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ENERGY AND EXERGY EFFICIENCY OF ORGANIC RANKINE CYCLE FOR SUPERCRITICAL CYCLE

A.F. Sherwani
[*] Department of Mechanical Engineering, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi,India

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ABSTRACT
Existing ORC power cycle system still tend to use refrigerant with relatively high global warming potential and ozone layer depletion because of limited options for the working fluid.Recently,several studies have been carried out on a new refrigerant called HFO-1234yf.This refrigerant /working fluid exhibits more desirable properties than the present refrigerant/working fluid such HFC,HCFC,CFC.

KEYWORDS: -First Law efficiency, Second law efficiency, Exergy efficiency, Working fluids.

INTRODUCTION
The Basic ORC simulation model as shown in fig 1. There are four main components: expander, condenser, and pump.The operation principles are similar to those of the Rankine cycle, the working fluid, which is initially in a liquid state, is delivered by the pump to the evaporator at a designated pressure and mass flow rate.

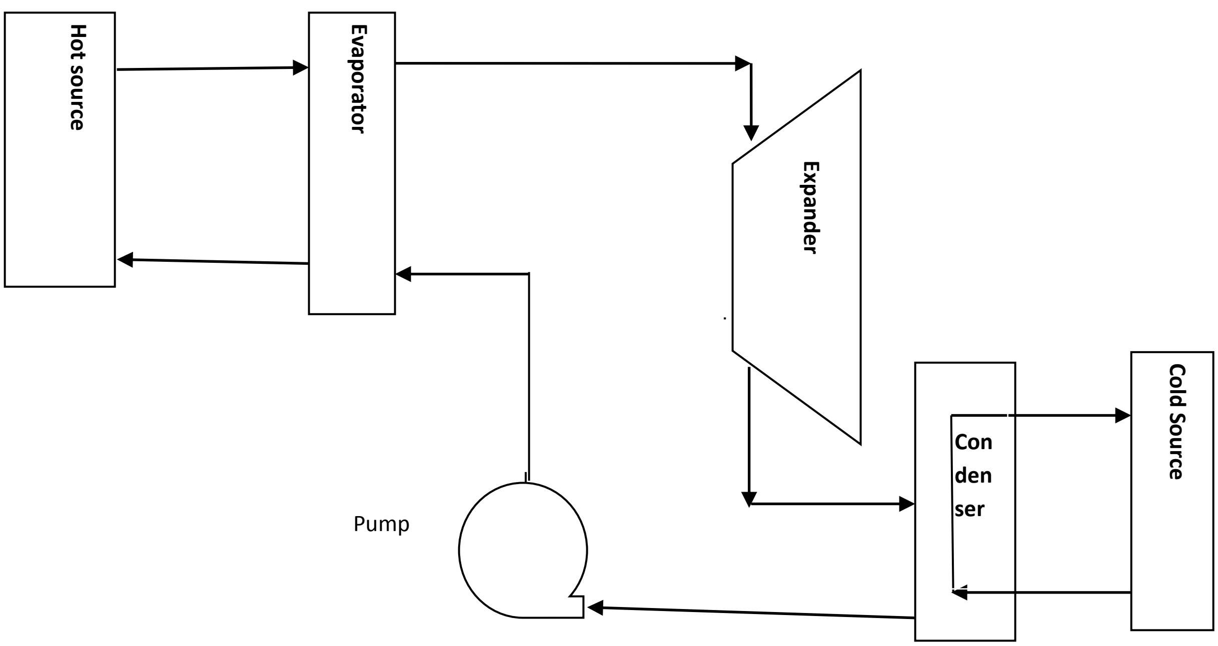

Fig.1. Basic ORC model

The working fluid is heated to a specified temperature level inside the evaporator, and the high-temperature and high-pressure liquid from evaporator expands inside the expander to produce rotational power.The low-pressure

fluid from the expander is then condensed inside the condenser to the liquid state before the liquid is re-circulated by the pump.The thermodynamic ORC models were examined for five working fluids in this study, different cycle path should be determined for each combination of ORC model and working fluid.
Temperature-entropy (T-S) diagram are best way to represent these path Figs.2and3, and 4 show the T-S diagrams of five ORC models for ‘‘wet’’, ‘’dry’’ and’ ‘‘isentropic’’ fluids, respectively.

