CANDIDATE'S DECLARATION

I hereby declare that the work presented in this thesis titled **"Exergy And Energy Analysis Of Modified Organic Rankine Cycle For Reduction Of Global Warming And Ozone Depletion**", in the partial fulfillment for the award of the degree of Master of Technology in "**THERMAL ENGINEERING**" submitted to Department of Mechanical Engineering, is an authentic recordof my own work carried out under the supervision of Prof. Dr. R. S. MISHRA Department of Mechanical Engineering, Delhi technological university, Delhi. This report does not, to thebest of my knowledge, contain part of my work which has been submitted for the award ofany other degree either of this university or any other university without proper citation.

Date:

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2K15/THE/22

CERTIFICATE

This is to certify that above statement made by "Mr. **YUNIS KHAN**" is correct

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ABSTRACT

There is great importance of using the Organic Rankine cycle plant in world.Low and medium grade energy is converted into the useful high grade energy by ORC. These low and medium grade energy sources are geothermal, solar energy, exhaust from the engine and other industrial waste energy.In this study the solar energy source is used. The main purpose of the solar integrated power plant is to mitigate the emission and risk associated with the already running plant and the other important purpose of integration of solar energy into already running power cycles is to minimize the cost without changing already existing equipments. In this work exergy and energy analysis of Organic Rankine Cycle with the solar heating source is done and bleeding regeneration is used for obtaining good performance.The performance of system is compared with different organic fluids such as R134a, R407C, R404A, and R410A at different organic Rankine cycle maximum temperature and maximum pressure. R410A shows maximum thermal and exergetic efficiency around 16.51% and 64.75% respectively Exergetic efficiencies of cycle with regeneration 61.78%, 64.75%, 60.14%and 48.51% for R407C, R410A, R404A and R134a respectively and thermal efficiencies are 15.75%,16.51%,15.34%,12.37% respectively. Due to highest exergy and energy efficiency and low global warming potential and zero ozone depletion potential, R410A is recommended for practical applications. There is also no problem regarding flammability and explosion risks.

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NOMENCLATURE

h	specific Enthalpy (kJ/kg)
s	specific Entropy (kJ/kgK)
m	mass flow rate (kg/s)
P	pressure (kPa)
T	temperature (^{0}C)
Q	heat Exchange per unit mass (kW)
W	work (kW)
ἠ	isentropic Efficiency(dimensionless)

subscript/superscripts

Ex	expander
Cond	condenser
Op	organic pump
Qs	heat supplied
F	fluid
ET	exergy transfer
ED	exergy destruction
EDR	exergy destruction ratio
m_x	bleeding mass
HE	heater
EVAP	evaporator
ORC	organic Rankine cycle

CHAPTER 1
INTRODUCTION

Several solar integrated combined cycles (ISCCs) are being used in all the world (USAAfrica, North America,Italy,) and there are many projects are processing (China, Mexico, USA). ISCCs have several advantages as compared to solar thermal power plants, because these give higher conversion solarefficiency and it have very low investment cost. Many entrepreneursand owners are ready to invest the many due to it low risk associated with the smaller plants as compared to the solar thermal power plants.

Organic fluids are advantageous in comparison to water, when the maximum temperature is low and/or the power plant is small. At low temperatures, organic fluids lead to higher cycle efficiency than water. and organic fluids are preferred in small plants, since fluid mechanics leads to high turbine efficiency also in partial load, which is the main reason to use ORC for biomass application. Another advantage of ORC in small plants is a legal and economic one. Water shows good efficiency at high pressure requiring increased safety measures which are not economically feasible for small plants. The organic fluids used in ORC can be categorized into three groups of wet, dry and isentropic fluids. The dry fluids have disadvantages of reduction of net work due to superheated vapor at turbine exit and wet fluids of the moisture content at turbine inlet, so isentropic fluids are to be preferred

The procedure for changing the energy in a fuel into electric power incorporates the formation of mechanical work, which is then changed into electric power by a generator. Depending upon fuel type and thermodynamic process, in general productivity of this change can be as low as 31 %. This implies 66% of the energy of the fuel goes up loss. For instance, steam electric power plants which utilize boilers to combust a petroleum derivative normal 33% efficiency. Basic cycle gas turbine plants normal just shy of 30 percent productivity on gaseous petrol, and around 25 % on fuel oil.

ORCs with expander bleeding, coupled to a direct contact heat exchanger, are typically designated as regenerative ORCs. These cycles closely resemble the ORC with recuperator, as both pre-heat the working fluid before entering the evaporator Exergy is a measure of the departure of the state of a system from that of the environment, and the method of exergy analysis is well suited for furthering the goal of more energy resource use, for it enables the location, cause, and true magnitude of waste and loss to be determined

1.1 Organic Rankine Cycle:-

Organic Rankine Cycles have gotten more consideration amid the most recent decade. This cycle takes after the crucial principles of regular Rankine cycles working with steam in like manner plants however has a few points of interest over steam Rankine cycle which made it prevalent. Firstly this cycle can work on low pressures and temperatures in comparison to the conventional Rankine cycle and reveals a better result than steam Rankine cycle especially from low grade heat sources because it has working fluids include such as variety of HCs and other refrigerants what's more, as per scope of open heat source pressure and temperatures,different outputs can be obtained by using useful working fluids, secondly, it can also work without tmulti-stage turbines and feed-water heaters and that thing makes it simple. Although this, solar parabolic collectors are atremendous source of heat energy but these have low grade thermal energy. Because of this, these solar collectors give only some KWs to some mega watts of power generation mainly near factories and rural areas to generate own electricity consumption without the necessity for connection to grid that may be costly.

Disadvantages of solar ORCs are comparatively high costs and low thermal efficiency (10 to 25 %according to working fluids and working conditions) mainly because of low HTF (Heat transfer fluids) temperature in solar collector. As described before, the organic fluid works in ORC cycles are classified into HCs and refrigerants, some of thoseare dry liquids which mean they have a +ve slope T-S graph in the immersion vapor area. This makes it reasonable for some organic liquids to works legitimately without superheating to an extraordinary possibility and make no harm turbine. It has been appeared in this review, an examination of various dry organic liquids with or without superheating and recuperations has been done to reveal the difference in cycle effectiveness and execution of the system that encourages us to settle on a choice to pick the system condition as indicated by our requirements.

1.2 Principle of solar heating:-

The organic Rankine cycle works on the principle of a turbo generator which works as a simple steam turbine to convert thermal power into mechanical power and then into electrical power by an electrical generator. Besides of using steam of water, ORC system evaporates organic fluid, classified by a molecular weight higher than the water, that leads to slow rotation of the organic expander shaft. That also leads to the less erosion of metallic parts and the blades. Organic Rankine cycle is normally a Rankine cycle in which besides of using water other organic fluid is used such R134a, R407C,R404A,R410Aetc.

Evaporator is nothing but is the simple heat exchanger, or it can be used as a series of heat exchangers. It is also can be called a boiler, because it produces organic vapor for the ORC expander by taking energy from the solar heat source. This heat source is nothing simple solar heat flat plate collector. From solar plate heat collector the heat is taken by the evaporator working fluid is heated in evaporator and converted in to the hot vapor this vapor goes to the expander and this heat energy converted in to the rotation of expander. Instead of the flat plate heat collector there concentrated parabolic heat collector can be used

The economizer works as a heat exchanger which preheats the organic fluid (liquid) to get the temperature to the saturation temperature (boiling point), that liquid to be supplied to a thick-walled boiler drum. That drum is installed where finned evaporator tubes is located that circulate heated organic fluid. The solar radiation incident on to the evaporator tubes, and the heat is being absorbed and then the vapor is being created of in the tubes. This vapor-liquid mixture goes to the boiler drum where the vapor is separated from the hot liquid by using moisture cyclones and separators. That separated liquid is again recurculated to the evaporator tube. The function of the some boiler drums is also to storage and water treatment functions. There are several other design of steam boiler in which another design is a once-through where thin-walled components are used in place of boiler drum which are better for handling changes in exhaust gas temperature and vapor pressures during frequently stops and starts. In other designs, duct burners can be used for adding heat to the exhaust gas current and boost vapor manufacturing; it’s have been used to generate vapour even if not sufficient exhaust gas flow is there.

Saturated vapor from boiler drums or any once-through boiler system has been sent to superheater toproduce dry vapour that is requirement for the organic expander.The organic fluids goes to the preheaters, that are placed where very low amount of heat is available and then this fluid takes energy from the and heated by the heat exchanger liquids such as the mixture of glycol water and from there very economic and useful amount of heat is extracted.

The superheated organicvapor produced from the evaporator is supply to organic expander where it is expanded and gives rotation to turbine shaft. The mechanical energy delivered to the generator driving shaft is transformed into high grade energy (electricity). After exiting the organic expander, the organic vapor goes to the condenser which paths the condensed organic liquid back to evaporator.

In this research the main purpose is the selection the working fluid which is give the

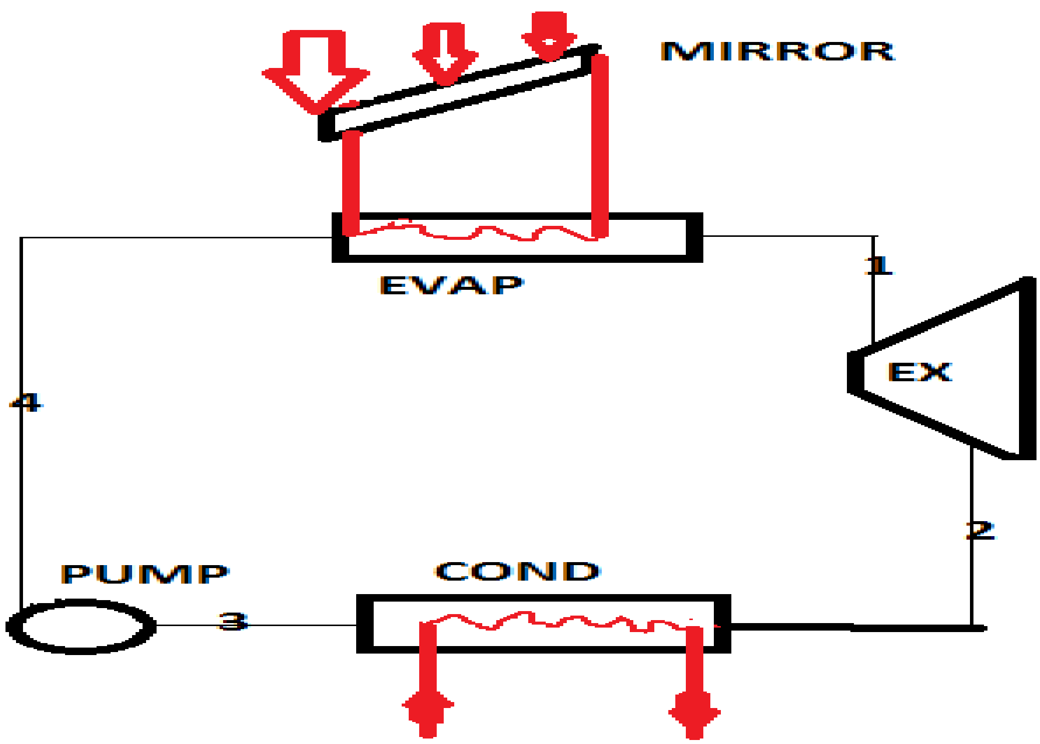
- Maximum exergetic and the first law efficiency.
- Low global warming potential and the zero ozone depletion potential.
- And give lower exergy destruction in the each component.

Some important properties of working fluids.

Working fluids	**Constituents**	**Toxicity**	**Flammability**	**ODP**	**GWP**
R407C	R32(23%),R125(25%), R134(52%)	None toxic	None flammability	0	1526
R410A	R125(50%),R32(50%)	None toxic	None flammability	0	1725
R134a	Tetrafloroethane	None toxic	None flammability	0	1300
R404A	R125(44%),R143a(52%), R134a(4%)	None toxic	None flammability	0	3260

Table:1 general properties of the working fluids

1.2 organic Rankine cycle plant without regeneration:



Fig;1;organic Rankine cycle without regeneration

This is the organic Rankine cycle without regeneration, working fluid fallows path as 1-2-3-4-1.In evaporator working fluids gets heated from the solar radiation and then heated from saturated liquid to super heated vapor. After that this vapor goes to the expander where it is expanded and heat energy is converted in the mechanical energy and after the expansion mechanical energy further transformed in to the electrical energy by the generator. After the expansion the remaining vapor which has some heat energy goes to the condenser where heat rejected from the vapor .In condenser cooling water is enter for cooling purpose after then it is pumped to the boiler pressure by liquid organic pump. Then again the heating process is done and the cycle is repeated.

