International Journal of Research in Engineering and Innovation
(IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Thermodynamic analysis of brayton cycle for power generation

R.S. Mishra, Manish Kumar

Department of Mechanical, Production, Industrial and Automobiles Engineering, Delhi technological University, Delhi, India

Abstract

This paper mainly deals with the thermodynamic performances of Brayton Cycle in detail. The performance equation are developed which includes the effect of intercooling and reheating using three operating fluids R123, R245fa and R134a for improving its thermodynamic performances. It was observed the Brayton cycle working on R123 gives better thermodynamic performances then R245fa & R134a. Since R123 containing chlorine content therefore R245fa is recommended which has better thermodynamic performance then HFC-134a. The effect of various performance parameters such as pressure ratio, maximum temperature in cycle, inlet temperature of compressor the change in Net efficiency and net-work of the Brayton cycle is investigated.

Keywords: Joule cycle thermodynamic performance, ecofriendly fluids, gas turbines cycle

1. Introduction

Energy security, economic development and atmosphere protection are not very well balanced these days which has put further pressure on energy demand which is closely connected to the economic process. At the same time, the over-consumption of fossil fuels has led to a lot of surroundings issues like heating, ozone depletion and atmosphere pollution. Fossil fuels are still the dominant form of energy resources worldwide, accounting for 77 of the increasing energy demand 2007-2030 (IEA 2009). When combined with the quick development of business, a significant increase in energy shortages and blackouts has been noticed a lot frequently everywhere around the globe. Due to of those reasons, utilizing inferior waste heat for energy consumption. The most ordinarily investigated in inferior heat supply and waste heat utilizations these days are Organic Rankine Cycle (ORCs) and Kalina Cycle (binary fluids and fluid mixtures). When low grade heat is used, the conventional steam Rankine cycle does not offer acceptable performance as a result of its poor thermal efficiency and big volume flows, and so therefore known as Organic Rankine Cycle (ORCs) are projected. These cycle use organic substances as operating fluid system comprises a minimum of 4 major comparisons, a regenerator is additionally enclosed within the current calculation.

In this study the Combined Organic Cycle focuses the performance of three fluids R123, R134a and R245fa. Though earlier studies hold innumerable options, this work provides a much clearer statement on IHE in subcritical ORC system setting a new model taking pressure drop by loops and pinch point into thought. The common operating fluids R123, R134a and R245fa have been chosen for subcritical cases.

2. Literature review

The theoretical investigation and has instructed the feasibleness of introducing a waste heat recovery system in 2 stage turbocharged HDD engine.The waste heat recovery (WHR) is earned by introducing a Rankine cycle that uses an organic substance or directly water as operating fluid looking on energetic performance concerns.They additionally instructed an alternate for rising the general thermal efficiency of internal-combustion engine consists of recovering the energy lost by suggests that of a waste heat recovery (WHR) system. These solutions are supported adapting one among the turbochargers by removing its rotary engine and making an attempt to recover the energy by Rankine cycle. Finally, the rotary engine of the Rankine cycle provides the recovered energy on to the compressor of this turbocharger [1]. The strategy for customizing an organic Rankine cycle to a fancy heat supply for economical energy conversion, demonstrated on a Fischer Tropsch plant. Organic Rankine Cycle offer an alternate to ancient steam temperature unit cycle for the conversion of low grade heat supply into power, wherever typical steam power cycle is thought to be inefficient. A large process plant typically has multiple low temperatures waste heat supply obtainable for conversion to electricity by a low temperature cycle, leading to composite heat supply with a

Corresponding author: R.S. Mishra
Email Address: hod.mechanical.rsm@dtu.ac.in

complex temperature-enthalpy profile. Organic fluids are sculptured employing a pure substance information. The pinch analysis technique of forming composite curve is applied to research the impact of every building block on the temperature-enthalpy profile of the ORC heat demand [2]. The performance analysis of double organic Rankine cycle for discontinuous temperature waste heat recovery. The optimum operation of many operating fluids are calculated by a procedure using MATLAB and REPROP. The influence of outlet temperature of warmth supply on internet power output, thermal efficiency, power consumption, mass rate of flow, expander outlet temperature, cycle irreversibility and exergy potency at a given pinch temperature difference has been used to get a thermodynamically understanding of the ORC performance [4]. Electricity from industrial waste heat exploitation high speed organic Rankine cycle. Within the conversion of cold heat into electricity the best efficiency is obtained in several cases by using AN Organic Rankine Cycle. The ORC method additionally be possible also in warm temperature applications. This paper deals with an ORC style, during which a high speed oil free turbo generator feed pump is employed [5].

