PERFORMANCE ANALYSIS OF REHEAT ORGANIC RANKINE CYCLE FOR WASTE HEAT RECOVERY USING R245fa AS WORKING FLUID

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Abstract *:* Energy has played a key role to create the world as we see it today. Fossil fuels account for the majority of the world's energy consumption, but they have been estimated to be finite sources because the rate of resource usage is much higher than the rate of discovery of new reservoirs. Due to rapid depletion of fossil fuel resources and their environmental impact, the world is being challenged to shift the energy dependence from fossil fuel . New energy conversion technologies are required to utilize energy resources suitable for power generation without causing environmental pollution an organic Rankine cycle (ORC) used to recover waste heat to produce additional power. WHR using ORCs involves the utilization of the sensible enthalpy of the hot exhaust to heat an organic fluid, preferably to saturated or superheated vapour, and then the energy of the vapour is used to obtain additional useful power from a small turbine. Organic Rankine cycle (ORC) technology has been identified as one of the most promising technologies in recovering low-grade heat sources there is an inherent demand for using sustainable and renewable energy systems for an energy production in the future. This paper mainly concentrate on the power production by recovering waste heat from steam power plant using Organic Rankine Cycle(ORC) .This paper also had a discussion of using a reheating process in ORC to increase the output of cycle by using a Aspen HYSYS V9 package**.**

IndexTerms **– Waste Heat Recovery, Organic Rankine Cycle(ORC), Reheat Organic Rankine Cycle(RORC), Aspen HYSYS, Efficiency Improvement.**

1.INTRODUCTION

WASTE HEAT:

Many processes, especially in industrial applications, produce large amounts of waste or excess heat, i.e., heat beyond what can be efficiently used. Waste heat is heat generated in a process by way of fuel combustion or chemical reaction, which is usually discarded into the environment and not utilized. Waste heat recovery (WHR) methods attempt to extract some of the energy that otherwise would be wasted. The mechanism to recover the unused heat depends on the temperature of the waste heat gases and the economics involved. Typical methods of recovering heat in industrial applications include direct heat recovery to the process itself, recuperators, regenerators, and waste heat boilers. If some of the waste heat could be recovered, then a considerable amount of primary fuel could be saved. An important issue to consider is that in many applications, especially those with low-temperature waste heat streams.

WASTE HEAT RECOVERY BY ORC

The temperatures of the exhaust from most industrial processes and power plants are less than 370 °C (643.15 K). If this kind of waste heat is let into the environment directly, it would not only waste heat but also make heat pollution to the environment. Using conventional methods to recover energy from this kind of exhaust is economically infeasible. The organic Rankine cycle (ORC) system exhibits great flexibility, high safety and low maintenance requirements in recovering this grade of waste heat. Integrating the ORC to the energy system, such as power plants, could achieve using low grade energy (waste heat) to generate high grade energy (power), easing the power burden and enhancing system efficiency. Since the ORC consumes virtually no additional fuel, for the same added power, the emission of environmental pollutants such as carbon dioxide (CO2), sulphur dioxide (SO2) and so on would be decreased. According to the local demand, the exhaust heat exiting from the ORC could be further utilized to drive chillers such as absorption chillers to supply cooling capacity

An ORC system using low-grade energy sources in the system is composed of an evaporator (waste heat boiler), a turbine expander, a condenser, and a pump. A working fluid flows into the evaporator in which the high-temperature heat source (which is in the form of steam) is utilized. The vapour of the boiling fluid enters the turbine expander and generates power.