1.4 Organic Rankine cycle with regeneration;-

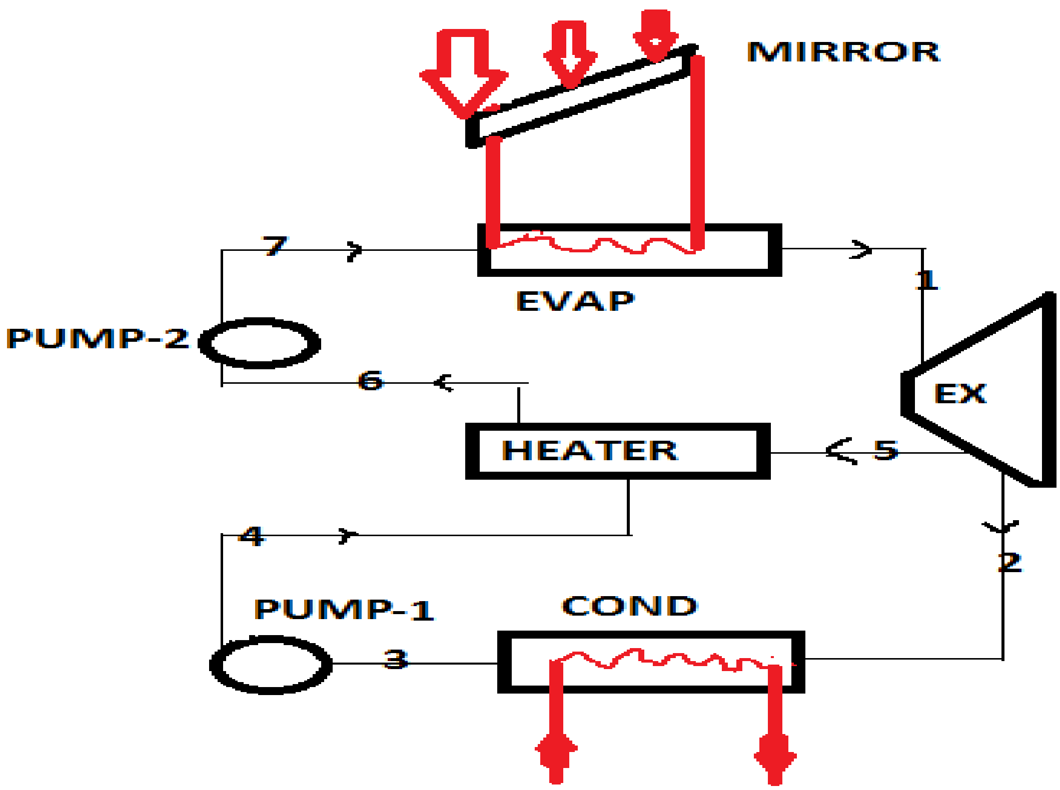


Fig-2;-organic rankine cycle with regeneration

A regenerator is installed which heat the organic fluid (liquid) by the high temperature vapor that is coming from the organic expander. In many organic fluids when expanded in ORC expander, at the exit give superheated vapor this vapor enthalpy is used in heating organic fluid. That results heat addition required in the evaporator is reduced. and condenser temperature is again set 35˚C.Some organic vapor at intermediate pressure is extracted .this bled of vapor is goes to heater for heating the organic liquid coming out from the pump-1.After gating heat from heater liquid is heated and then go to the pump -2 .From pump -2 it is pumped to the evaporator pressure. Main purpose of the bleeding regeneration is that it is reduced the heat addition in evaporator .Almost sensible heat addition reduced in evaporator.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it is intended to give a brief literature review of work being carried out on solar integrated Organic Rankine cycle power plant. Many papers have appeared since the late nineties about the thermodynamic analysis of focusing on integration of solar energy into the ORC

2.1 LITERATURE

Kelly et al [1] demonstrated that the most efficient way for converting solar thermal energy into electricity is to withdraw feed water from the heat recovery steam generator (HRSG)downstream of the last economizer, to produce high pressure saturated steam and to returnthe steam to the HRSG for superheating and reheating. The integrated solar plant conceptoffers an effective means for the continued development of parabolic trough technology. In acareful plant design, solar thermal to electric conversion efficiencies will exceed, often by asignificant amount, those of a solar-only parabolic trough project. An integrated plant bears only the incremental capital cost of a larger Rankine cycle which provides further reductionsin the levelized cost of solar energy.

He Ya Ling et al [2] proposed a model for a typical parabolic trough solar thermal powergeneration system with Organic Rankine Cycle (PT-SEGS–ORC) was built within thetransient energy simulation package TRNSYS. They found that the heat loss of the solar collector (qloss) increases sharply with the increase in pinter at beginning and then reaches to an approximately constant value. The variation of heat collecting efficiency with v is quitesimilar to the variation of qloss with pinter. However θ exhibit opposite effect on ηhc. Inaddition, it is found that the optimal volume of the thermal storage system is sensitivelydependent on the solar radiation intensity. The optimal volumes are 100, 150, 50, and 0 m3forspring equinox, summer solstice, autumnal equinox and winter solstice, respectively.

Gang et al. [3] proposed the innovative configuration of low temperature solar thermal electricity generation with regenerative Organic Rankine Cycle (ORC) mainly consisting ofsmall concentration ratio compound parabolic concentrators (CPC) and the regenerative ORC. The effects of regenerative cycle on the collector, ORC, and overall electricity efficiency are then analyzed. The results indicate that the regenerative cycle has positive effects on the ORC efficiency but negative ones on the collector efficiency due to incrementof the average working temperature of the first-stage collectors. And found that there generative cycle optimization of the solar thermal electric generation differs from that of a solo ORC. The system electricity efficiency with regenerative ORC is about 8.6% forirradiance 750 W/m^2 and is relatively higher than that without the regenerative cycle by4.9%.

Manolakos D et al [4] proposed co-generation system producing electricity and fresh water by a solar field driven supercritical organic Rankine cycle (SORC) coupled with desalination.The proposed system can use parabolic trough solar collectors (among other options) toproduce 700 kW thermal energy with temperatures up to 400°C at peak conditions. Thermalenergy is delivered to the SORC which uses hexamethyldisiloxane (MM) as the workingorganic fluid and could achieve cycle efficiency close to 21%. The SORC condensationprocess is undertaken by the feed seawater to reduce thermal pollution. Due to the elevatedtemperature of the preheated seawater, the RO unit specific energy consumption decreases.

Nafey et al[5] carried out design and performance analysis using MatLab/SimuLink computational environment. The cycle consists of thermal solar collectors (Flat Plate Solar Collector (FPC), or Parabolic Trough Collector (PTC), or CompoundParabolic Concentrator (CPC)) for heat input, expansion turbine for work output, condenserunit for heat rejection, pump unit, and Reverse Osmosis (RO) unit. Reverse osmosis unitspecifications used in this work is based on Sharm El-Shiekh RO desalination plant. Differentworking fluids such as: butane, isobutane, propane, R134a, R152a, R245ca, and R245fa areexamined for FPC. R113, R123, hexane, and pentane are investigated for CPC. Dodecane,nonane, octane, and toluene are allocated for PTC. Exergy and cost analysis are performedfor saturation and superheated operating conditions. Toluene and Water achieved minimumresults for total solar collector area, specific total cost and the rate of exergy destruction.

Sharaf et al [6] carried out thermo-economic analysis of PTSC integrated with an ORC and amulti-effect distillation. Two scenarios of generation were considered in their study: the firstone was with only water production and the second one was with both power and waterproduction.

The comparison is implemented according to the operation of Parabolic Trough Collector (PTC) with toluene organic oil and water working fluids. Therminol-VP1 HeatTransfer Oil (HTO) is considered for indirect vapor generation operation across the solarfield and evaporator heat exchanger. The comparisons are manipulated according to100 m^3/day of distillate product as a case study. As a result, only desalination technique isconsidered more attractive than desalination and power technique due to higher gain ratio andlower solar field area needed.

Delgado-Torres et al. [7] -[8] conducted thermodynamic analysis of athermal system which consists of an ORC, a PTSC, and an RO (Reverse Osmosis). Initiallythey analyzed the system assuming only water production through RO then they extendedtheir study to include both electrical and water production the main objective of their studywas to examine the effect of different organic fluids on the aperture area of the PTSC.

Al-Sulaiman et al. [9] -[10] proposed the energetic performance analysis of PTSCintegrated with an ORC in which the waste heat from the ORC is used for cogeneration wasconducted. It was found that there was an energy efficiency improvement, when trigenerationwas used, from 15% to 94% (utilization efficiency). On the other hand using exergy analysis,found that there was an exergetic efficiency improvement from 8% to 20% whentrigeneration is used as compared to only power generation.

Al-Sulaiman[11] carried out solar field sizing and overall performance analysis of differentvapor cycles. The systems considered are parabolic trough solar collectors integrated witheither a binary vapor cycle or a steam Rankine cycle (SRC). The binary vapor cycle consists of an SRC as a topping cycle and an organic Rankine cycle as a bottoming cycle. Seven refrigerants are examined for the bottoming cycle: R600, R600a, R134a, R152a, R290,R407c and ammonia. Founds that significant reduction in the solar field size is gained due tothe performance improvement when the binary vapor cycle is considered as compared to asteam Rankine cycle with atmospheric condensing pressure; however, SRC with vacuumpressure has the best performance and smallest solar field size. It further reveals that theR134a binary vapor cycle has the best performance among the binary vapor cyclesconsidered and, thus, requires the smallest solar field size while the R600a binary vapor cyclehas the lowest performance.

Fahad A. Al-Sulaiman[12] carried out detailed exergy analysis of thermal power systemdriven by parabolic trough solar collectors (PTSCs). The power is produced using either asteam Rankine cycle (SRC) or a combined cycle, in which the SRC is the topping cycle andan organic Rankine cycle (ORC) is the bottoming cycle. Seven refrigerants for the ORC wereexamined: R134a, R152a, R290, R407c, R600, R600a, and ammonia. The R134a combined cycle demonstrates the best exergetic performance with a maximum exergetic efficiency of26% followed by the R152a combined cycle with an exergetic efficiency of 25%. Alternatively, the R600a combined cycle has the lowest exergetic efficiency, 20–21%.

MiladAshouri et al [13] carried out analysis of a photovoltaic through collector (PTC)integrated with an organic Rankine cycle (ORC) for small scale electricity generation nearTehran. The system includes a solar field, a storage tank, and a small scale ORC engine.Performance evaluation has been done by means of commercial software Thermoflex19. Acomparison of different working fluids is presented and results shows that Benzene has thebest performance among fluids butane, n-pentane, is pentane, R123 and R245fa for thesystem conditions described.

Dimityr Popov [14] proposed a concept for innovative hybridization of gas turbine combinedcycle plant and solar power system. This conceptual plant is named as Solar AssistedCombined Cycle, as the solar energy is indirectly involved in power generation. Theproposed solar hybridization can be accomplished in two ways. The first solar assisted optionintroduces mechanical chillers for a complete cooling of gas turbine inlet air. The next solarassisted option does the same but with an absorption chiller. They find that the configurationwith absorption chillershas lower specific incremental plant capital costs and requiressmaller land area than the others.

Wang et al [15] analyzed a 1.6 kW solar ORC using a rolling piston expander. An overallefficiency of 4.2% was obtained with evacuated tube collectors and 3.2% with flat-platecollectors. The difference in terms of efficiency was explained by lower collector efficiency (71% for the evacuated tube vs. 55% for the plate technology) and lower collection temperature.