Analysis of external heat loss from a little scale expander employed in organic Rankine cycle. With the lowering of the ORC, the engine shaft power isn't solely determined by the enthalpy drop by the expansion method however additionally the external heat loss from the expander. On paper and by experimentation support in evaluating tiny scale expander heat loss is rare. They give a quantitative study on the convection, radiation and conductivity heat transfer from a kw-scale expander. A mathematical model is constructed and valid [6]. Recent interests in little scale solar thermal combined heat and installation has coincided with the demand growth for distributed electricity providers in space poorly served by centralized power stations. One potential technical approach to fulfill this demand is parabolic trough solar thermal collector including Organic Rankine Cycle engine. He additionally describes the planning of solar organic Rankine cycle being put in in Kingdom of Lesotho for rural electrification purpose. The system carries with it parabolic trough collectors, a tank, atiny low scale ORC engine scroll expanders. A model of every part is developed that permits sizing the various parts of cycle and evaluates the performance of system [7].

Energy primarily based fluid choice for a geothermic Organic Rankine Cycle for combined heat power generation. During this study the choice of combined heat and power generation was thought-about for geothermic resources at a temperature level below 450k. Series and parallel circuits of an organic Rankine cycle and extra heat generation was organized by second law analysis. The result shows that the second law efficiency of energy station will be considerably enlarged compared to power generation [8]. The investigation of 2 stage Rankine cycle for power plant. A 2 stage Rankine cycle for power generation is given during this paper. It's product of water steam Rankine Cycle and Organic Rankine bottoming Cycle. By using an organic fluid with density over water. The performance of 2 stage Rankine cycle operative with those completely different operating fluids is evaluated. System efficiency may be increased by introducing a regenerator for a few of operating fluids [9]. Pumping within Rankine cycle and created calculation based mostly result for the pumping work on ORC. Analysis has been administrated for eighteen completely different organic fluids that may be used an operating fluids within the subcritical ORC system. A trial was created to search out correlations between numerous thermo-physical properties of operating fluids, specific work and power of cycle [10].

The energy potency analysis of organic Rankine cycle with scroll expanders for co-generative applications. The model of scroll machine is applicable to calculate the performance of each a compressor and expander, as perform of pure mathematics of device and dealing fluid [11]. Solar power-driven Rankine cycle for water production. He additionally centered that on the analysis of distributed solar power-driven generation systems for driving a reverse diffusion method process. Results signifies the desalinization system coupled to solar power-driven organic Rankine cycle exhibit lower specific consumption of solar power than solar distillation [12]. The review of temperature unit Cycle for combustion engine exhaust waste heat recovery. This paper review the history of combustion engine exhaust waste heat recovery specializing in organic Rankine cycle since this thermodynamically cycle works well with medium grade energy of exhaust. Choice of cycle expander and dealing fluid are primary focus of the review. Results demonstrate a possible fuel economy improvement around ten [13]. Exergy based mostly fluid choice for a geothermic Organic Rankine Cycle for combined heat and power generation [14]. The comparative energetic analysis of hot temperature subcritical and trans critical Organic temperature unit cycle during a biomass application within the Sibari district. The current work aims to research the energetic performance of ORC’s for tiny scale applications [15]. The improvement of temperature exhaust gas waste heat fueled organic Rankine cycle. Cycle parametric analysis was performed to look at the consequences of thermodynamically parameters on the cycle [16]. The constant theoretical study of a 2 stage solar Rankine cycle for Ro distillation. The current work issues the constant study of an autonomous 2 stage solar ORC for Ro desalinization. The most aim is to estimate the efficiency similarly on calculate annual energy out there for desalinization [17]. An analysis of regenerative Organic Rankine Cycle (ORC), supported constant quantity optimization using R-123 and R-134a throughout superheating at a continuing pressure of 2.50 MPa underneath realistic conditions. The aim was to pick a much better operating fluid on the idea of obtained system efficiency, turbine work output, irreversibility rate and second law efficiency underneath applied fastened and variable heat supply temperature conditions, R-123 has been found a more robust operating fluid than R-134 for changing low grade heat to power. A computer program has been developed to parametrically optimize and compare the system and irreversibility ratio with will increase in rotary engine water temperature (TIT) underneath completely different heat supply temperature conditions to get the optimum operative conditions whereas using R-123 as the operating fluid throughout superheating at varied rotary engine water pressures for the use of the waste heat sources of temperatures higher than 150ºC. The calculated results reveal that an water pressure of 2.70 MPa offers the most system efficiency, rotary engine work output and second law efficiency with minimum irreversibility rate, irreversibility magnitude relation and system mass rate of flow up to a TIT within the vary of 165ºC-250ºC [18].