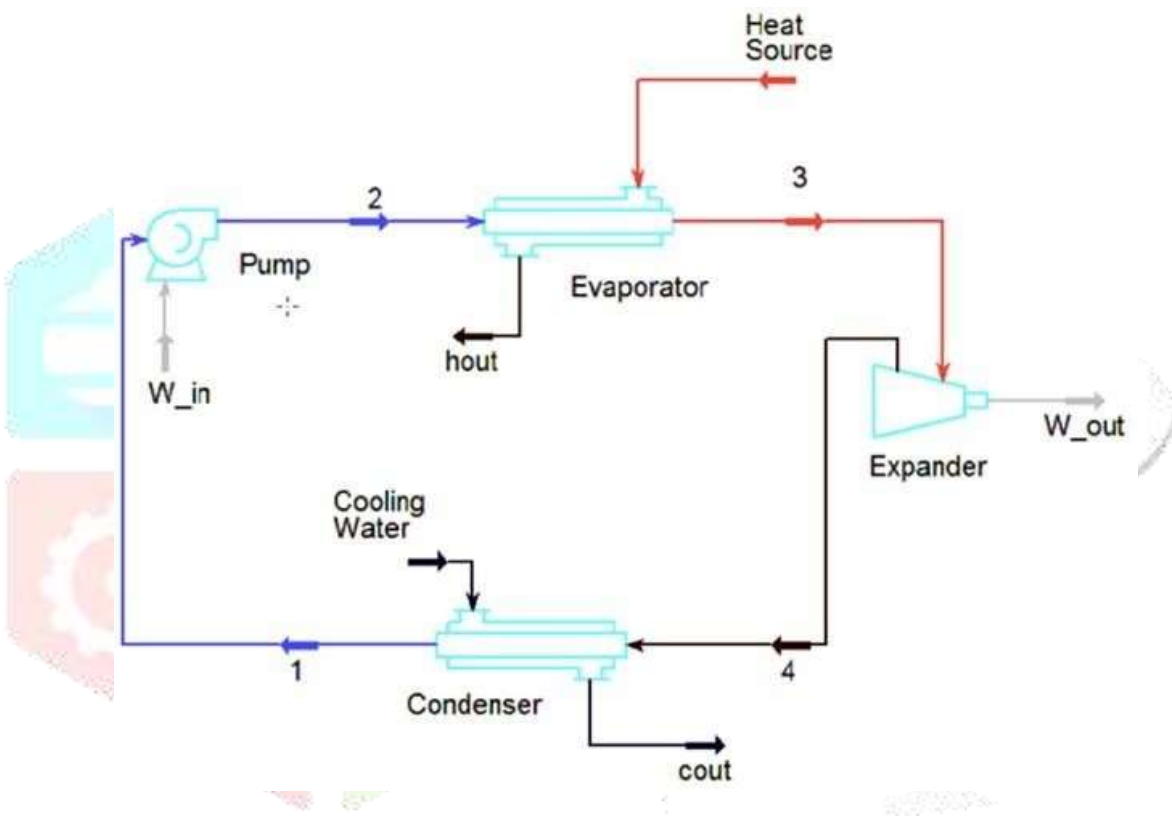


Fig-1.2 line diagram of ORC

The exit fluid from the turbine expander then enters the condenser in which the low-temperature cooling water (i.e., the cold water) is utilized to condense the fluid. Finally a fluid pump raises fluid pressure and feeds the fluid into the evaporator to complete the cycle. So long as a temperature difference between the high and low-temperature ends is large enough, the cycle will continue to operate and generate power. The objective of this study is focused on thermodynamic analyses of the working fluid and the overall system efficiency rather than hard ware arrangements such as the system integration of thermal energy. Therefore, issues regarding material selections, component configurations, frictional losses, heat transfer performances of the evaporator and condenser, and cost analysis are not considered in this study.

2. Condenser And Gland Steam Condenser:

CONDENSER: The main function of condenser is to convert gaseous form of exhaust steam into liquid or it is a heat sink in the thermal cycle in which rejection of heat energy takes place on condensation of exhaust steam of turbine. Cooling medium is used such as water/air to convert steam into water.

GLAND STEAM CONDENSER :The function of the gland steam condenser is to maintain a sub-atmospheric pressure at the outermost leak-off belt of the glands and thereby prevent the leakage of steam from the glands into the turbine hall, where it would condense on the walls and plant.

The condenser is vented to the atmosphere via a blower. The small vacuum created by the blower is sufficient to draw air into the glands where it mixes with steam leaking from the cylinder; the air is separated in the gland condenser and passed back to the atmosphere via the vent fans. The steam is condensed and the condensate passes to the main condenser.

WASTE HEAT RECOVERY FROM STEAM CONDENSERS

HEAT RECOVERY IN MAIN CONDENSER: The main steam coming from the turbine is allowed to pass through a condenser/ evaporator. In which constant mass flow rate of liquid refrigerant is passed through a small tubes of the condenser. The main steam is allowed to pass over the tubes in counter direction

During which steam will loos the latent heat and turns into water and liquid refrigerant will gain the sensible heat as well as latent heat and turns into vapour refrigerant, hence the refrigerant is having low boiling point will turns into super heated vapour and then passes through the main turbine.