S. Quoilin et al [16] carried out thermodynamic modeling of a proposed small scale PTSCintegrated with an ORC for power production, considering different design options to belocated in a rural location in South Africa and presented an optimization and sizing procedureof heat exchangers in a small scale solar driven ORC by pinch and pressure drop andoptimized it by turbine input pressure and evaporator temperature. Then they further focusedon the evaluation of the thermodynamic performance of the system. With conservativehypotheses, and real expander efficiency curves, it was found that an overall electricalefficiency between 7% and 8% reached. This efficiency is steady-state efficiency at anominal working point. The comparison between working fluids showed that the most efficient fluid is Solkatherm. R245fa also shows a good efficiency and has the advantage ofrequiring much smaller equipment.

Maria E Madejar et al.[17] presents the quasi-steady state simulation of a regenerative organic Rankine cycle (ORC) integrated in a passenger vessel, over a standard round trip. He used experimental data like exhausts temperature, engine speed and electricity demand on board for simulation purpose and to estimate the average net power production of the ship over a round trip.

Finaly he conclude that The maximum net power production of the ORC during the round trip was estimated to supply approximately 22% of the total power demand on board. The results showed potential for ORC as a solution for the maritime transport sector to accomplish the new and more restrictive regulations on emissions, and to reduce the total fuel consumption.

Harrison Warren et al.[18] proposes enhancement of power generation unit-organic rankine cycle (ORC) system through the electric energy storage and proposes the use of an electric energy storage (EES) device in conjunction with a PGU-ORC. The idea is to use the energy stored by EES at different times of the day so that continuous operation of the PGU is not required. The potential of the proposed PGU-ORC-EES system is assessed by evaluating the performance in terms of operational cost, primary energy consumption (PEC) and concluded that the potential of a PGU-ORC-EES system to reduce the operational cost, CDE, and PEC compared with a conventional system. performance of simulations of a restaurant facility at 12 different geographical locations reflecting a variety of climate conditions. Results indicated that the addition of EES is beneficial to the PGU-ORC system for most locations in terms of the three evaluated parameters.

Ayad M. Al Jubori et al.[19]proposed Modeling and parametric analysis of small-scale axial and radial outflow turbines for Organic Rankine Cycle applications using a range of organic working fluids (R141b, R245fa, R365mfc, isobutene and n–pentane). And he conclude that the efficiency of axial small scale turbine is better than radial out flow turbine .axial turbine have efficiency 82.5% and power output 15.15kw.and on other hand the efficiency of radial outflow efficiency is 79.05% and power output is 13.625kw with n-pentane as the working fluid in both cases. The maximum cycle thermal efficiency was 11.74% and 10.25% for axial and radial-outflow turbine respectively with n-pentane as the working fluid and a heat source temperature of 87 ^{0}C

Jui-Ching Hsieh et la.[20]Design and preliminary results of a 20-kW transcritical organic Rankine cycle with a screw expander for low-grade waste heat recovery .nad they examine a trnscritical Rankine cycle with screw expander with R218 as the working fluid in both sub critical and super critical state of working fluid they used the low grade heat at 90^{o}C -100 ^{o}C. They used two centrifugal pumps in series .for control controlling the pressure used variable frequency drive (VFD). Finally they concluded the efficiency of the expander and the working fluid pump is peak at peak pressure. The output power was not significantly affected by heat sourcetemperature but thermal efficiencyslightlydecreed by increasing heat sourcetemperaturesThe present TRC system successfully converted the low-grade heat into approximately 20 kW of power. The thermal efficiency of the TRC system was 5.7%, 5.38%, and 5.28% for the heat source temperatures 90, 95, and 100^{o}C, respectively, with the VFD at 50 Hz.

Dong junqi et la.[21]proposed Experimental investigation on heat transfer characteristics of plat heat exchanger applied in organic Rankine cycle (ORC) .and experimentally study the single phase and boiling heat transfercharacteristics' of three types of working fluids on plate types of heat exchangers surface. These three working fluid are water and 50%coolant and R 245fa.and heat transfer dimensionless empiricalequations for three types of working fluids are provided. Finally he obtained evaporation heat transferempiricalequation for the organic fluid R245fa is given with the meanabsolute error9.97%which prevents 90% data with error less than ±20%.

Ayad Al Jubori et la [22] proposed Three dimensional optimization of small-scale axial turbine for low temperature heat source driven organic Rankine cycle Advances in optimization techniques can be used to enhance the performance of turbines in various applications. However, limited work has been reported on using such optimization techniques to develop small-scale turbines for organic Rankine cycles. This paper investigates the use of multi-objective genetic algorithm to optimize the stage geometry of a small-axial subsonic turbine. And he concluded that using working fluid R123 for a turbine with mean diameter of 70 mm, the maximum isentropic efficiency was about 88% and power output of 6.3 kW leading to cycle thermal efficiency of 10.5% showing an enhancement of 14.08% compared to the baseline design. Such results highlight the potential of the 3D optimization technique to improve the organic Rankine cycle performance.

Constantine N. Michos et al[23]proposed the backpressure effect of an Organic Rankine Cycle (ORC) evaporator on the exhaust line of a turbocharged, V12 heavy duty diesel engine, for typical marine and power generation applications has been investigated using the commercial software Ricardo WAVE. Three different state-of-the art turbo charging strategies are assessed in order to counterbalance the increased pumping losses of the engine due to the boiler installation: fixed turbine, Waste-Gate (WG) and Variable Geometry Turbine (VGT). At the same time, the And he concluded that engine side point of view, a VGT turbocharger is the most favorable solution to withstand increased backpressure, while, regarding the ORC side, between the considered fluids and layouts, acetone and a recuperated cycle show the most promising performance.

Wen Su, Li Zhao et al.[24] developed a performance evaluation model of Organic Rankine Cycle for working fluids based on the group contribution method An Organic Rankine Cycle (ORC) model is presented in his paper to easily, quickly, and inexpensively evaluate the performance potentials of various working fluids. When given molecular structure of working fluid, the normal boiling temperature, critical properties, liquid density and ideal gas heat capacity can be obtained via the existing group contribution methods (GCMs). Other properties required in the ORC model are calculated out by the thermodynamic relationships with the estimated properties of GCMs. Based on the calculated properties, four basic processes of the ORC including compression, evaporation, expansion and condensation are modeled. the cycle parameters of 21 potential working fluids for typical ORC operating conditions are obtained from the molecular structures by the developed model. He compared with the REFPROP, the model shows sufficient accuracy for engineering purposes. The relative errors of thermodynamic properties and cycle parameters are less than 10% for most of working fluids. He concluded that the proposed model can estimate the ORC characteristics of any pure working fluid only based on its molecular structure. Thus, a large amount of working fluids formed by the combination of groups can be directly screened by this model, and the optimal working fluids can be identified for engineering field.

Pedro J .Mago et al.[25] evaluates the potential carbon dioxide emissions reduction from the implementation of electric energy storage to a combined power generation unit and an organic Rankine cycle relative to a conventional system that uses utility gas for heating and utility electricity for electricity needs. Conclusion indicate that carbon dioxide emission reductions from the operation of the proposed system are directly correlated to the ratio of the carbon dioxide emission conversion factor for electricity to that of the fuel. The location where the system is installed also has a strong influence on the potential of the proposed system to save carbon dioxide emissions. Finally, it is shown that by using carbon emissions cap and trade programs, it is possible to establish a frame of reference to compare operational cost gains with carbon dioxide emission reductions/gains.

In Seop Kim et al.[26] developed an off-design analysis model for the ORC which is driven by waste heat or residual heat from a combined cycle cogeneration plant. The applied heat sources are the exhaust gas from the heat recovery steam generator (Case 1) and waste heat from a heat storage unit (Case 2). Optimal design points of the ORC were selected based on the design heat source condition of each case. Then, the available ORC power output for each case was predicted using actual long-term plant operation data and a validated off-design analysis model. The ORC capacity of Case 2 was almost two times larger than that of Case 1. The predicted average electricity generation of both cases was less than the design output. And he made conclusion from this research is that an off-design analysis model was set up and operating data were applied to produce practical predictions of the ORC output. It is important to secure a tool for practical analysis to apply the ORC to an existing plant. The analysis method could be used to choose the most economical design conditions, including the optimal sizing of the ORC through an iterative thermo-economic procedure involving both design and anal off –design analysis.

Kiyarash Rahbar et al.[27] reviewed only organic Rankine cycle for small scale application .study literature review .Finally find that organic Rankine cycle technology is applicable for small scale experiment.

Wenqiang Sun et al.[28] proposed exergy efficiency analysis of ORC (Organic Rankine Cycle) and ORC based combined cycles driven by low temperature. and did that the ORC system driven by industrial low-temperature waste heat was analyzed and optimized. The impacts of the operational parameters, including evaporation temperature, condensation temperature, and degree of superheat, on the thermodynamic performances of ORC system were conducted, with R113 used as the working fluid. In addition, the ORC-based cycles, combined with the Absorption Refrigeration Cycle (ARC) and the Ejector Refrigeration Cycle (ERC), were investigated to recover waste heat from low temperature flue gas. Finally concluded that The exergy efficiency of both systems decreases with the increase of the evaporation temperature of the ORC. The net power output, the refrigerating capacity and the resultant exergy efficiency of the uncoupled ORC-ARC are all higher than those of the ORC-ERC for the evaporation temperature of the basic ORC >153^{0}C, in the investigated application. Finally, suitable application conditions over other temperature ranges .

Yue Cao et al.[29] done Comparative analysis on off-design performance of a gas turbine and ORC combined cycle under different operation approaches having different input variable and results are obtained by using the modified sliding pressure operation (MSPO). He concluded that the sliding pressure operation had an optimal sliding condition to make the GT-ORC combined cycle have the best off-design performance. This condition was a fixed superheat degree of 0.1 K for organic vapor, and the operation approach under such condition was named modified sliding pressure operation (MSPO). Simulation results showed the MSPO performed better than the constant pressure operation and bivariate operation under off-design conditions. Therefore, the MSPO might be more suitable for the off-design operation of the GT-ORC combined cycle. Finally, the sensitivity analysis indicated that the MSPO was more favorable for the GT-ORC combined cycle to reduce the influence of ambient temperature.

Weicong Xu et al.[30] proposed the Novel experimental research on the compression process in organic Rankine cycle (ORC).and made A small-scale ORC system is built in the present work to test the performance of a diaphragm pump, and the working fluids of R245fa, R123, R152a and R600a are tested under various conditions. The isentropic efficiencies of diaphragm pump for compressing those working fluids are between 57.22% and 93.51%.Concluded that the Circulating pump is the major power-consuming component in ORC system, but only very few studies are made to study its performance. A small-scale ORC test rig is built in the present paper and one type of diaphragm pump is installed in the system. The working fluids of R245fa, R123, R152a and R600a are used to test the performance of diaphragm pump, and the isentropic efficiencies for compressing different working fluids under various conditions are obtained.

Tao Chen et al.[31] proposed a novel cascade organic Rankine cycle (ORC) system for waste heat recovery of truck diesel engines. confluent cascade expansion ORC (CCE-ORC) system for engine waste heat recovery, which has simpler architecture, a smaller volume and higher efficiency compared with conventional dual-loop ORC systems. Cyclopentane is analyzed to be regarded as the most suitable working fluid for this novel system. A thermodynamic simulation method is established for this system, and off-design performance of main components and the working fluid side pressure drop in the condenser have been taken into consideration. System performance simulations under full engine operating conditions are conducted for the application of this system on a heavy-duty truck diesel engine. He concluded that the there is system proposed for using waste heat from the truck diesel a engine in single loop .this system used only the single working fluid. Working fluid is used is cyclopentane. and it increased thermal efficiency to some extent 45.3% to 49.5%.at minimum specific fuel consumption.

Xianglong Luo at al.[32] developed a mathematical model for designing of liquid surface condenser for organic Rankine cycle. He collected different variables for designing purpose and the modeling equations contains both type of variables decreat and continuous variables .continuous variables contains the length of condensor,pressure drop, fluid velocity ,air velocity ,heat transfer cofficient,outlet temperature. And the descreat variables are type selection of finned-tubes, number of passes, number of tubes per pass, fin number per unit tube length.this model is called non-convex mixed integer non-linear programming (MINLP) model. Finally he concluded that this proposed mathematical model is suitable for low temperature heat sources organic Rankine cycle. and successfully applied for design optimization for liquid surface condenser (LSC).