Some initial conditions, boundary conditions, and hypothesis for a mathematical model. 3 types of pure fluid and one mixture were hand-picked as operating fluids and their constant quantity changes were calculated below totally different evaporating temperatures. Once organic Rankine cycle (ORC) is supplied with internal device (IHE), its parameters varies whereas using totally different operating fluids [19]. Constant optimization and comparative study of Organic Rankine Cycle for low grade waste heat recovery in saturated cycle [20].

A subcritical cycle and stimulated it beneath constant operation conditions as superheated cycle, however, the pumping pressure is unbroken above the pressure used for superheated cycle however slightly less than the critical pressure for operating fluids [21]. The results of an experimental study administered on a model of an open-drive oil-free scroll expander integrated into an ORC operating with refrigerant HCFC-123. By exploiting the expander performance measurements, the eight parameters of a scroll expander semi-empirical model are then known. The model is ready to calculate variables of 1st importance like the mass rate, the delivered shaft power and also the discharge temperature, and secondary variables like the availability heating-up, the exhaust cooling-down, the close losses, the interior escape and also the mechanical losses. The utmost deviation between the predictions by the model and also the measurements is two hundredth for the mass rate, 5-hitter for the shaft power and 3K for the discharge temperature. The valid model of the expander is finally wont to quantify the various losses and to point how the planning of the expander can be altered to realize higher performances. This analysis detected that the internal leakages and, to a lesser extent, the availability pressure drop and also the mechanical losses are the most losses moving the performance of the expander [22]. The use of organic operating fluids for the conclusion of the thus known as Organic Rankine Cycle (ORC) has been established to be a promising resolution for decentralized combined heat and power production (CHP). The method permits the employment of low temperature heat sources, giving an advantageous efficiency in tiny scale applications. This is often the explanation why the quantity of energy and biomass fired power plants supported this technology are enhanced among the last years. The favorable characteristics of ORC build them appropriate for being integrated in applications like solar desalinization with reverse diffusion system, waste heat recovery from biogas digestion plants or micro-CHP systems. During this paper, the state of the art of ORC applications are going to be given beside innovative systems that are simulated in an exceedingly method simulation setting using experimental data. The results of the simulations like efficiencies, water production rates or possible electricity cost are given and mentioned [23]. The choice of combined heat and power generation was thought of for energy resources at a temperature level below 450 K. Series and parallel circuits of an Organic Rankine Cycle (ORC) and a further heat generation were compared by second law analysis. Looking on operative parameters criteria for the selection of the operating fluid were known. The results show that because of a combined heat and power generation, the second law efficiency of an energy station will be considerably enhanced as compared to a power generation, the second law efficiency of an energy station will be considerably enhanced as compared to a power generation. The foremost economical conception may be a series circuit with an organic operating fluid that shows high critical temperatures like iso-pentane. For parallel circuits and for power generation, fluids like R227ea with low critical temperatures are to be most well-liked [24]. Parametric optimization and performance analysis of a waste heat recovery system supported Organic temperature unit Cycle, using R-12, R-123 and R-134a as operating fluids for power generation are studied. The cycles are compared with heat supply as waste heat of flue gas at 140ºC and 312 Kg/s/unit mass rate of flow at the exhaust of ID fans for 4×210 MW, NTPC Ltd. Kahalgaon, India. Optimization of rotary engine inlet pressure for max work and efficiencies of the system on the saturated vapor line and isobaric superheating at completely different pressures has been carried out for the chosen fluids. The results show that R-123 at corrected pressure evaluated among all the chosen fluids. The Carnot efficiency for R-123 at corrected pressure evaluated underneath similar conditions is near to the particular potency. It will generate 19.09 MW with a mass rate of flow of 341.16 Kg/s having a pinch point of 5ºC, 1st law efficiency of 25.30% and also the second law efficiency of 64.40%. Therefore choice of an Organic Rankine Cycle with R-123 as operating fluid seems to be an alternative system for utilizing inferior heat sources for power generation [25].