MATERIALS AND METHODS

Supercritical cycle model:

In the supercritical cycle, the expander inlet condition inlet condition(pressure and temperature) are kept higher than the critical point of the working fluid.The main advantage of the supercritical cycle is that the hot –source temperature can be raised to an ever higher level than the other cycles.Acording to the carnot efficiency, the thermal efficiency of this cycle of this cycle can be increased even further reported that propane and HFC-134a are appropriate working fluid for the supercritical cycle geothermal binary design.In the present simulation, the pumping expanded through isentropic expansion(3-4) to either the superheated(4) or two-phase mixture(4) state.
Through isobaric condensation (4-1), the working fluid is then condensed into saturated liquid.

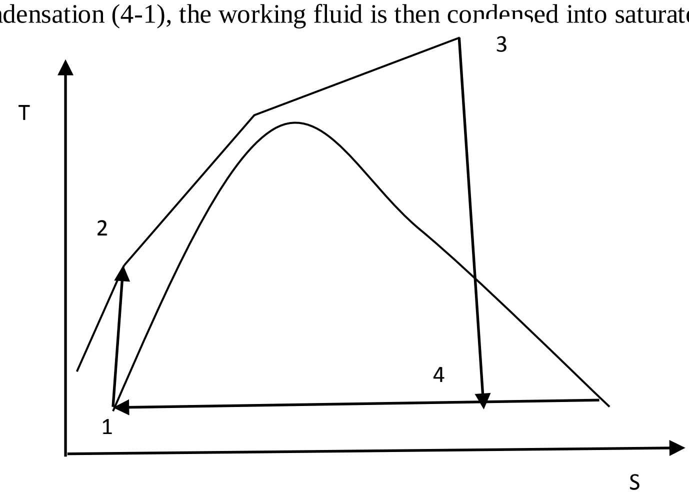

Fig.2

Stefano et al. [1] proposed the Energy efficiency analysis of organic Rankine Cycle with scroll expanders for co-generative applications.Small scale Organic Rankine(ORC) system has been the object of a large number of studies in the last decade, because of the suitability for energy recovery and cogenerative applications.The paper an ORC numerical model and its applications to two different case studies; the code has been obtained by combining a one-dimensional model of scroll machine and a thermodynamic model of a whole ORC system.Series production components, such as scroll compressor, from HVAC field have been first considered in order to reduce costs, because this is a critical issue for small scale energy recovery and cogeneration systems.
The detailed model of the scroll machine is applicable to calculate the performances of both a compressor and expander, as function of geometry of the device and the working fluid.The model has been first tested and validated by comparing its outputs with experimental test on a commercial scroll compressor, then used to calculate the working curves of commercial scroll machine originally designed as compressor in the HVAC field, but operating as expanders.The model of the expander has been then integrated in the thermodynamic model of the ORC system.A series of comparison have been carried out in order to evaluate how the performances are influenced by scroll parameters, scroll geometry and working fluid for different applications.
The result confirm the feasibility of small scale CHP systems with acceptable electrical efficiency, taking into account the low-temperature thermo source, small power output and the low-cost series production components employed.Lourdes et al. [2] proposed Solar-powered Rankine cycle for fresh water production.
The lack of access to electricity grid and fresh water strongly limits the development and the quality of life to many rural locations.The distributed solar power generation can be applied to many basic needs, not only electricity

generation, but also desalination, cooling, heating, etc.For this reason it provides opportunity of social and economic development and therefore promoting employment.This paper is focused on the analysis of distributed solar-powered generation systems for driving a reverse osmosis desalination process based on solar-heated Rankine cycles.Three different top temperature ranges are considered in order to consider medium to low temperature solar thermal collectors.

Result presented in this paper points out the desalination system coupled to solar-powered organic Rankine cycle exhibit lower specific consumption of solar energy than solar distillation and solar photovoltaic reverse osmosis system.Therefore, there are interesting prospects for developing cost-effective solar desalination system based on such a technology although intensive experimental research is still needed.Charles and Christopher [3] suggested the Review of Rankine cycle for internal combustion engine exhaust waste heat recovery.Escalating fuel and future carbon dioxide emission limits are creating a renew interest in method to increase thermal efficiency of engine beyond the limit of in-cylinder techniques.One promising mechanism that accomplishes both objectives is the conversion of engine waste heat to a more useful form of energy, either mechanical or electrical.

This paper review the history of internal combustion engine exhaust waste heat recovery focusing on organic Rankine cycle since this thermodynamic cycle works well with the medium-grade energy of exhaust.Selection of the cycle expander and working fluid are the primary focus of the review, since they are regarded as having the largest impact on system performance.Result demonstrates a potential fuel economy improvement around 10% with modern refrigerators and advancements in expander technology.Florian and Dieter[4] suggested exergy based fluid selection for a geothermal Organic Rankine cycle for combined heat and power generation.