HEAT RECOVERY IN GLAND CONDENSER: The gland steam condenser typically consists of a steel shell closed by a dished-end and U tubes. Refrigerant provided by main turbine is circulated through the U-tubes to condense the steam and to increase the heat energy of refrigerant. When the gland steam condenser is out of service, steam is prevented from escaping into the turbine hall by operating the vent fans.

3.PROPERTIES OF ORGANIC FLUID:

An important factor that affects the efficiency of an ORC is the selection of the organic working fluid, which must be carefully selected based on safety and physical and thermodynamically feasibility

TOXICITY OF WORKING FLUID: All organic fluid is inevitably toxic. A working fluid with a low toxicity should be used to protect the personnel from the threat of contamination in case of a fluid leakage

BOILING TEMPERATURE: Some of the organic fluid has a very low boiling temperature under atmospheric pressure. For those fluids, the temperature of cooling water in the condenser should be reduced. can result in a more stringent requirement for the selection of the condenser

FLASH POINT: A working fluid with a high flash point should be used in order to avoid flammability

SPECFIC HEAT: A high value of specific heat represents a high load for the condenser. Hence a working fluid with a low specific heat should be used

LATENT HEAT: A working fluid with a high latent heat should be used in order to raise the efficiency of heat recovery

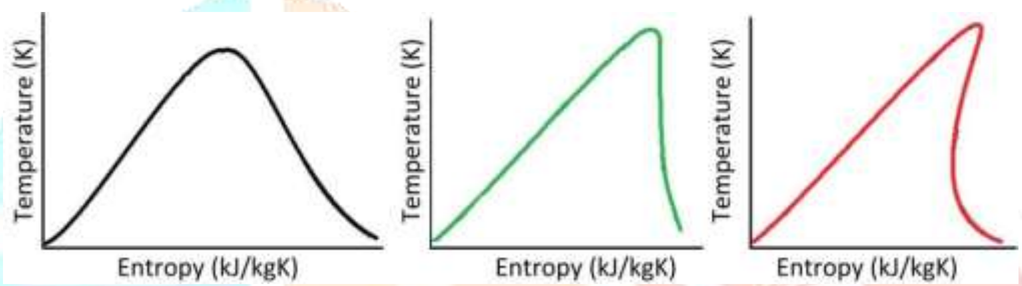
THERMAL CONDUCTIVITY: A high conductivity represents a better heat transfer in heat-exchange components

The presence of hydrogen bond in certain molecules such as ammonia, water, and ethanol may cause these fluids behave like wet fluids due to their large vaporization enthalpies, and these fluids are regarded as inappropriate for ORC systems

4.Working Fluid Selection:

Except for the structural point of view and type of atoms in the fluid molecule, the working fluids could be categorized according to the saturation vapour curve, which is one of the most crucial characteristics of the working fluids in an ORC. This characteristic affects the fluid applicability, cycle efficiency, and arrangement of associated equipment in a power generation system there are generally three types of vapour saturation curves in the temperature-entropy (*T*–*s*) diagram

wet, isentropic and dry fluids



- A wet fluid with negative slopes and ,(e.g. water ,ammonia)
- A dry fluid with positive slopes.(e.g.R245fa)
- An isentropic fluid with nearly infinitely large slopes (e.g.R11)

While isentropic and dry fluids do not need superheating, thereby eliminating the concerns of impingement of liquid droplets on the expander blades. Moreover, the superheated apparatus is not needed. Therefore, the working fluids of dry or isentropic type are more adequate for ORC systems. If the fluid is too dry, the expanded vapour will leave the turbine with substantial super- heat, which is a waste and adds to the cooling load in the condenser. Usually a regenerator is used to reclaim these exhaust vapour to increase the cycle efficiency; however, it would increase the system's initial investment and complexity, which exists trade-off. Therefore, isentropic fluids are most suitable for recovering low-temperature waste heat.