The reducing of the Organic Rankine Cycle (ORC), the engine shaft power isn't solely determined by the enthalpy drop by the expansion method however additionally the external heat loss from the expander. Theoretical and experimental support in evaluating tiny scale expander heat loss is rare. This paper presents a quantitative study on the convection, radiation and conductivity heat transfer from a kW-scale expander. A mathematical model is constructed and valid. The results show that the external radiative or convective heat loss constant was regarding 3.2 or 7.0 W/m2K once the ORC operated around 100ºC. Radiative and convective heat loss coefficients enhanced because the expander operation temperature enhanced. Conductive heat loss because of the affiliation between the expander and also the support accounted for an oversized proportion of the warmth loss. The fitting relationships between heat loss and mean temperature distinction were established. It's recommended that low conduction material be embodied within the support of expander. Mattress insulation for compact expander may be eliminated once the operation temperature is around 100ºC [26]. Recent interests in little scale solar thermal combined heat and installation has coincided with the demand growth for distributed electricity providers in space poorly served by centralized power stations. One potential technical approach to fulfill this demand is parabolic trough solar thermal collector including Organic Rankine Cycle engine. He additionally describes the planning of solar organic Rankine cycle being put in in Kingdom of Lesotho for rural electrification purpose. The system carries with it parabolic trough collectors, a tank, a tiny low scale ORC engine scroll expanders. A model of every part is developed that permits sizing the various parts of cycle and evaluates the performance of system. Totally different operating fluids area unit compared, and 2 totally different growth machine configurations area unit simulated (single and double stage) [27].

HFO-1234yf could be a new refrigerant with a virtually zero warming potential (GWP) and gas depletion potential (ODP); it exhibits thermodynamically properties just like HFC-134a. The potential if HFO-1234yf as an operating fluid for organic Rankine cycle (ORC) is elucidated through a primary order simulation. A basic thermodynamically model of ORC with 5 forms of cycles trilateral, saturated, superheated, sub-critical, and critical wont to compare the thermal efficiency of HFO-124yf thereupon of different operating fluids. HFO-1234yf was found to supply a thermal efficiency that was like that of HFC-134a. This paper provides a helpful clearly shows the simplest attainable thermal efficiency among the 5 forms of cycle for numerous expander recess and condensation temperatures. the best thermal potency vary (8.8%- 11.4%) was obtained once the critical ORC was used at an expander inlet temperature of 170ºC and condensation temperature vary of 20-40ºC for the given pump and expander potency. it's concluded that HFO-1234yf could be a potential operating fluid for ORC applications, particularly for those with low to medium temperature heat sources [28].

The study presents the thermo economic improvement formulations of 3 new tri-generation systems using organic Rankine Cycle (ORC): SOFC-tri-generation, biomass-tri-generation, and solar-tri-generation systems. A thermoeconomic modeling is used using the precise exergy costing (SPECO) methodology whereas the improvement performed using the Powell's methodology to reduce the product value of tri-generation (combined cooling, heating, and power) [29]. This study reveals that the utmost tri-generation-exergy efficiencies are regarding thirty eighth for the SOFC-tri-generation system, twenty eighth for the biomass-tri-generation system and eighteen for the solar-tri-generation system. Moreover, the most price per exergy unit for the SOFC-tri-generation system is about 38$/GJ, for the biomass-tri-generation system is 26$/GJ and for the solar-tri-generation system is 24 $/GJ. This study reveals that the solar tri-generation system offers the simplest thermoeconomic performance among the 3 systems. This is often as a result of the solar-tri-generation system has the lowest price per exergy unit. Moreover, the solar tri-generation system has zero carbon dioxide emissions and it's supported a free renewable energy supply [30].