In the study the option of combined heat and power generation was considered for geothermal resources at a temperature level below 450k.Series and parallel circuits of organic Rankine cycle(ORC) and an additional heat generation were compared by second law analysis.Depending on operating parameter criteria for the choice of the working fluid were identified.The result show that due to a combined heat and power generation, the second law efficiency of geothermal power plant can be significantly increased in comparison to power generation.The most efficient is series circuits with an organic working fluid that show high critical temperature like Isopentane.For parallel circuits and for power generation, fluids like R227ea with low critical temperature are to preferred.Angelo and Pietropaolo[5] suggested the comparative energetic analysis of high-temperature subcritical and transcritical Organic Rankine Cycle(ORC). A biomass application in the sibari district.

The present work aims to analyze the energetic performance of organic Rankine cycle(ORCs) for small-scale applications.To this purpose, a parameter energy analysis has been performed to define the proper system configurations for a biomass power plant.Saturated and superheated conditions at the turbine inlet have been imposed and subcritical and transcritical cycle have been investigated.Furthermore, the effect of operating conditions and the impact of internal regeneration on system performed have been analyzed.Finally, the possible exploitation of biomass resulting from pruning residues of peach trees in the sibari district(Southern Italy) has been evaluated for configurations optimized during the energetic analysis.The analysis show that ORCs represent a very interesting solution for small-scale and decentralized power production.Moreover, the result highlight the large influence of the maximum temperature and the significant impact of the inter regeneration on the power plant performances.

Wang et al. [6] did the optimization of Low-Temperature Exhaust Gas waste heat Fueled Organic Rankine Cycle.

Low temperature exhaust gas carrying large amount of waste heat released but steel- making process and many other industries, Organic Rankine Cycle are proven to be the most promising technology to recover the low-temperature waste heat, thereby to get more financial benefits for these industries.The exergy analysis of ORC units driven by low-temperature exhaust gas waste heat and charged with dry and isentropic fluid was performed, and and intuitive approach with simple impression was developed to calculate the performances of the ORC unit.

Parameter optimization was conducted with turbine inlet temperature simplified as the variable and exergy efficiency or power output as the objective function by means of penalty function and golden Section Searching algorithm based on formulation of the optimization problem.The power generated by optimized ORC unit can be nearly as twice as that generated by a non-optimized ORC model unit.In addition, cycle parametric analysis was performed to examine the effects of thermodynamic parameters on the cycle performed such as thermal efficiency and exergy efficiency.It is proven that performance of ORC unit is mainly affected by the thermodynamic property of working fluid, the waste heat temperature, the pinch point temperature of the evaporator, the specific heat capacity of the heat carrier and the turbine inlet temperature under a given environment temperature.

G. et al. [7] suggested the parametric theoretical study of a two-stage solar organic Rankine cycle for RO desalination.The present work concerns the parametric study of an autonomous; two stage solar organic Rankine cycle for RO desalination.The main goal of the current simulation is to estimate the efficiency, as well as to calculate the annual mechanical energy available for desalination in the considered cases, in order to evaluate the influence of various parameters on the performance of the system.The parametric study concerns the variation of different parameters, without charging actually the baseline case.

The effect of the collectors slope and total number of evacuated tube collector used, have been extensively examined.

The total cost is also taken into consideration and is calculated for different cases examined, along with the specific fresh water cost.Betrand et al. [8] Fluid selection for a low-temperature solar organic Rankine cycle.Theoretical performance as well as thermodynamic and environmental properties of few fluids have been comparatively assessed for use in low-temperature solar organic Rankine cycle systems.Efficiencies, volume flow rate, mass flow rate, pressure ratio, toxicity, flammability, ODP and GWP were used for comparisons.Of 20 fluids investigated, R134a appears as the most suitable fo small scale solar applications.R152a, R600a, R600 andR290 offer attractive performances but need safety precautions, owing to their flammability.Z. et al. [9] did performance comparison and parametric optimization of subcritical Organic Rankine Cycle(ORC) and transcritical power cycle system for low temperature geothermal power generation.

Organic Rankine cycle is a promising technology for converting the Low-grade energy to electricity.This paper presents an investigation on the parameter optimization and performance comparison of the fluids in subcritical ORC and transcritical power cycle in low-temperature binary geothermal power system.The optimization procedure was conducted with simulation program written in Matlab using five indicators: thermal efficiency, exergy efficiency, recoveryefficiency, heat exchanger area per unit power output(APR)and the level zed energy cost.