Angad Singh Panesar et al.[33] proposed An innovative Organic Rankine Cycle system for integrated cooling and heat recovery to recover exhaust heat and coolant haet a cascade system is employed. This system has two fluid that one of them is the water and second one is R245fa and combine cycle is used for improvement break thermal efficiency almost 1.8%. After doing that research work he concluded that the use of exhaust and coolant heat to be most beneficial across the all engine works .its uses one different amount of heat second one is differ quality of heat it compete the single loop ORC system.

Dan Wu et la.[34] proposed optimization and financial analysis of an organic Rankine cycle cooling system driven by facade integrated solar collectors. and used three combined system for better utlizatation solar energy for cooling purpose. These three system used are façade integrated evacuated tube collector (ETC)-organic Rankine cycle (ORC)-vapour compression cycle (VCC).He concluded that façade integrated ETC-ORC-VCC system for a typical office building in a tropical climate was optimized to maximize the electricity savings from the ORC separately. In the financial point of view depends on heat exchanger area but when applied more no. plate it increases the overall cost.

Dong Kyu Kim et al.[35] developed a model of Parametric study and performance evaluation of an organic Rankine cycle (ORC) system using low-grade heat temperatures below 80 ^{o}C. In this model they uses the low grade heat source at 80 ^{o}C with cycle power at 10kw undertaken to analyze the performance and efficiency .it uses the R245fa as working fluid for system. Finally he concluded that small scale low grade heat source system efficiency is increased by increasing the heat source temprature and system able to generate 300kw power and 3.6% efficiency. using a heat source at 80%.

D. Ziviani et al.[36] Optimizes the performance of small-scale organic Rankine cycle that utilizes a single-screw expander. with this model they used the three off shelf component a liquid reciever,three plate heat exchanger a multi-stage centrifugal pump and a single-screw compressor adapted to operate as an expander and ORC system is used the 11kw power. They two working fluids first one is R245fa and other one is SES36. He concluded that in the case of SES36 both the expander efficiency and system performance were maximized for a pressure ratio between 7 and 9. In the case of R245fa, while the system efficiency achieved values similar to SES36 but the expander maximum isentropic efficiency was 17% lower.

Jian Li et al.[37] proposed Performance analysis of organic Rankine cycles using R600/R601a mixtures with liquid-separated condensation. He used working fluid as azotrops R600/R601a .and he used liquid separated condenser method this method is the process to separate the condensed from two phase flow during condensation, and is this method the use of les heat transfer condenser area by reducing the pressure drop and by increasing the condensation heat transfer area by using azotrops R600/R600a. Finally concluded that The liquid-separated condensation can increase the average condensation heat transfer coefficient by 23.8% and reduce the condenser heat transfer area by 44.1% compared to the conventional condensation.

Jian Song et al.[38] proposed the Performance estimation of Tesla turbine applied in small scale Organic Rankine Cycle (ORC) system the performance of tesla turbine is evaluated with help of different operating conditions and operating parameters .and the model is used to predict the efficiency of tesla turbine for use of small scale organic Rankine cycle. Thermodynamic analysis of the ORC system with different organic working fluids and under various operating conditions is conducted. Finally he concluded that the tesla turbine is effective for small scale organic Rankine cycle because ORC system generate effective power output.

Bensi Dong et al.[39] analyzed the supercritical organic Rankine cycle and the Radial Turbine design for high temperature applications. Thermodynamic design of the supercritical organic Rankine cycle (SORC) and the aerodynamic design of its radial turbine for high temperature applications. The siloxane MM with high comprehensive properties is chosen as the working fluid. The performance of the supercritical organic Rankine cycle with MM of different inlet conditions is analyzed. And he concluded that The total to static efficiency of the SORC radial turbine is 80.84% at the nominal condition with the pressure ratio of 6.86 and the rotational speed of 23,000 rpm. The proposed radial turbine could effectively handle a relatively large variation of the pressure ratio with slight performance degradation at the nominal rotational speed.

Kaiyong Hu, Jialing Zhu et al.[40].proposed Effects of evaporator superheat on system operation stability of an organic Rankine cycle. He analyzed the effect of evaporator super heat with R245fa as working fluid. The experimental apparatus used in this research is an installed 500W ORC system integrated with a plate evaporator and a shell-and-tube evaporator in parallel results that the super heat at evaporator’s outlet is main parameter for system performance and stability of the system. the relationship of the vapor dryness, the entrainment quality fraction, and the superheat was analyzed. It is suggested that installing a vapor liquid separator or maintaining a relatively high superheat could be an effective way to avoid the liquid entrainment and hence to have a better operation stability.

Abid Ustaoglu et al.[41] In this study, the energetic and exergetic performance analysis of a rotary kiln and cooling section in a cement factory using wet method was carried out based on the actual operational data. The energy and 2nd law efficiencies of the wet type rotary kiln are about 46% and 35%, respectively. The results showed that a great amount of heat energy of 30.5MW is exhausted from the chimney of rotary kiln. In order to evaluate recovery capacity of exhausted gas, Organic Rankine Cycle was considered and its energetic and exergetic performance were evaluated for isentropic and dry type fluids for different conditions. Isentropic fluid. He concluded that the R245a gives better performance than other dry fluid R600a. The exergy destruction rates in heat exchanger and evaporator are about 80% of the total exergy destruction

Y.Z. Wang et al.[42] Multi-objective optimization and grey relational analysis on configurations of organic Rankine cycle Concerning the comprehensive performance of organic Rankine cycle (ORC), comparisons and optimizations on 3 different configurations of ORC (basic, regenerative and extractive ORCs) are investigated and different operating conditions are used as input parameter. He concluded that best organic Rankine cycle performs well another than three system in terms of thermodynamic and economic performance using R245fa as working fluid.

Zhonglu He et al.[43] proposed the Thermodynamic analysis of a low temperature organic Rankine cycle power plant operating at off-design conditions. He used the screw expander and simulation is ny different working fluids This work was purposed to assess the ORC system and get the performance map at off-design operating conditions in a typical year from the view of the first and the second law of thermodynamics. The maximum electricity production and thermal efficiency were 46.5 kW and 6.52% respectively at the optimal operating condition.onther hand the exergy analysis shows that condenser and evaporator pressure are main parameter which affect exergy efficiency. He concluded that Exergy destruction in expander contributes the more percentage of the exergy loss. Evaporation pressure affects the exergy flow significantly and condensation pressures play important roles in determining the exergetic efficiency. The largest exergetic efficiency reached is 36.2% at pressure ratio around 3.32.

Shih-Cheng Yang et al.[44] proposed the Experimental investigation on a 3 kW organic Rankine cycle for low grade waste heat under different operation parameters. In this 3kw organic Rankine cycle is used having R245fa as working fluid. and the expander is used is the hermetic type. The effects of pressure drop, degree of superheating and condenser temperature on system overall performance are examined. He concluded that pressure drop is have high impact system efficiency power output. Pressure drop in condenser have more impact on electrical power and the thermal efficiency of ORC system.

2.2 CONCLUSION AND GAP

By incorporation of solar energy in organic Rankine cycle plant the output of plant can be increased. From literature survey of solar integrated ORC plant, it is found that detailed energy and exergy analysis of Organic Rankine cycle plant and regeneration with single working fluid are done earlier. From literature survey it is found that energy and exergy analysis of solar operated organic Rankine cycle with regeneration and selection of working fluid are not done yet. Solar energy is used as heating source for the heating of working fluid in the evaporator.

2.3 PROBLEM FORMULATION

In the present study thermodynamic analysis of Organic Rankine cycle plant with solar reheating source is investigated and comparison of various organic fluids is carried out to find best organic fluid which will give maximum efficiency. It is proposed to examine the effect of following parameters on the efficiency of organic Rankine cycle with solar heated plant and selection of better organic fluid for global warming and ozone depletion.

- Effect of using regeneration in system on efficiency and exergy destruction.
- Effect of Organic turbine inlet temperature.
- Effect of Organic turbine inlet pressure.

- Effect of various organic fluids.
- And find maximum exergy destruction component.
- Effect of varying solar collector plate area.

CHAPTER 3

SYSTEM DESCRIPTION

For thermodynamics (energy and exergy) analysis of organic Rankine cycle with the regeneration and solar heating source is considered .which is given in figure.In this figure there are six component which are given as

- An organic expander
- A condenser
- Two pumps
- An evaporator
- Heater

All stages are defined by the numbers at stage 1 the organic fluid which in vapor forms goes to the organic expander where it is expanded and gives the work W_{ex} After expansion the organic fluids goes to condenser for rejection of the heat from the remaining organic vapor at stage 2 and heat Qr heat is rejected. After rejection of heat it goes to pump 1 giving work of Wc_1 where it is brought to the heater pressure or intermediate pressure where some part of vapor is extracted for heating purpose for the organic liquid. The organic vapor is extracted from the expander at the stage 5.and it is mixes in the heater .after mixing and getting heat, it goes to the pump 2 at the stage of 6and pump-2 increases the pressure to the evaporator pressure at the stage of 7 and Wc2 work is done the stage of 7 saturated fluid goes to the evaporator where heat is taken by the liquid working fluid is heated by solar heating constant temperature heat source .Qs heat is supplied to the working fluid and then cycle is repeated.

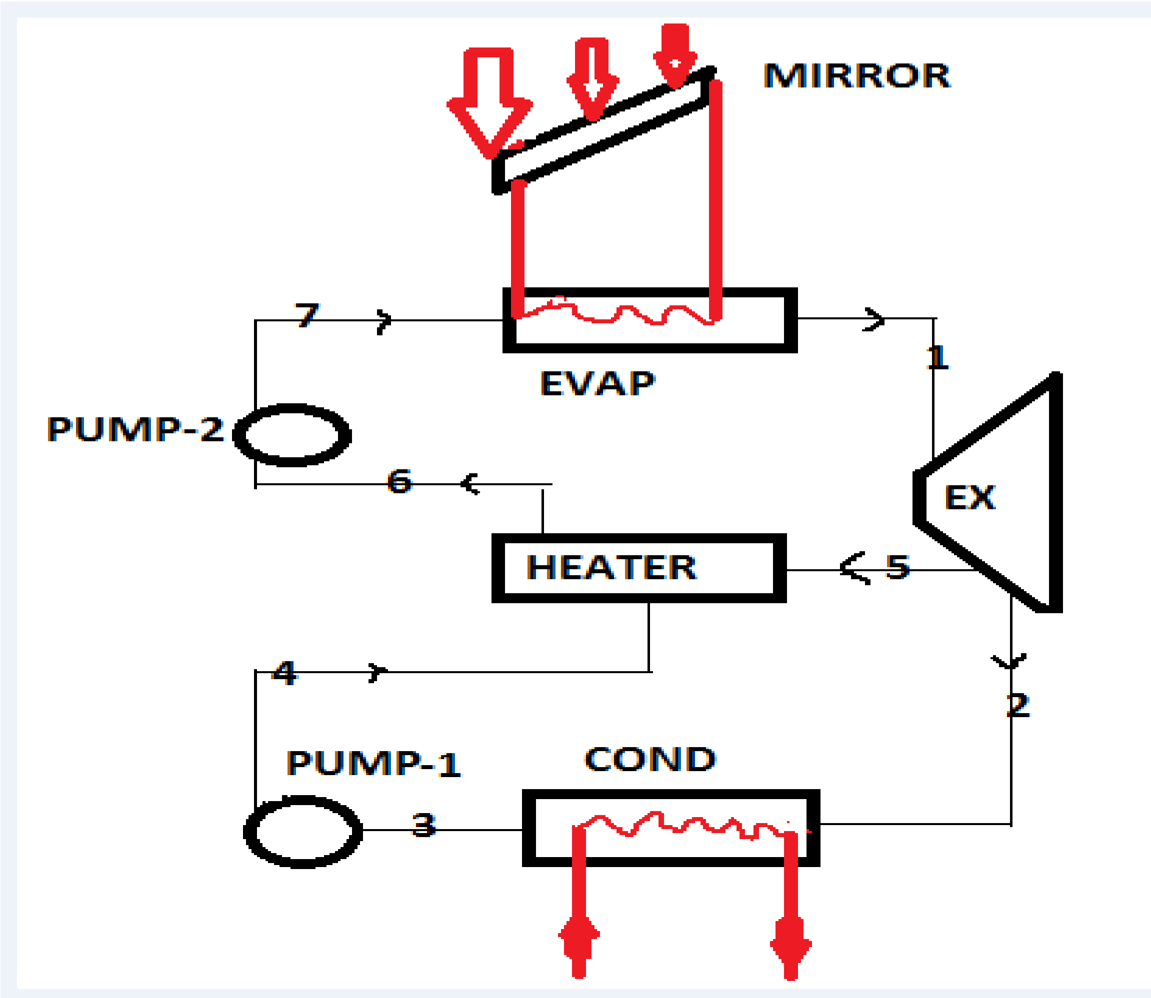


Fig 3: model for organic Rankine cycle with regeneration

CHAPTER 4

THERMODYNAMIC ANALYSIS

In this present work, a parametric study with various temperature and pressure at organic expander inlet has been considered to determine efficiency and performance of organic fluids in system. The following assumptions are there to simplify the analysis, also taking energy analysis.