2.1 Simple Brayton Cycle

The Brayton cycle highlights the standard model for a gas turbine power cycle. According to the principle, the compressor compresses the air, which is then mixed with fuel and burned in the combustor under a consistent pressure. This air can also be heated by a waste heat flow. The resultant high pressure and temperature gas is then allowed to expand through a turbine to perform work. The majority work produced in the turbine is used to support the compressor while the remaining is available for further applications. This is commonly used for stationary power generation plants (electric utilities) and mobile power generation engines (ships and aircraft). For power plant applications, the turbine output is used to provide shaft power to drive a generator. A jet engine aircraft is propelled by the reaction thrust of the exiting gas stream. The turbine provides enough power to run the compressor and deliver auxiliary power.

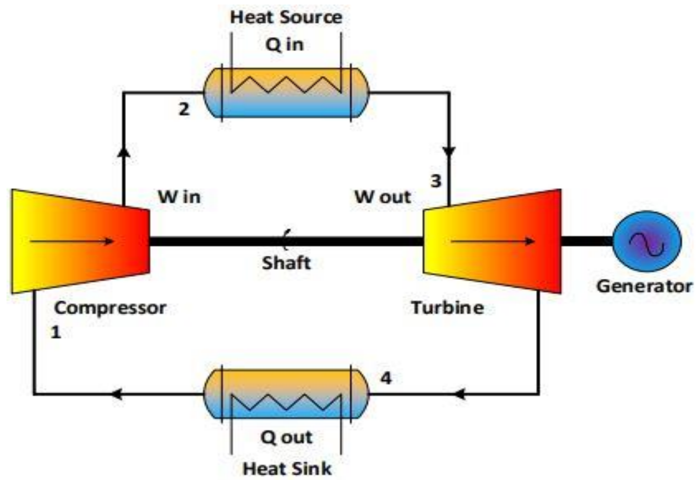

Figure 1: Schematic Diagram of Simple Brayton cycle

Working fluids such as R123, R134a and R245fa have been used in the present investigation. Several researchers investigated these operating fluids and are representative operating fluids that are employed in ORC, Not solely HFC-134a is employed however additionally HFC-245fa and iso-pentane are employed in an Organic Rankine Cycle to collect low heat from the industrial plants. Ethanol performs fine at medium temperature level i.e. 200-300ºC hence, it is also a common as an automotive ORC operating fluid. The evaporation temperature for organic substances is comparatively lower as compare to steam, this being the most reason and advantage of exploitation them as operating fluid in ORC. The low evaporation temperature makes it attainable for them to vaporize or superheat with just low or medium heat sources. Additionally, the expander life are often extended by using the organic substances which are classified as dry or isentropic fluids. Under the saturated or superheated tends to be dry. The particular performance needs to be verified by playing elaborate simulations for the model that employs heat exchanger. The major focus these days is kept on the subcritical cycle, however a number of the research on critical cycle using heat exchanger has also been done. The aim of the study is to identify the impact of internal heat exchanger on the sub-critical, as well as super-critical Organic Rankine Cycle. Net power output, thermal and exergy efficiency are the key performance analysis parameters observed in this study.
In the Brayton cycle, following processes are used

1-2: Isentropic compression of the compressor
2-3: Constant pressure heat inclusion in the combustion chamber
3-4: Isentropic Expansion of the turbine
4-1: Constant pressure heat rejection of the cooler.

For thermodynamic analysis of Brayton cycle the following assumptions are taken:

- The turbine's isentropic efficiency is taken to be 90% and pump's isentropic efficiency is taken to be 89%.
- The cycle is working at steady state conditions.
- Dropping of pressure in the heat exchangers can neglected.
- Minimum temperature of cycle is set as 25ºC.

2.2 Brayton Cycle with Intercooling

In this cycle multi compression is done in intercooler. The low-pressure stream is firstly made to enter a heat exchanger (pre-cooler) and was allowed to cool thereafter. The cooled flow was then made to go along the pre-compressor, from where it is made to compress to a halfway pressure. Then, the fluid enters the intercooler and is cooled down there again before entering the main compressor. Fig.2 shows the layout of Brayton cycle with Intercooling.