With the given heat source and heat sink conditions, performances of working fluids were evaluated and compared under their optimized internal operation parameters.The optimum cycle design and the corresponding operation parameters were provided simultaneously.The optimum cycle design and the corresponding operation parameters were provided simultaneously.The results indicates that the choice of working fluids varies the objective function and the value of the optimized operation parameters are not all the same for different indicators.R123 in subcritical ORC system yields the highest thermal efficiency and exergy efficiency of 11. 1% and 54%, respectively.Although the thermal efficiency and exergy efficiency of R125 in transcritical cycle is 46. 4% and 20% lower than that of R123 in subcritical ORC, it provides 20.7% larger efficiency.And the LEC value is relatively low. More ever, 22032L Petroleum is saved and 74, 019kg CO_2 is reduced per year when the LEC value is used as the objective function.

In conclusion, R125 in transcritical power cycle show excellent economic and environmental performance and can maximized utilization of the geo thermal.It is preferable for the low-temperature geothermal ORC system.R41 also exhibits favourable performance except for its flammability.Nobru et al. [10] presented Study on thermal efficiency of low –to medium-temperature organic Rankine cycle using HFO-1234yf.Heat recovery using organic Rankine cycle is considered to be an important method among renewable energy processes because of its capability to generate power from available waste heat and natural heat sources, such as solar radiation, ocean thermal sources, geothermal sources, biomass, and waste heat from fuel combustion or industrial process.

RESULTS AND DISCUSSION

This section deals with the result and discussion for simple ORC cycle with various working fluids at different Expander inlet temperature at fixed condenser temperature (30^{0}C), Isentropic Expander efficiency (ηT=75%), IsentropicpumpEfficiency (ηP=60%). Fig.3. Shows relative Comparison of Thermal Efficiency of supercritical by using various working fluid. In saturated Rankine cycle model by using HFO-1234yf shows Lowest Thermal Efficiency (7%) and Isopentane shows highest thermal efficiency as compared to other working fluid in temperature Range (80-90^{0}C).

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Fig.3 shows Thermal Efficiency vs Expander inlet temperature. From given isopentane shows highest efficiency, HFO-1234yf shows lowest.