5. DESIGN AND SIMULATION OF ASPEN HYSYS:

Aspen Hysys (Or Simply Hysys) is a mechanical, chemical process simulator used to mathematically model mechanical chemical processes, from unit operations to full chemical plants, thermal plants and refineries. HYSYS is able to perform many of the core calculations of thermal engineering, including those concerned with mass balance, energy balance, vapor-liquid equilibrium, heat transfer, mass transfer, chemical kinetics, fractionation, and pressure drop. HYSYS is used extensively used in industry for steady-state and dynamic simulation, process design, performance modeling, and optimization..

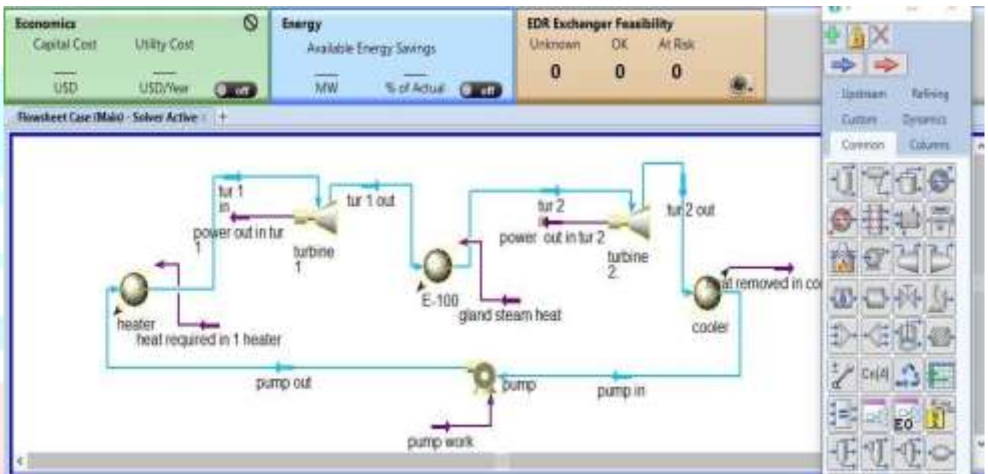
In Aspen HYSYS Package problem solving involves three mains steps

- Creating a Component List

- Selecting a fluid package
- The Simulation Environment
- Building the Flow sheet

6.Design And Simulation Of Reheat Organic Rankine Cycle

- Open Aspen HYSYS V9 workbench
- Select the fluid package then select the Aspen Properties
- Select the basis 1 ,select property package and select Peng-Robinson
- Add component list1 [Aspen Properties database], select component in R245fa(1,1,1,3,3-pentafluropropane)
- Open the Simulation work bench
- Open model palette containing all the components



- Add the components from palette to flow sheet
- Add heaters , turbines , condenser , pump to work bench
- Rename the components
- Give the connections of material streams
- Give the connections of energy streams
- Give the input data for material stream at pump inlet
- Give the output data for material stream at pump outlet 1
- worksheet of pump is generated 1
- Give output data for heater 1
- Worksheet of heater 1 is generated
- Give output data for turbine 1
- Worksheet of turbine 1 is generated
- Give input data for turbine 2
- Worksheet of heater 2 is generated
- Give output data for turbine 2
- Worksheet of turbine 2 is generated