1. Assumed all the components are steady-state process and steady flow.

2. The change in the kinetic energy and the potential energy are assumed to be negligible.

3. There are negligible heat and pressure loss in pipes that are connecting all the components to each other.

4. Expander and pumps work adiabatically.

5. Pressure drops in feed heater and condenser are neglected.

6. It is assumed the vapor after expansion is saturated.

7. Liquid after pump 1 is saturated.

8. No pressure loss in evaporator.

9. Constant heat source and 100 %is solar collector efficiency.

4.1 ENERGY ANALYSIS

Based on assumptions, the equations for mass balance and energy are written for each component. Each component in a solar heated source organic Rankine cycle plant is shown in Fig.3 considered as control volume.

Mass Balance

$\sum m_{in} = \sum m_{out}$

Energy Balance

$Q - W + \sum m_{in} - \sum m_{out} = 0$

4.1.1 Energy changes in the each component of organic Rankine cycle with regeneration cycle plant:-

Organic Rankine expander: organic expander is a work obtaining device in which organic fluid is expanded from evaporator pressure to condenser pressure adiabatically. The isentropicwork output of expander.

$W_{EX} = m_f * (h_1 - h_{2s})$

Organic expander efficiency given as,

$\eta_{EX} = (h_1 - h_2)/(h_1 - h_{2s})$

Actual organic turbine work is

$W_{EX} = (h_1 - h_2)$

Condenser: Condenser is a heat exchanger in which heat is rejected to environment isgiven by

$Qcond = (m_f - m_x) * (h_2 - h_3)$

Organic pump 1: organic pump is used for increasing pressure of organic fluid from condenser pressure to boiler pressure. Ideal work of organic pump

$W_{OPi} = (m_f - m_x) * v_3 * (P_5 - P_2)$

Organic pump efficiency as,

$\eta_{OP} = W_{OPi} / W_{OP}$

Actual organic pump work is given by

$W_{OP1} = m_f * v_3 * (P_5 - P_2)/\eta_{OP}$

Organic pump 2: organic pump is used for increasing pressure of organic fluid from condenser pressure to boiler pressure. Ideal work of organic pump given as

$W_{OPi} = m_f * v_6 * (P_1 - P_5)$

Organic pump efficiency as,

$\dot{\eta}_{OP} = W_{OPi/}\ W_{OP}$

Actual organic pump work is given by

$W_{OP2} = m_f * v_6 * (P_1 - P_5)/\dot{\eta}_{OP}$

Feed heater: feed water heater is the device in which the vapor is extracted from the turbine and mixes with liquid and heat is transferred from vapor to the liquid. And feed liquid is heated.

Energy balance in feed heater is given as

$m_f * h_6 = (m_f - m_x) * h_4 + m_x * h_5$

Evaporator: evaporator is a device in the organic fluid is heated by solar collectors heater and working fluid is converted in to the vapor this vapor goes to the expander.

Heat is given by evaporator per unit mass as

$q_s = h_7 - h_1$

Total heat supplied to the working fluid from solar energy collector

$Q_s = I_s * A_s$

Mass flow rate is calculated as

$m_f = Q_s/q_s$

Efficiency of Organic Rankine cycle: it is the ratio of the net work output of ORC and total heat supplied in ORC

$\dot{\eta}_{ORC} = (W_{OT} - W_{OP1} - W_{OP2})/\ Q_S$

4.2 EXERGY ANALYSIS

Exergy loss or destruction is given by

$$\dot{E}D_i = \sum(\dot{m}e)_{in} - \sum(\dot{m}e)_{out} + \left[\sum\left(\dot{Q}(1-\frac{T_O}{T})\right)_{in} + \sum\left(\dot{Q}(1-\frac{T_O}{T})\right)_{out}\right] \pm \sum \dot{W}$$

4.2.1 Exergy analysis of the each component of the organic Rankine cycle plant with regeneration-

Exergy destruction in organic expander given as

$ED_{EX}= m_f*[(h_2- h_1)-T_0*(s_2 - s_1)]+m_{x*}[(h_5- h_2)-T_0*(s_5- s_2)]-W_{EX}$

Exergy destruction in condenser given as

$ED_{cond}=(m_f- m_x)*[T_0*(s3-s2)+q_r*T_0/T_c]$

Exergy destruction in pump given as

$EDpump1=(m_f- m_x)*T_0*(s_4-s_3)$

Exergy destruction in pump 2 given as

$EDpump\ 2=m_f*T_0*(s_7-s_6)$

Exergy destruction in thefeed heater given as

$ED_{HE}=m_x*Ex_5+(m_f- m_x)*Ex_4-m_f*Ex_6$

Exergy destruction in the evaporator given as

$ED_{EVAP}=m_f*[T_0*(s1-s7)-qs*T_0/T_H]$

Exergy transfer from evaporator given as

$ET_{EVAP}=Qs*(1-T0/T_H)$

Second law efficiency of ORC plant given as

$\dot{\eta}_{second}=(W_{EX}-W_{pump1}-W_{pump2})/ET_{EVAP}$

Exergy destruction ratio given as

$EDR=(ED_{EX}+ED_{cond}+ED_{pump1}+ED_{pump2}+ED_{HE}+ED_{EVAP})/ET_{EVAP}$

4.3 Input Parameters:

The input parameters taken for computation of results are given below:

Organic expander inlet pressure	P_1= 4000kPa
Organic expander inlet temperature	T_1= 100˚C
Isentropic efficiency of organic expander	η_{EX}= 0.80
Condenser fixed temperature	Tc= 35^0 C
Isentropic efficiency of both pumps	η_{pump}= 0.60
Intermediate or bled off pressure	P_5= 1000kPa
Organic expanderinlet pressure	P_1=2500 to 4500kPa
Organic expander outlet pressure	P_2=500 kPa
Solar irradiation on CSP collector	I_S= 700 W/m^2
Condenser Temperature	Tc = 35˚C
Constant heat source temperature	T_H=127^0C
Dead State Temperature	To= 25^0C
Organic fluid used	R404A,R410A,R407C and R134a

CHAPTER 5

RESULTS AND DISCUSSION

A computational model is developed by using Engineering Equation Solver (Klein andAlvarado, 2005) for evaluating exergy and energy analysis of organic Rankine cycle plant with solar heating source and regeneration from vapor bled of. The input data for evaluation are mentioned in chapter 4 The parameter, whose effect is discussed in particular plot and it varied.

5.1 Comparisons of different working fluids with regeneration and solar heating source:-

Figure 4 to 6 shows comparison of the efficiency against the organic turbine inlet pressure and temperature. From the figures it is obvious that the efficiency of organic Rankine cycle increases with regeneration. By using the regeneration heat supplied to the organic cycle plant decreases hence the rate of evaporation increase which results output increases and hence the organic Rankine cycle efficiency increases.

5.2 Comparison of the various organic fluids:

Figure 4 to 6 shows variation of efficiencies of the system at organic turbine inlet pressure, temperature, mass of vapor extracted, and the comparison fluids also done to the maximum work done by the expander. Among all organic fluid R410A shows maximum efficiency of the organic Rankine cycle which is about 16.51% and R134a, R407C, R410A and R404A have organic Rankine cycle efficiency of 12.37%, 15.75%, 16.51.% and15.34% respectively at 4000kPa maximum pressure and at temperature 200˚C of ORC fluid. and mass of fluid extracted at intermediate pressure also plotted in figure with respect to the inlet temperature of organic expander.

5.3 Exergy efficiency:

Variation of the Exergy efficiency of various organic fluids withmaximum pressure and maximum temperature,of organic cycle is shown in figure 7 to 9. It is seen that exergy efficiency of the organic Rankine cycle increases with maximum pressure and maximum temperature.

5.4 Exergy destruction ratio:

Exergy destruction ratio is plotted with respect to the inlet temperature and pressure of expander and what was the effect on cycle founded.it is shown in fig10 and 11.

5.5 Expander output: Expander output with respect to the temperature and pressure inlet of the expander is plotted in figures 12 and 13.

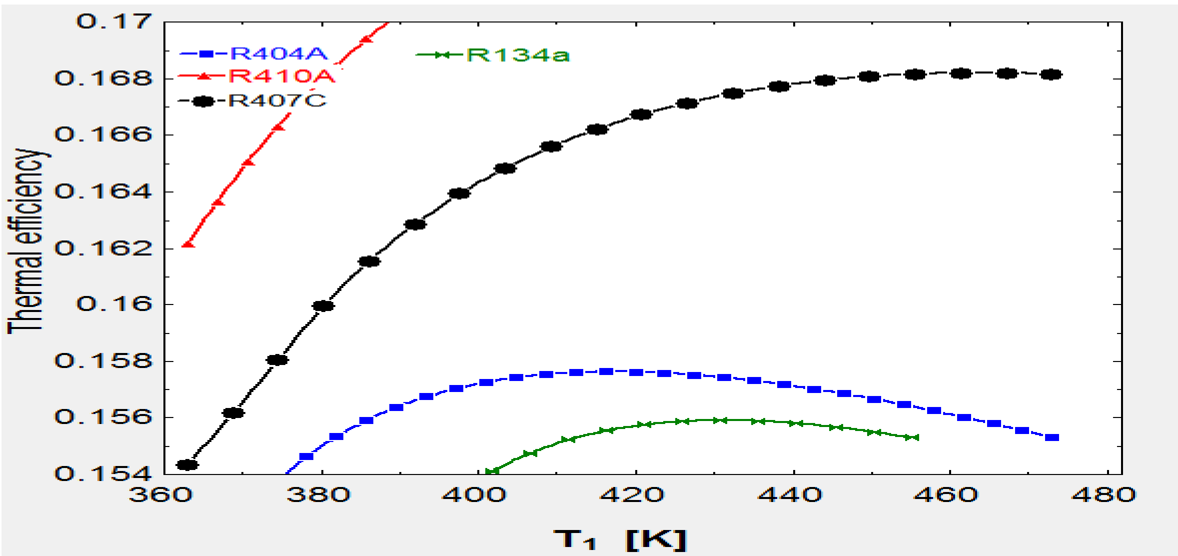


Fig 4; variation of thermal efficiency of organic rankine cycle with expander inlet tempreture.