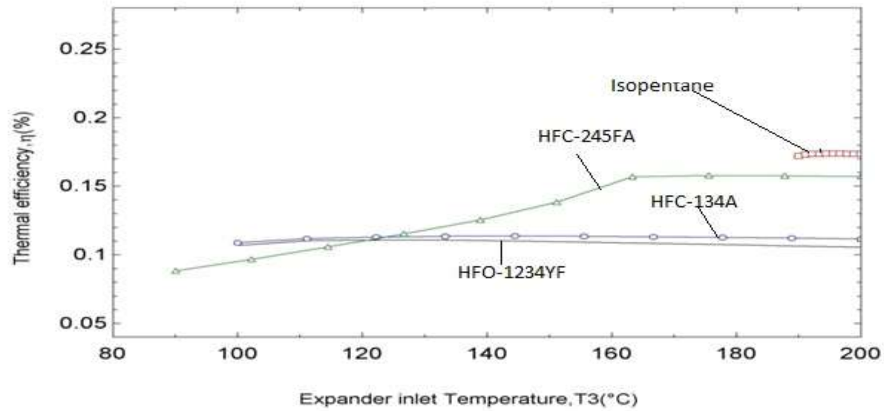

Fig.3

Fig.4 shows Expander inlet Temperature vs Exergetic Efficiency

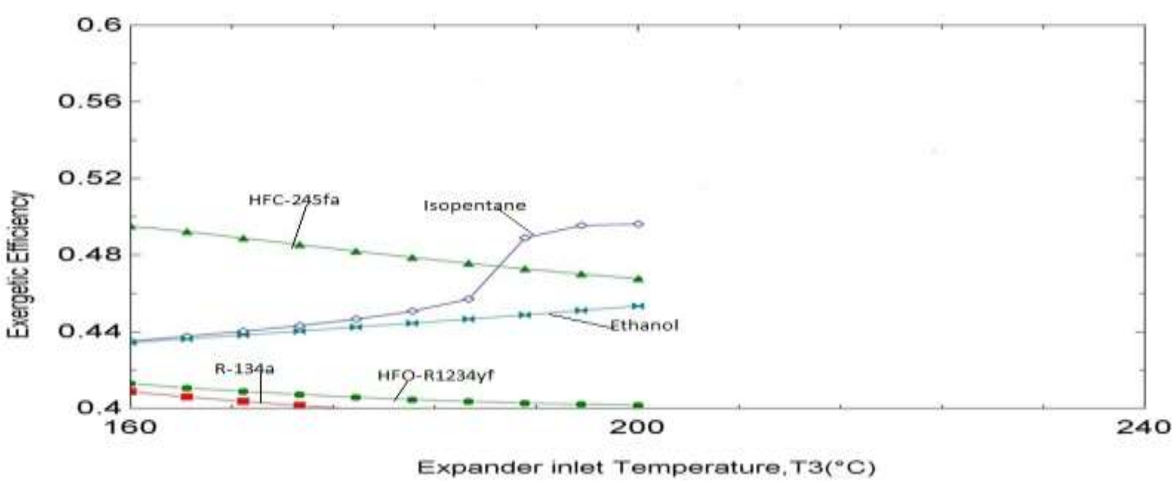

Fig.4

From above figure isopentane shows highest and R-134a shows Lowest.

Fig.5 Shows Expander inlet Temperature vs Exergy Destruction in various components For HFO-R1234yf.

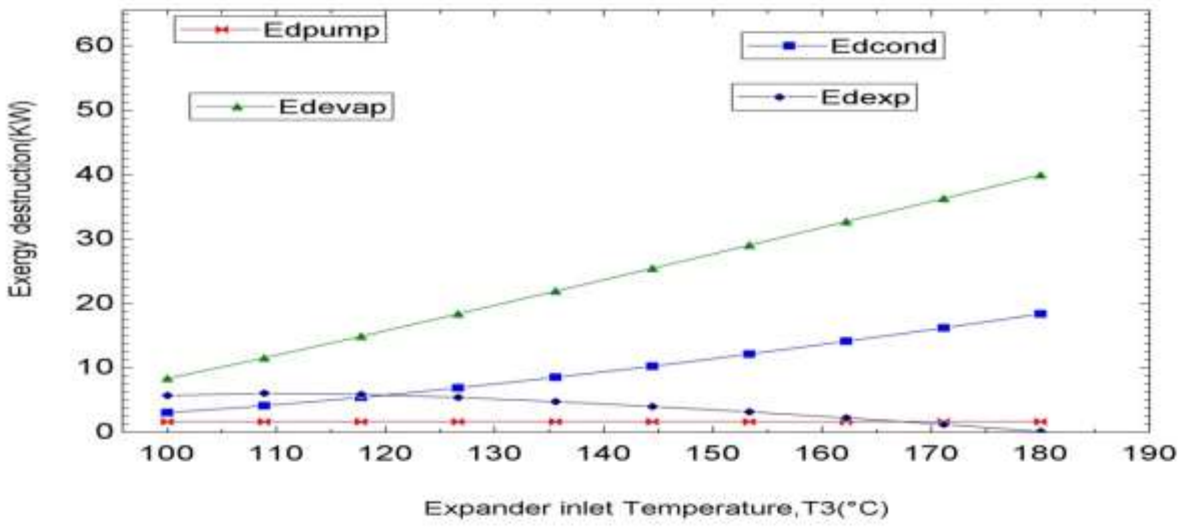

Fig.5

From above Figure Evaporator shows higher Exergy destruction and pump shows Lowest Exergy Destruction.

Formulae:

THERMODYNAMIC MODELLING

In this sub-section, fundamental equations are introduced that are based on the energy balance of the ORC model according to the first law of thermodynamics.

The general energy balance equation for all existing cycle (Saturated, Trilateral, Supercritical, Superheated, Subcritical) is as follow:

The pump isentropic efficiency and pumping power are defined as

$\eta_p = \frac{h_{2s}-h_2}{h_2-h_1}$ ….. (1)

$W_P=\dot{m} * (h_2-h_1)$ …… (2)

For the expander

Isentropic efficiency(η_e)

$\eta_e=\frac{(h_3-h_4)}{(h_3-h_{4s})}$ ……. (3)

$W_e=\dot{m} * (h_3-h_4)$ ………. (4)

The heat input in the working fluid through Evaporator

$Q_{in}=\dot{m}*(h_3-h_2)$ ………..(5)

Thermal Efficiency Of the ORC cycle

$\eta_{th}=\frac{w_e-w_P}{Q_{in}}$ …….. (6)