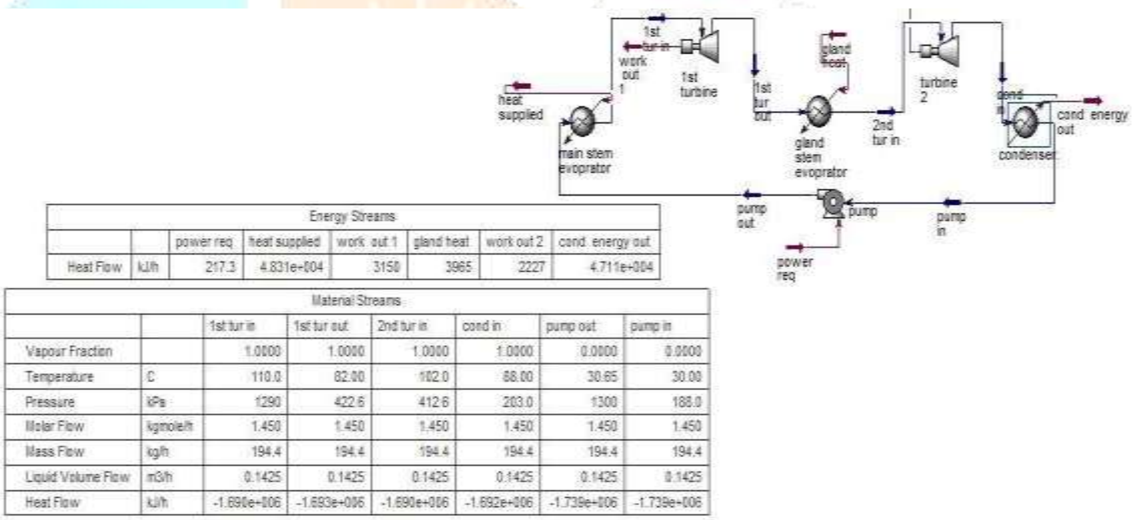
All the required data is given

Simulation is in active mode hence there was no mistakes in the circuit and output is generating

Energy Streams							
		power req	heat supplied	work out 1	gland heat	work out 2	cond energy out
Heat Flow	kJ/h	217.3	4.831e+004	3150	3965	2227	4.711e+004

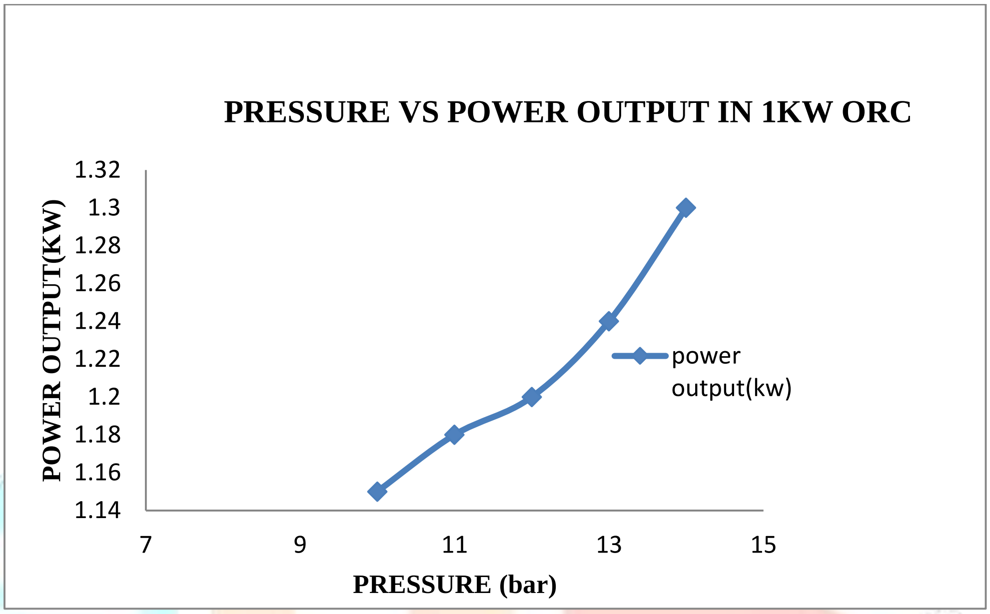
Material Streams							
		1st tur in	1st tur out	2nd tur in	cond in	pump out	pump in
Vapour Fraction		1.0000	1.0000	1.0000	1.0000	0.0000	0.0000
Temperature	C	110.0	82.00	102.0	88.00	30.65	30.00
Pressure	kPa	1290	422.6	412.6	203.0	1300	188.0
Molar Flow	kgmole/h	1.450	1.450	1.450	1.450	1.450	1.450
Mass Flow	kg/h	194.4	194.4	194.4	194.4	194.4	194.4
Liquid Volume Flow	m3/h	0.1425	0.1425	0.1425	0.1425	0.1425	0.1425
Heat Flow	kJ/h	-1.690e+006	-1.693e+006	-1.690e+006	-1.692e+006	-1.739e+006	-1.739e+006