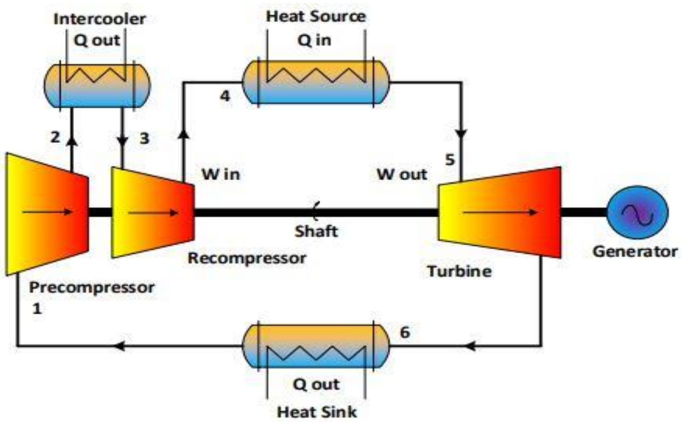

Figure 2: Brayton cycle with intercooling

The inlet temperature in the compressors does not need to be equal, but since only 1 cold sink is need to be used, the temperature should be equal. Hence, the compressor inlet temperature is alike in this above study.

2.3 Brayton cycle with Reheating

The third cycle is with reheating. Fig. 3 shows the layout of Brayton cycle with reheating. It is similar to simple Brayton cycle i.e. after compression process the gas goes to combustion chamber and then to the turbine for expansion, the only difference is that the expansion process is done in multiple stages i.e. first the gas will expand in High pressure turbine and after reheating it expands in low pressure turbine.

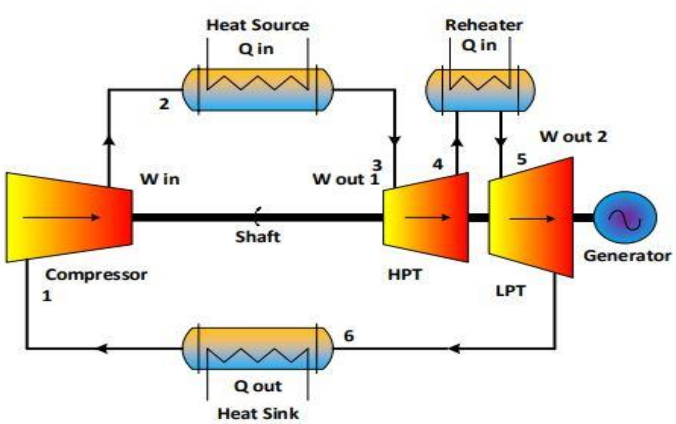

Figure 3: Layout of Brayton cycle with Reheating

The reheating resulted in the improvement of the cycle efficiency by raising the Carnot temperature of the cycle. The fluid at high pressure leaves the compressor and passes into the gas heater or heat exchanger as the cold stream (2). The stream at high temperature and pressure pass on to the HP turbine (3) and faces energy loss in the HP turbine door (4). Low- pressure stream has gained energy in the re-heater and made to exit through the LP turbine (5). It is possible to initiate more than one reheat stage where two reheat stages being used. In the case of 3 stages of reheat, there occurs an inclusion of another turbine body into the working system. At the end, the heat is rejected in the pre-cooler (6), where the working fluid is allowed to cool to the temperature according to the temperature of the compressor inlet

2.4 Brayton cycle with Intercooling and Reheating

In this given cycle, there is multistage compression and expansion. The stream, which exits from pre-cooler, enters into the pre-compressor (1) shown in Fig.4. After the stage of compression, the fluid passes on to an intercooler to dissipate heat (2). After the intercooler, stream enters to the main compressor (re-compressor) where its pressure and temperature increased (3).