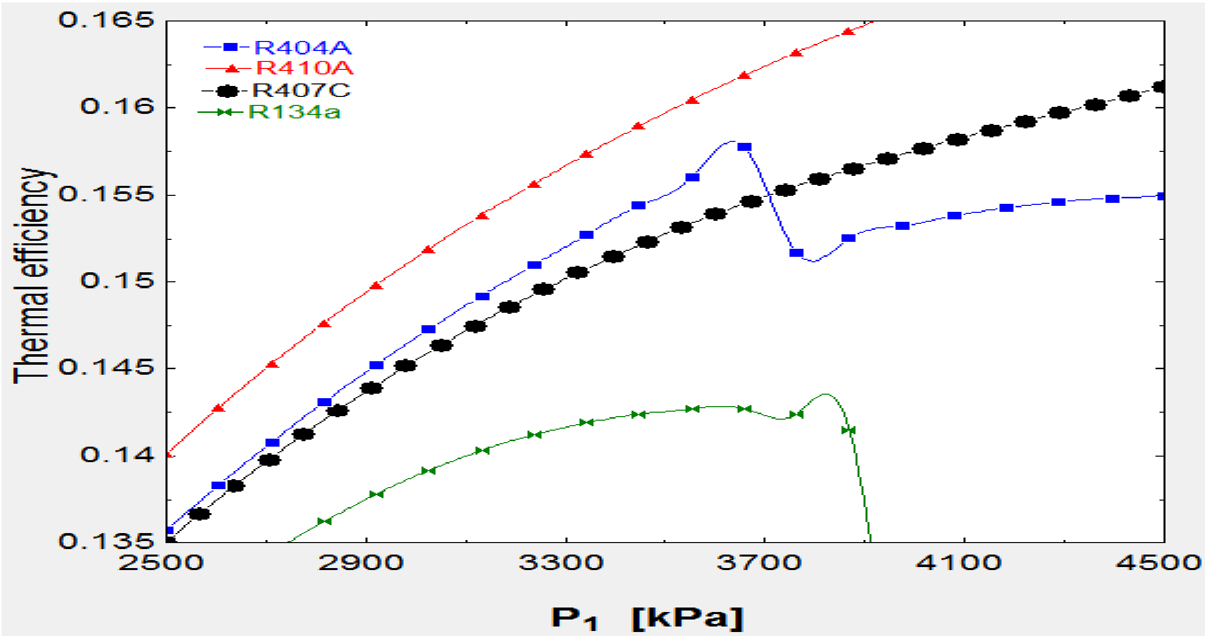


Fig 5:variation thermal efficiency of organic rankine cycle with turbine inlet pressure

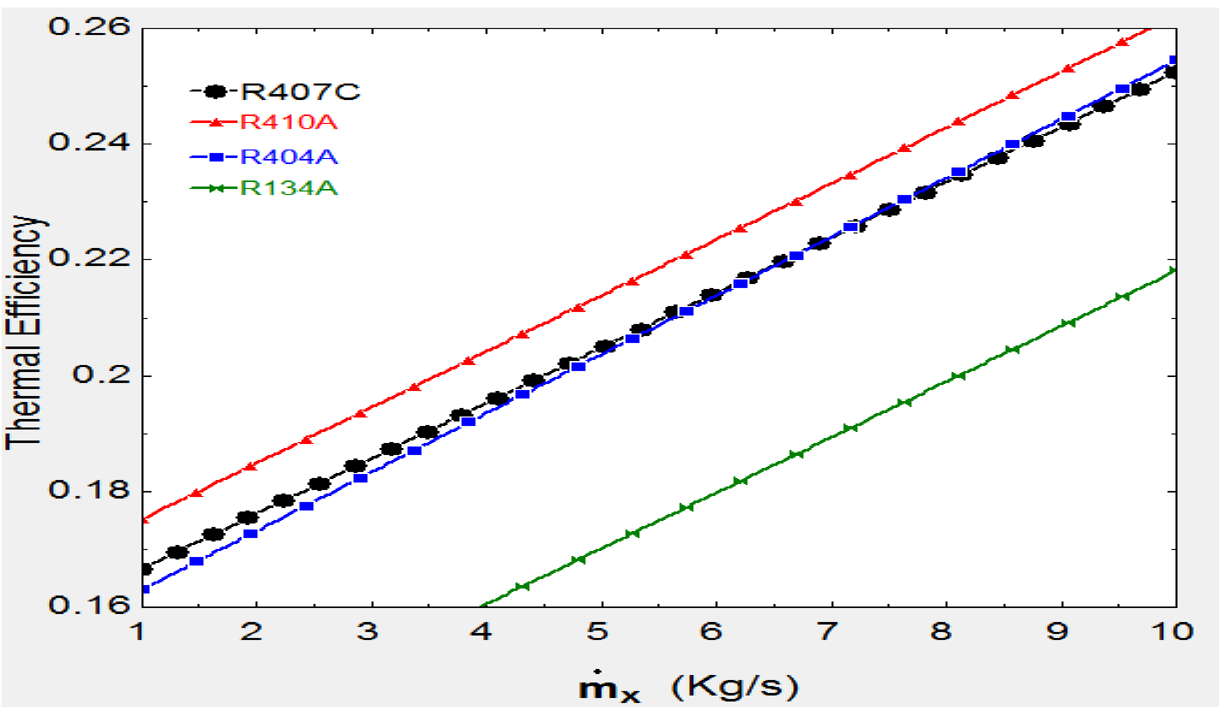


Fig 6: variation of thermal efficiency with extraction mass from expander

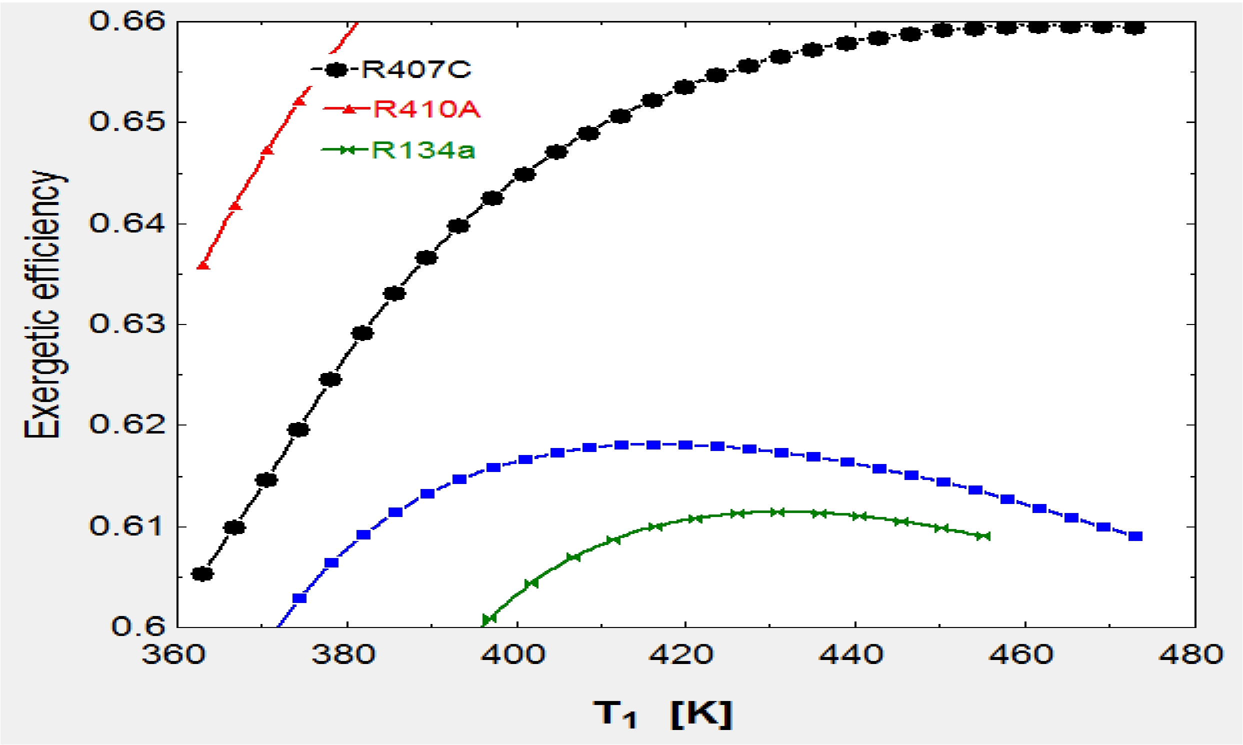


Fig 7: variation of exergetic efficiency with inlet temperature of expander

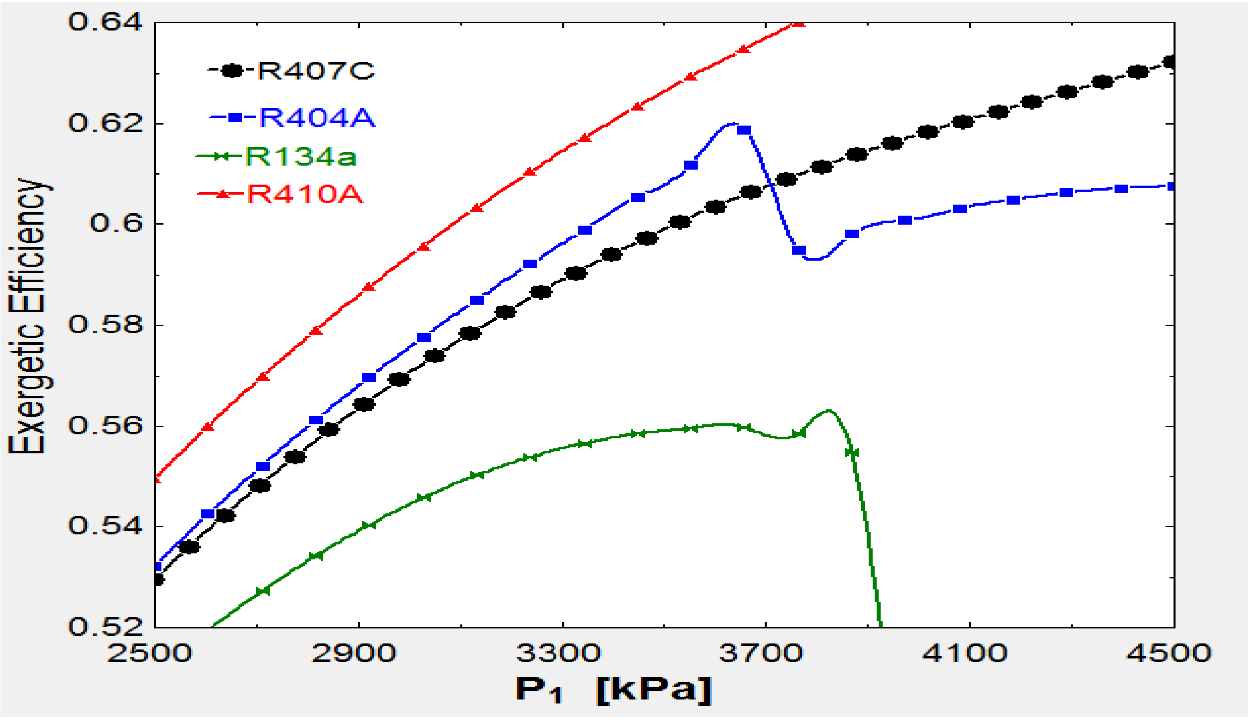


fig 8: Variation of exergetic efficiency with the inlet pressure of expander.