By using workbook table tool results are found



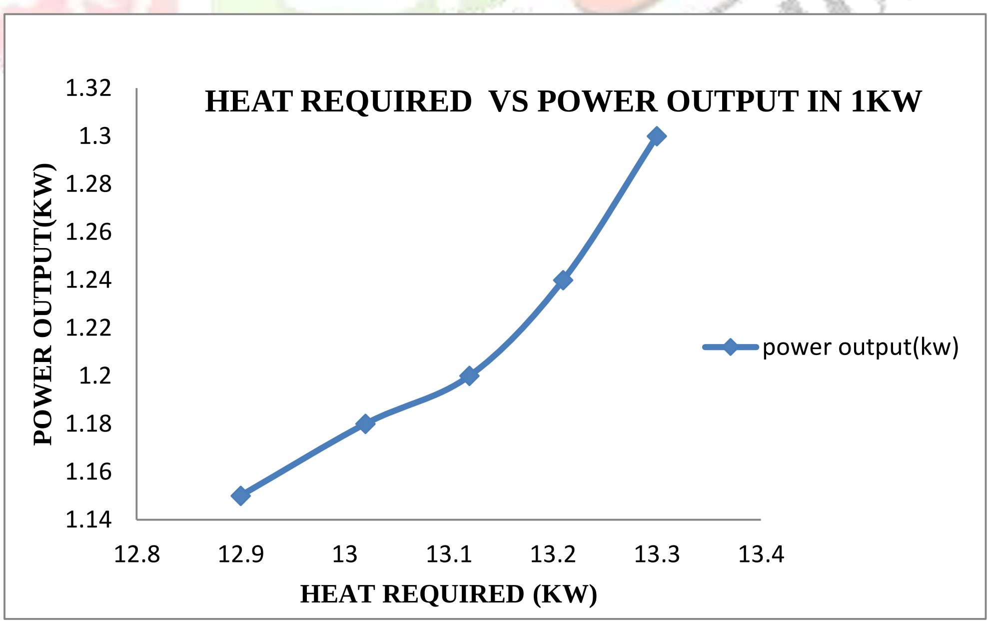
7. Results :

7.1RESULTS WITH RESPECT TO PRESSURES IN SIMPLE ORC



PRESSURE VS POWER OUTPUT IN 1KW ORC

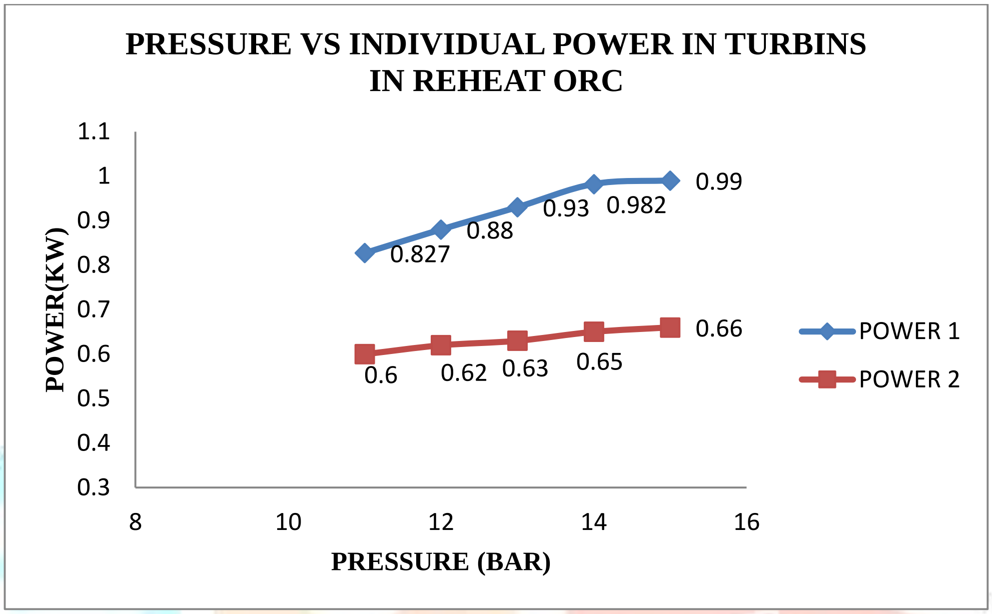
- During the analysis of a simple organic rankine cycle with refrigerant R245fa in Aspen HYSYS as the pressure increases the power out is also increases