$\eta_{th}=\frac{(h_3-h_4)-(h_2-h_1)}{Q_{in}}$ ………… (7)

Exergy Analysis

Exergy destruction in evaporator:

$E_{devap}=(h_2-T_O*S_2)-(h_3-T_0*S_3)+q_s*[1-T_O/(T_3+273)]$

Exergy destruction in expander:

$E_{dexp}=(h_3-T_O*S_3)-(h_4-T_O*S_4)-(h_3-h_4)$

Exergy destruction in condencer:

$(h_4-T_O*S_4)-(h_1-T_o*S_1)$

Exergy destruction in pump:

$E_{dpump}=(h_1-T_o*S_1)-(h_2-T_o*S_2)+(h_2-h_1)$

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$Edtotal = E_{devap} + E_{dexp} + E_{dcond} + E_{dpump}$

Exergetic Efficiency

$\eta_{ex} = 1 - E_{dtotal}/E_{inpu}$

$Einput = q_S * [1 - T_O/(T_3+273)] + W$

$\eta_{ex1} = W_T/E_{input}$

CONCLUSION

First law efficiency and second law efficiency of various fluids are such as R-134a,R-245fa,R-1234yf,Ethnol,Isopentane are tested and found that First law efficiency and second law efficiency increases first and decreases. Exergy destruction in various component are calculated found that exergy destruction in pump is lowest and highest in Evaporator

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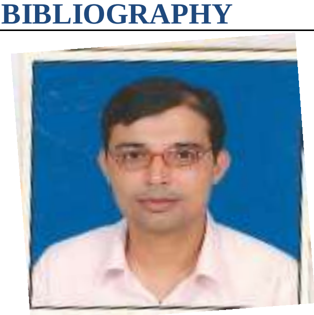
REFERENCES

1. Stefano Clemente,Diego Michel,Mauro Reini,Rodolfo Taccani 2012.,Energy Efficiency analysis of organic Rankine cycle with scroll expander.Applied Energy 97(2012) 792-801.
2. Lourdes Garcia-Rodriguez,Austin M.Delgado-Torres 2006.,solar-powered Rankine cycle for fresh water Production-Desalination 212(2007) 319-327.
3. Charles sprouse iii,Christopher Depick 2012.,Review of organic Rankine cycle fo internal combustion engine Exhaust Waste heat Recovery.Applied Thermal Engineering 51(2013) 711-722.
4. Florian Heberle,Dieter Bruggemann 2010.,Exergy Based fluid selection for Geothermal organic Rankine cycle for combined heat and Power generation.Applied Thermal Engineering 30(2010) 1326-1332.
5. Angelo Algieri,Pietropaolo Morrone 2011., Comparative energetic analysis of high-temperature sub-critical&Transcritical organic Rankine cycle.A biomass application in the sibri district.Applied Thermal Engineering 36(2012) 236-244.
6. Wang Hui-tao,Wang Hua,Zhang Zhu-ming 2011., Optimization of Low-Temperature Exhaust Gas Waste Heat Fueled organic Rankine cycle.Journal of iron&steel Research,International 2012,19(6).,30-36.
7. G.Kosmadakis,D.Manolakos,G.Papadakis 2009.,Parametric Theoritical study of a two-stage solar organic Rankine cycle for RO desalination 2009.,Renewable Energy 35(2010) 989-996.
8. Betrand Fankam Tchanche,George Papadakis,Gregory Lambrinos,Antonios Frangoudakis 2008.,Fluid selection for a Low-temperature Solar organic Rankine cycle.Applied Thermal Engineering 31(2011) 2885-2893.
9. Zhang shengjun,wang Huaixin,GuoTo 2011.,Performance comparision and Parametric optimization of subcritical organic Rankine cycle and Transcritical power cycle system for low-temperature geothermal Power generation Applied Energy 88(2011) 2740-2754.
10. Noboru Yamada,Md Nor Anuar Mohamad,Trinh Trung Kien 2011.,study on Thermal Efficiency of low to medium organic Rankine cycle using HFO-1234yf.Renewable Energy 41(2012)368-375

AUTHOR BIBLIOGRAPHY



Author Name here
Ahmad Faizan Sherwani

Graduated from zakir hussain college of engineering in 2000 and his masters in the area of thermal engineering.he did his Ph.D from jamia milia islamia new delhi in the area of solar energy.his area of interest is IC Engines and non conventional energy resources.Taught at various level in more than four reputed universities and presently working in jamia millia islamia