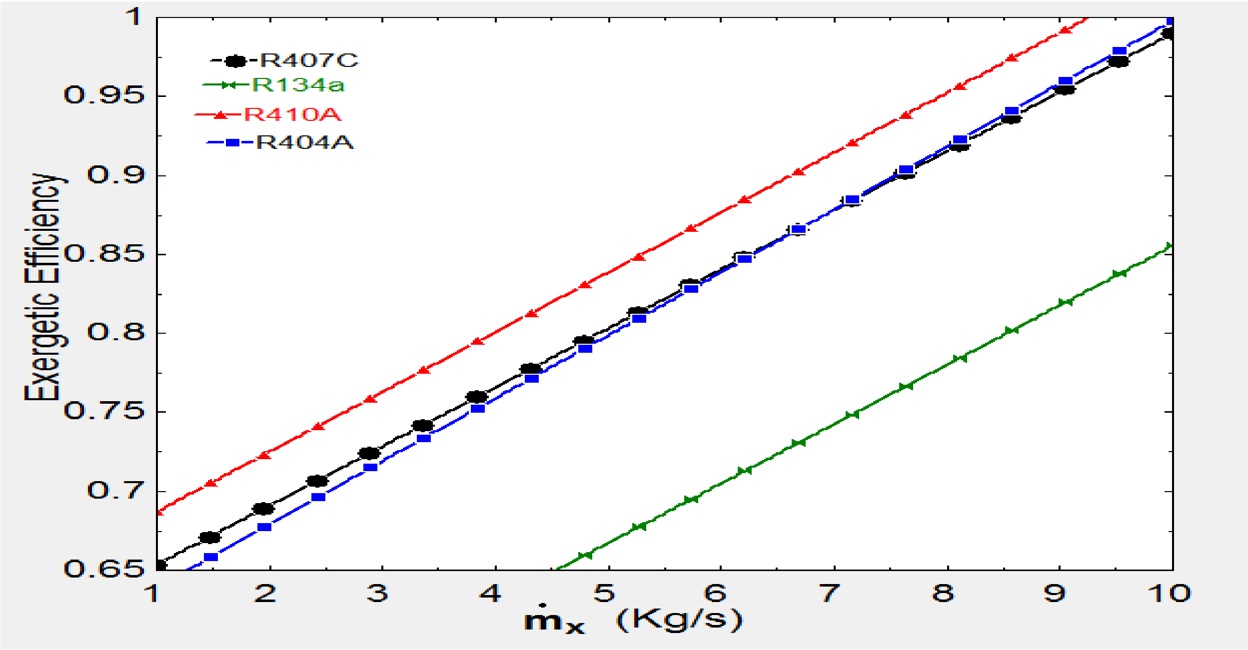


Fig 9: variation of exergetic efficiency with mass extracted from expander

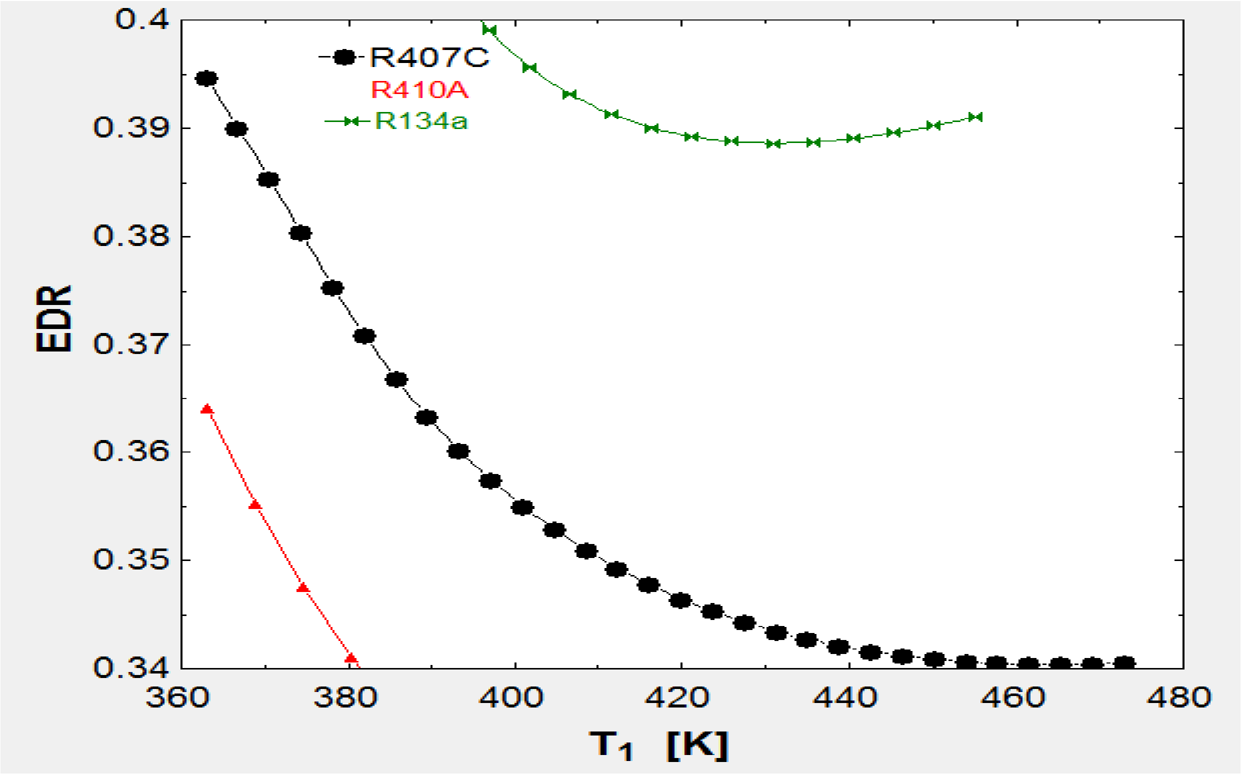


Fig 10: variation of EDR with the inlet temperature of expander

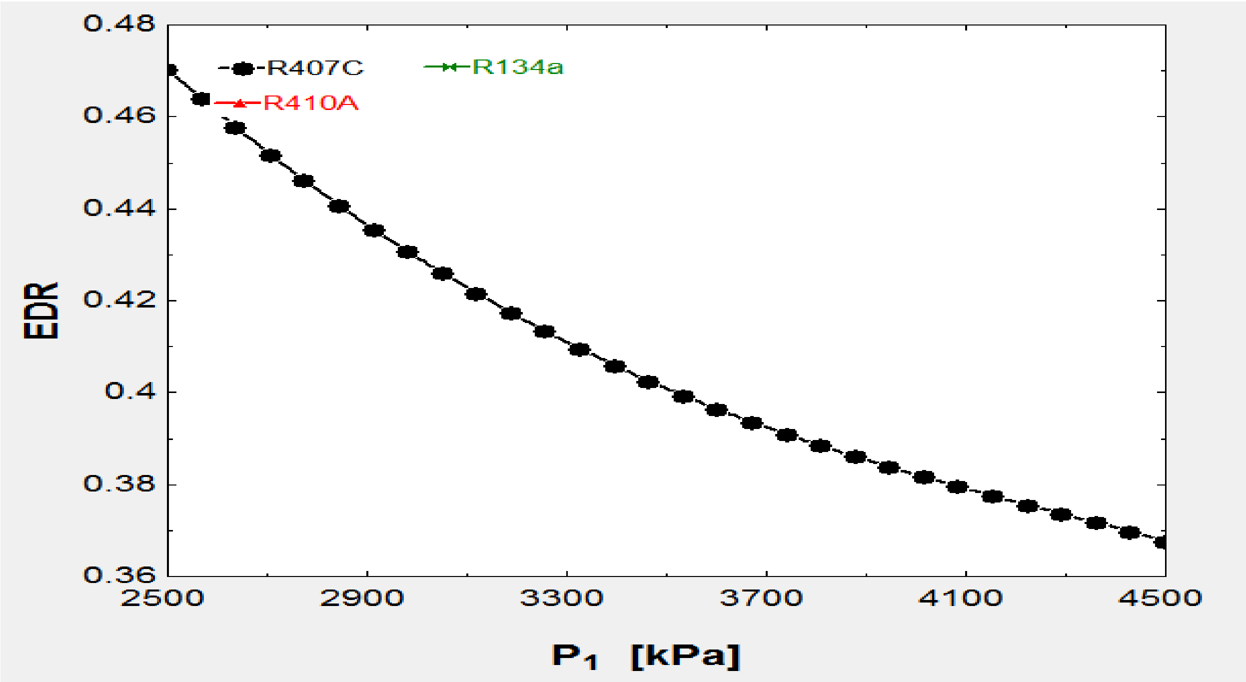


Fig 11: variation of EDR with the inlet pressure of expander

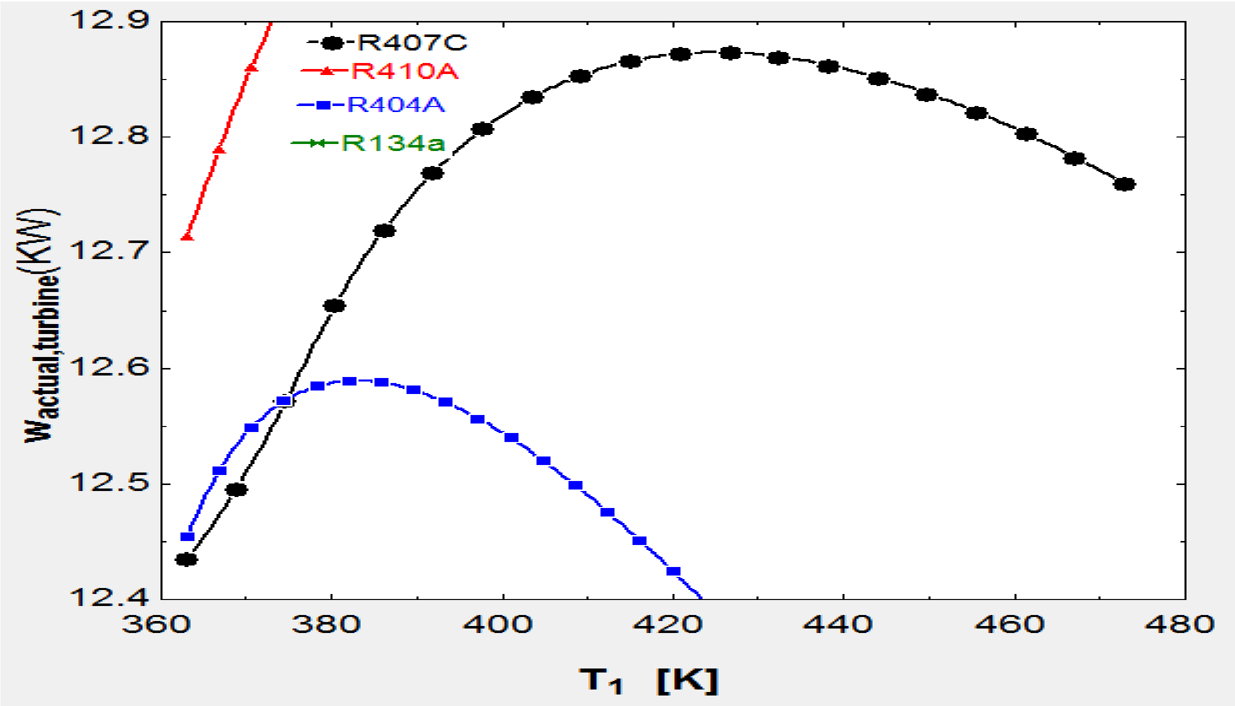


Fig 12:variation of turbine work output with the inlet tempreture of the expander

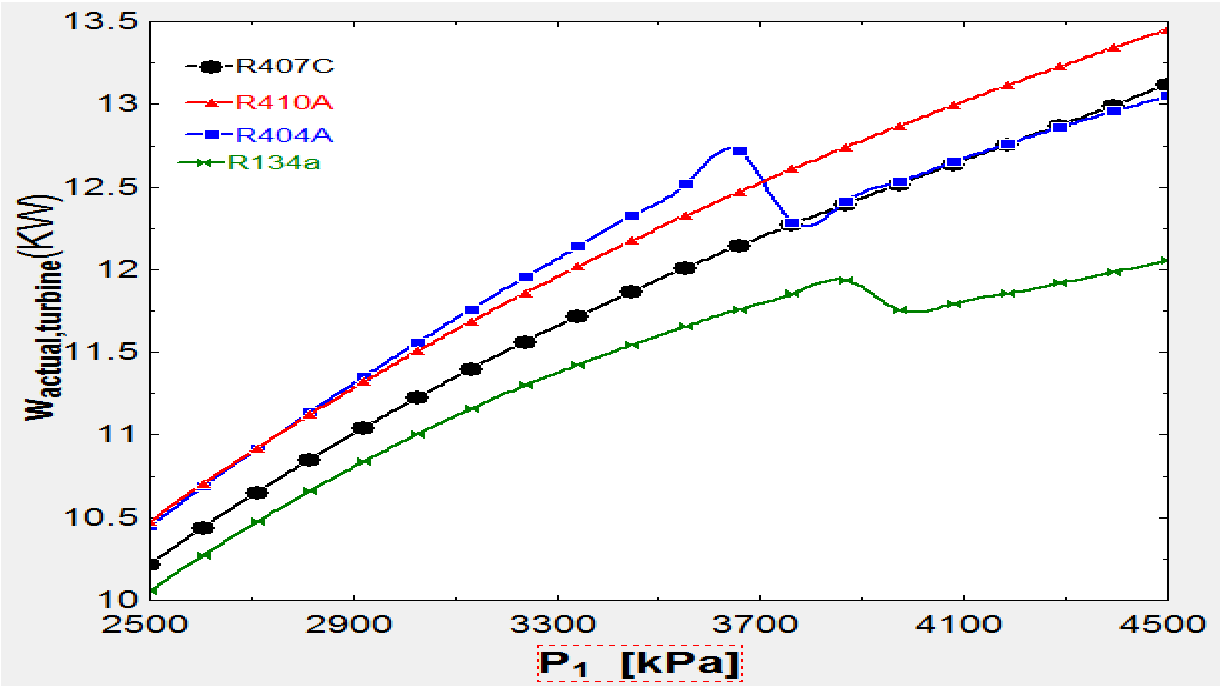


Fig 13: variation work output of expander with the inlet pressure of expander

CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS

In this thesis an extensive first law (energy) and second law (Energy) analysis of R134a, R407C, R410A, and R404A Organic fluids in cycle with regeneration is presented. Conclusions of this analysis are summarized as follows:

1. R410Ahave higher first law efficiency and Exergetic efficiency (second law efficiency)in Organic Rankine Cycle.
2. From solar heating source there is no effect of area of solar collectors on the first law and second law efficiency.
3. Exergetic efficiency of plant increases rapidly with respect to the inlet expander temperature and maximum for R410A among all selected working fluids.
4. Exergetic efficiency for the R410A is maximum among the other selected working fluids and increases gradually with inlet pressure of expander.
5. Thermal efficiency for the plant is increases with respect to inlet temperature of expander.
6. R134a has lowest thermal and energetic efficiency among selected working fluids.
7. Thermal efficiency for the R410A is maximum among the selected working fluids and increases gradually with respect to the inlet expander temperature.
8. Exergy Destruction Ratio is lowest for R410A and decreases with the inlet temperature of the expander.
9. Work output for R410A is maximum among the other selected working fluids and increases with increase in inlet temperature.
10. Since work output is maximum for the R404A than R410A.but decrease rapidly at 3700kPa pressure.
11. Thermal efficiency is increases with the extraction mass for regeneration from the expander
12. Exergetic efficiency is also increases with the increase in mass extraction.
13. That’s why R410A is selected for organic Rankine cycle power generation and this also suitable for low global warming and ozone depletion.
14. Maximum exergy destruction component is evaporator for all selected working fluids

REFERENCES

[1] Kelly B, Herrmann U, Hale MJ. “Optimization studies for integrated solar combinedcycle systems” In: Proceedings of solar forum 2001, solar energy: the power to choose; 2001April 21–25, Washington DC, USA.