HEAT REQUIRED VS POWER OUTPUT IN 1KW

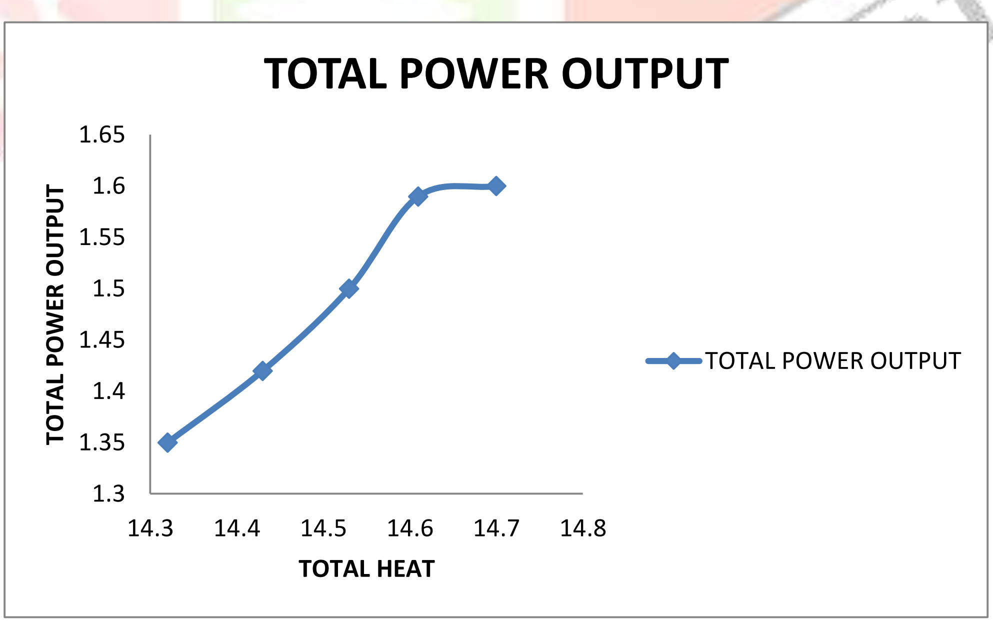
- During the analysis of a simple organic rankine cycle with refrigerant R245fa in Aspen HYSYS as the heat input increases the power output also increases

7.2 RESULTS WITH RESPECT TO PRESSURES IN REHEAT ORC



PRESSURE VS INDIVIDUAL POWER IN TURBINS IN REHEAT ORC

- During reheat ORC as the pressure increases the power output also increases



TOTAL POWER OUTPUT VSTOTAL HEAT IN REHEAT ORC

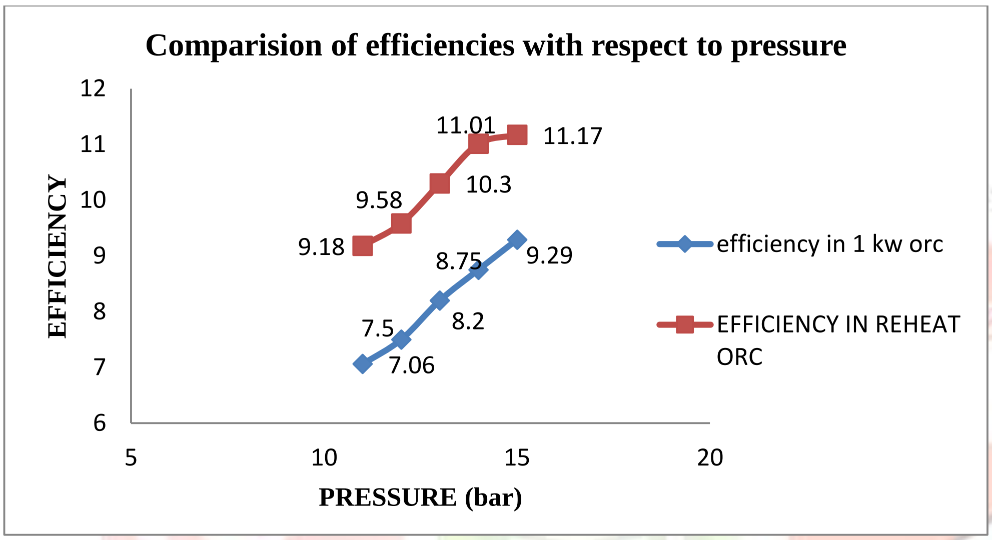
- During reheat ORC as the pressure increases the heat required is high and the power output is also increases

8.Conclusion And Future scope:

8.1 CONCLUSION: Many industrial processes produce waste heat that is typically rejected to lower temperature heat sinks. There are number of ways in which such waste heat can be recovered to produce useful energy. Recovery of waste heat offers the benefit of increasing overall efficiency in case of power generation or provides auxiliary power in other waste heat application.

