Huang(2014)[3] studied the solar organic rankine cycle, in which solar heat was taken as the input to the organic rankine cycle to be studied. Experimentation was done on cascaded system for single stage as well as two-stage systems. In single stage system R134a was used. For two-stage system in first stage again R124a and then in second stage R245fa was used. R245fa being heavier than R134a was used in the later stage. The superheated degree of R245fa is lower than that of R134a, which results in higher density and higher heating efficiency in the superheater compared with that of R134a. R245fa is better for the specified conditions when it is used as the working fluid in the first stage of ORC system.

The possibility of utilizing a low temperature geothermal resource as part of a sustainable energy supply for Waddan City in the Al Jufrah region of Libya was studied by S. Masheiti, B. Agnew and S. Walker(2011)[4]. The selected fluids covered a wide range of critical temperatures from 101.3℃ for R-134a up to 280.5℃ in the case of cyclo-hexane, which was further compared with R245fa. It was revealed that the refrigerant R-245fa had a better performance. The condenser was the component that controlled the performance of the cycle, as this operated with the smallest temperature difference and was most sensitive to changes to demand. According to E.H. Wang, H.G. Zhang, B.Y. Fan, M.G. Ouyang, Y. Zhao, Q.H. Mu(2011)[8], if safety levels and environmental impacts are considered, R245fa and R245ca are the most suitable working fluids for an engine waste heat-recovery application. On the other hand, Fredy Vélez, Farid Chejne and, Ana Quijano(2015)[5] concluded that efficiency largely depends upon the pressure ratio in the turbine. Similarly, it also depends upon the the input temperature to the turbine. Moreover, considering the energy analysis carried out, it can be concluded that the ORC with R134a as working fluid is suitable for the production of useful energy using low enthalpy heat, as it is possible to operate in relatively low temperature ranges.

Ngoc Anh Lai, Martin Wendland, Johann Fischer(2010)[7] studied the working fluids for high temperature organic rankine cycle. Alkanes, aromates and linear siloxanes are considered as working fluids for high-temperature organic Rankine cycles. Maximum temperature range was taken between 250oC to 300oC. Amongst these, it was found, that, cyclopentane is the best working fluid for all cases studied.

From the study done by Bala V. Datla , Joost J. Brasz(2012)[9], a new refrigerant R1233zd has been introduced as a low GWP alternative for R245fa. The use of low GWP R1233zd for low temperature ORC system shows promising 8.7% higher cycle efficiency when compared to an equivalent R245fa based system.

IV. Heat Recovery by using ORC

The main advantage of the ORC is its ability of recovering waste heat with a low to medium temperature. There is a wide range of heat sources which can be applied to ORCs, such as waste heat from the condenser of a steam power plant, from industrial processes, solar radiation and geothermal energy studied by Tzu-Chen Hung(2000)[2]. In general, recovery of waste heat with temperature below 370°C is not economically feasible, and this kind of heat is usually exhausted and becomes a source of ollution. Therefore, power generation using an ORC in recovering the waste heat is beneficial in many aspects such as economical utilization of the energy, reduced electrical loads and reduced emission of CO_2.

Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work, stated J. S. Jadhao, D. G. Thombare(2013)[6]. The recovery and utilization of waste heat not only conserves fuel (fossil fuel) but also reduces the amount of waste heat and greenhouse gases damped to environment.

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