[2] He Ya-Ling, Mei Dan-Hua, Tao Wen-Quan, Yang Wei-Wei, Liu Huai-Liang. “Simulationof Parabolic trough solar energy generation system with organic Rankine cycle” Applied Energy2012;97 :630–41

[3] Gang Pei, Li Jing, JieJi. “Analysis of low temperature solar thermal electric generationusing regenerative organic Rankine cycle” ApplThermalEng 2010; 30:998–1004.

[4] Li C, Kosmadakis G, Manolakos D, Stefanakos E, Papadakis G, Goswami DY.
“Performance investigation of concentrating solar collectors coupled with a transcriticalorganic Rankine cycle for power and seawater desalination cogeneration Desalination”2013;318:107–17.

[5] Nafey AS, Sharaf MA. “Combined solar organic Rankine cycle with reverse osmosisdesalination process: energy, exergy, and cost evaluations” Renew Energy 2010; 35:2571–80.

[6] Sharaf MA, Nafey AS, García-Rodríguez Lourdes. “Exergy and thermo-economicanalyses of a combined solar organic cycle with multi-effect distillation (MED) desalinationprocess Desalination” 2011,272:135–47.

[7] Delgado-Torres AM, García-Rodríguez Lourdes. “Preliminary design of seawater andbrackish water reverse osmosis desalination systems driven by low temperature solar organicRankine cycles (ORC)” Energy Conveyers Manage 2010; 51:2913–20.

[8] Delgado-Torres AM, García-Rodríguez Lourdes. “Analysis and optimization of the lowtemperaturesolar organic Rankine cycle (ORC)” Energy Convers Manage 2010; 51:2846–56.

[9] Al-SulaimanFahad A, Hamdullahpur Feridun, Dincer Ibrahim” Performance assessmentof a novel system using parabolic trough solar collectors for combined cooling, heating, andpower production” Renew Energy 2012;48:161–72.

[10] Al-SulaimanFahad A, Dincer Ibrahim, Hamdullahpur Feridun. “Exergy modeling of anew solar driven trigeneration system” Sol Energy 2011; 85:2228–4

[11] Al-SulaimanFahad A. “Energy and sizing analyses of parabolic trough solar collectorintegrated with steam and binary vapour cycles” Energy 10.1016/ j. energy.2013.05.020. [inpress].

[12] Fahad Al-SulaimanFahad” Exergy analysis of parabolic trough solar collectorsintegrated with combined steam and organic Rankine cycles” 2013 Elsevier Ltd.

[13] MiladAshouri, Mohammad HosseinAhmadi , Michel Feidt “Performance Analysis ofOrganic Rankine Cycle Integrated with a Parabolic Through Solar Collector” licenseeMDPI, Basel, Switzerland.

[14] Dimityr Popov “Innovative solar augmentation of gas turbine combined cycle plants”2013 Elsevier Ltd.

[15] Wang, X.D., Zhao, L., Wang, J.L., Zhang, W.Z., Zhao, X.Z., Wu, W., 2010b “Performance evaluation of a low-temperature solar Rankine cycle system utilizing R245fa”Solar Energy 84, 353–364.

[16] S. Quoilin, M. Orosz, H. Hemond, V. Lemort “Performance and design optimization of alow-cost solar organic Rankine cycle for remote power generation” Solar Energy 85 (2011) 955-966.

[17] Maria E. Mondejar , Fredrik Ahlgren , Marcus Thern , Magnus Genrup“Quasi-steady state simulation of an organic Rankine cycle for waste heatrecovery in a passenger vessel”Applied Energy 185 (2017) 1324–1335.

[18] Harrison Warren, Pedro J. Mago, Alta Knizley, Rogelio Luck“Performance enhancement of a power generation unit–organic Rankine cycle system through the addition of electric energy storage”Journal of Energy Storage 10 (2017) 28–38.

[19] Ayad M. Al Jubori, Raya K. Al-Dadah , Saad Mahmoud , Ahmed Daabo“Modelling and parametric analysis of small-scale axial and radialoutflowturbines for Organic Rankine Cycle applications”Applied Energy 190 (2017) 981–996.

[20]Jui-Ching Hsieh, Ben-Ran Fu, Ta-Wei Wanga, Yi Cheng, Yuh-Ren Lee, Jen-Chieh Chang“Design and preliminary results of a 20-kW transcritical organic Rankine cycle with a screw expander for low-grade waste heat recovery”Applied Thermal Engineering 110 (2017) 1120–1127.

[21] Dong Junqi , Zhang Xianhui , Wang Jianzhang“Experimental investigation on heat transfer characteristics of plat heatexchanger applied in organic Rankine cycle (ORC)”Applied Thermal Engineering 112 (2017) 1137–1152.

[22] Ayad Al Jubori , Raya K. Al-Dadah , SaadMahmouda, A.S. Bahr Ennil , KiyarashRahbarThree dimensional optimization of small-scale axial turbine for lowtemperature heat source driven organic Rankine cycle”Energy Conversion and Management 133 (2017) 411–426.

[23] Constantine N. Michos , Simone Lion , IoannisVlaskos , Rodolfo Taccani“Analysis of the backpressure effect of an Organic Rankine Cycle (ORC)evaporator on the exhaust line of a turbocharged heavy duty dieselpower generator for marine applications”Energy Conversion and Management 132 (2017) 347–360.

[24] Wen Su, Li Zhao , Shuai Deng “Developing a performance evaluation model of Organic Rankine Cycle for working fluids based on the group contribution method” Energy Conversion and Management 132 (2017) 307–315.

[25] Pedro J. Mago , Rogelio Luck “Potential reduction of carbon dioxide emissions from the use of electric energy storage on a power generation unit/organic Rankine system” Energy Conversion and Management 133 (2017) 67–75.

[26] In Seop Kim, Tong Seop Kim, Jong Jun Lee” Off-design performance analysis of organic Rankine cycle using real operation data from a heat source plant” Energy Conversion and Management 133 (2017) 284–291.

[27] Kiyarash Rahbar,Saad Mahmoud, Raya K. Al-Dadah, Nima Moazami, Seyed A. Mirhadizadeh” Review of organic Rankine cycle for small-scale applications” Energy Conversion and Management 134 (2017) 135–155.

[28] Wenqiang Sun, Xiaoyu Yue,Yanhui Wanga “Exergy efficiency analysis of ORC (Organic Rankine Cycle) and ORC based combined cycles driven by low-temperature waste heat” Energy Conversion and Management 135 (2017) 63–73.

[29] Yue Cao, Yiping Dai” Comparative analysis on off-design performance of a gas turbine and ORC combined cycle under different operation approaches” Energy Conversion and Management 135 (2017) 84–100.

[30] Weicong Xu, Jianyuan Zhang, Li Zhao, Shuai Deng, Ying Zhang" Novel experimental research on the compression process in organic Rankine cycle (ORC)" Energy Conversion and Management 137 (2017) 1–11.

[31] Tao Chen, Weilin Zhuge, Yangjun Zhang, Lei Zhang "A novel cascade organic Rankine cycle (ORC) system for waste heat recovery of truck diesel engines" Energy Conversion and Management 138 (2017) 210–223.

[32] Xianglong Luo, Zhitong Yi a, Bingjian Zhang, Songping Mo, Chao Wanga, Mengjie Song,Ying Chen "Mathematical modelling and optimization of the liquid separation condenser used in organic Rankine cycle" Applied Energy 185 (2017) 1309–1323.

[33] Angad Singh Panesar "An innovative Organic Rankine Cycle system for integrated cooling and heat recovery" Applied Energy 186 (2017) 396–407.

[34] Dan Wu, Lu AyeTuan Ng, Priyan Mendis "Optimisation and financial analysis of an organic Rankine cycle cooling system driven by facade integrated solar collectors" Applied Energy 185 (2017) 172–182.

[35] Dong Kyu Kim, Ji Sung Lee, Jinwoo Kim, Mo Se Kim, Min Soo Kim "Parametric study and performance evaluation of an organic Rankine cycle (ORC) system using low-grade heat at temperatures below 80^0C.

[36] D. Ziviani,S. Gusev, S. Lecompte, E.A. Groll, J.E. Braun, W.T. Horton, M. van den Broek, M. De Paepe a "Optimizing the performance of small-scale organic Rankine cycle that utilizes a single-screw expander" Applied Energy 189 (2017) 416–432.

[37] Jian Li Qiang Liu, Yuanyuan Duan, Zhen Yang "Performance analysis of organic Rankine cycles using R600/R601a mixtures with liquid-separated condensation" Applied Energy 190 (2017) 376–389.

[38] Jian Song, Chun-wei Gu, Xue-song Li "Performance estimation of Tesla turbine applied in small scale Organic Rankine Cycle (ORC) system" Applied Thermal Engineering 110 (2017) 318–326.

[39] Bensi Dong, Guoqiang Xu, Xiang Luo, Laihe Zhuang, Yongkai Quan "Analysis of the Supercritical Organic Rankine Cycle and the Radial Turbine Design for High Temperature Applications" Applied Thermal Engineering (2017).

[40] Kaiyong Hu, Jialing Zhu ,Wei Zhang, Ketao Liu, Xinli Lu "Effects of evaporator superheat on system operation stability of an organic Rankine cycle" Applied Thermal Engineering 111 (2017) 793–801.

[41] Abid Ustaoglu, Mustafa Alptekin, Mehmet Emin Akay "Thermal and exergetic approach to wet type rotary kiln process and evaluation of waste heat powered ORC (Organic Rankine Cycle)" Applied Thermal Engineering 112 (2017) 281–295.
[42] Y.Z. Wang, J. Zhao, Y. Wang, Q.S. An "Multi-objective optimization and grey relational analysis on configurations of organic Rankine cycle" Applied Thermal Engineering 114 (2017) 1355–1363.
[43] Zhonglu He, Yufeng Zhang, Shengming Dong, Hongting Maa, Xiaohui Yu, Yan Zhang c, Xuelian Maa, Na Deng, Ying Sheng "Thermodynamic analysis of a low-temperature organic Rankine cycle power plant operating at off-design conditions" Applied Thermal Engineering 113 (2017) 937–951.
[44] Shih-Cheng Yang,Tzu-Chen Hung, Yong-Qiang Feng, Chia-Jung Wud, Kin-Wah Wonge, Kuo-Chen Huang "Experimental investigation on a 3 kW organic Rankine cycle for lowgrade waste heat under different operation parameters" Applied Thermal Engineering 113 (2017) 756–764.