In steam power plants a medium–low grade waste heat can be recovered from steam condenser to produce power using organic rankine cycle.

A reheat organic rankine cycle can be used instead of a simple organic rankine cycle to increase the overall efficiency of plant.



COMPARISION OF EFFICIENCIES WITH RESPECT TO PRESSURE

By comparing the efficiencies of simple ORC and Reheat ORC the Reheat ORC will give the high efficiency under the same working conditions From above it can be concluded that the efficiency of reheat organic rankine cycle is much better than simple organic rankine cycle to produce power form steam power plants.

8.2 FUTURE SCOPE: The temperature of the exhaust form the most industrial process and power plants are less than 370^{0}. If this kind of waste heat is let in to environment directly, it would not only waste heat but also make heat pollution to environment. Using conventional methods to recover energy from this kind of exhaust is economically infeasible. The organic Rankine Cycle (ORC) system exhibits great flexibility, high safety and low maintenance requirements in recovering this grade of waste heat.

ORC can be used in gas power plants as the exhaust gases coming out from turbine is at higher temperatures ORC can be used in cement industries , chemical industries as they liberate large amount of heat through exhaust

REFERENCES

[1] Usman Muhammad , Muhammad Imran , Dong Hyun Lee, Byung Sik Park *"Design and experimental investigation of a 1 kW organic Rankine cycle system using R245fa as working fluid for low-grade waste heat recovery from steam"* Energy Conversion and Management 103 (2015) 1089–1100 http://dx.doi.org/10.1016/j.enconman.2015.07.045 Elsevier Ltd

[2] Donghong Wei *, Xuesheng Lu, Zhen Lu, Jianming Gu "*Performance analysis and optimization of organic Rankine cycle (ORC) for waste heat recovery"* Energy Conversion and Management 48 (2007) 1113–1119

[3] Takahisa Yamamoto, Tomohiko Furuhata, Norio Arai , Koichi Mori "*Design and testing of the Organic Rankine Cycle"*Energy 26 (2001) 239– 251.

[4] P. J. Mago (2012) *"Exergetic Evaluation of an Organic Rankine Cycle Using Medium- Grade Waste Heat"*, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 34:19, 1768-1780, DOI: 10.1080/15567036.2010.492382

[5] Junjiang Bao, Li Zhao "*A review of working fluid and expander selections for organic Rankine cycle"* renewable and sustainable energy review 24(2013) 325-342 Elsevier Ltd

[6] T.C. Hung, S.K. Wang , C.H. Kuo, B.S. Pei, K.F. Tsai " *A study of organic working fluids on system efficiency of an ORC using low- grade energy sources Energy*" 35 (2010) 1403–1411

[7] L. Wei , Y. Zhang , Y. Mu , X. Yang & X. Chen " *Efficiency Improving Strategies of Low-temperature Heat Conversion Systems Using Organic Rankine Cycles*" An Overview, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33:9, 869-878

[8] Teemu Turunen-Saaresti et al *"Design and testing of high temperature micro-ORC test stand using Siloxane as working fluid"* J. Phys.: Conf. Ser. **821** 012024

[9] Bertrand F. Tchanche *, Gr. Lambrinos, A. Frangoudakis, G. *"Papadakis Low grade heat conversion into power using organic Rankine cycles – A review of various applications"* Renewable and Sustainable Energy Reviews 15 (2011) 3963–3979

[10] F.J. Fernández*, M.M. Prieto, I. Suárez *"Thermodynamic analysis of high-temperature regenerative organic Rankine cycles using siloxanes as working fluids"* energy 36(2011) 5239e5249

[11] Ulli Drescher,Dieter Brüggemann "*Fluid selection for the Organic Rankine Cycle (ORC) in biomass power and heat plants"* Applied Thermal Engineering 27 (2007) 223–228

[12] Ho-Myung Chang , Hye Su Lim, Kun Hyung Choe *"Effect of multi- stream heat exchanger on performance of natural gas liquefaction with mixed refrigerant using "**ASPEN HYSYS**"* Cryogenics 52 (2012) 642– 647