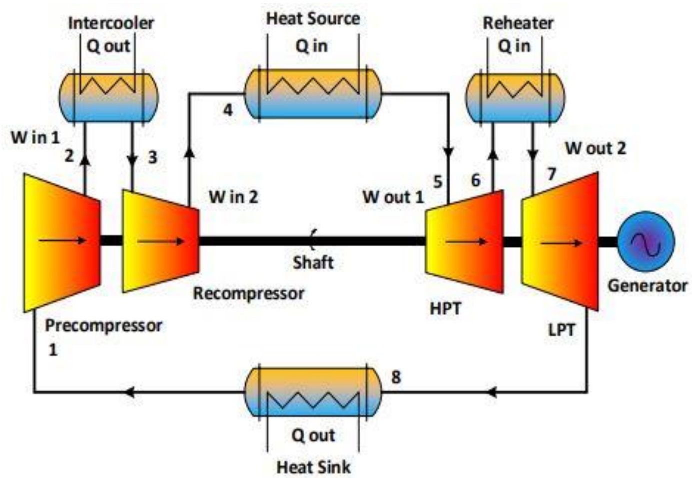

Figure 4: Layout of Brayton cycle with Intercooler and Re-heater

After this procedure, stream absorbs the heat from the heat exchanger (gas heater) (4 to 5) and made to move to HP turbine. The outlet fluid from HP turbine is hot in the re-heater at constant pressure (6). The low-pressure hot fluid (7) moves the LP turbine and allowed to expand there (8).After the generation of electricity, the fluid was made to go through heat sink where the remaining heat is dissipated and thereafter enters to a pre-compressor and the complete process starts all over again.

Thermal modelling

This chapter deals with the set of equations that are used for the different steps of analysis to be performed. They are presented in order of the showed system performance.

The equation of work of 1st compressor is

$$W_{in,precompressor} = h_2 - h_1 \quad (1)$$

The equation of work of 2nd compressor is

$W_{in,recompressor} = h_4 – h_3$ (2)

The equation for net compressor work is

$W_{in} = W_{in,precompressor} + W_{in,recompressor}$ (3)

The equation for high pressure turbine is

$W_{out,HPturbine} = h_6 – h_5$ (4)

The equation for low pressure turbine is

$W_{out,LPturbine} = h_8 – h_7$ (5)

The equation for net turbine work is

$W_{out} = W_{out,HPturbine} + W_{out,LPturbine}$ (6)

The equation for net work of the cycle is

$W_{net} = W_{out} – W_{in}$ (7)

The equation for heat input in combustor is

$q_{in,combustor} = h_5 – h_4$ (8)

The equation for heat input in reheater is

$q_{in,reheater} = h_7 – h_6$ (9)

The equation for net heat input is

$q_{in} = q_{in,combustor} + q_{in,reheater}$ (10)

The equation for heat output in intercooler is

$q_{out,intercooler} = h_2 – h_3$ (11)

The equation for heat output in heat exchanger is

$q_{out,hex}= h_8 – h_1$ (12)

The equation for net heat output in cycle is

$q_{out}=q_{out,intercooler} + q_{out,hex}$ (13)

The equation for thermal efficiency of the cycle is

$\eta = \frac{Wnet}{Qin}$ (14)

3. Results and Discussions

A steady temperature of 200ºC is used for warmth supply while maintaining a constant mass flow rate of 1 kg/sec. The Engineering Equation solver (EES) software package is utilized for analysis. A different approach to calculation of most heat exchange in Internal Heat Exchanger (IHE) is use when modelling a supercritical cycle, due to large dynamic heat component close to the critical point. Also, an alternative approach is required to compute the outlet temperature of the warmth source and identify the point of the pinch in supercritical cases. The results prove that IHE is useful in a subcritical case, but will improve system performance only partially for the low pressure stage in a supercritical scenario. In subcritical cycle it's discovered that power obtained is 27.33 kilowatt and cycle efficiency is 12.03% at an evaporator pressure of 1326 kPa and therefore the second law efficiency is 40.41% at an evaporator pressure of 1326 kPa using fluid R123. The cycle efficiency is coming out to be 11.27%, the second law efficiency is coming out to be 38.67% and net-work is 28.38 kW using fluid R245fa. Analysis is done on combined Organic Rankine cycle in which the exhaust coming out of heat exchanger of Brayton cycle is supplied to the Organic Rankine cycle. The analysis is done on both fluids R123 and R245fa.

In combined cycle the combined efficiency, Rankine efficiency, Brayton efficiency is 12.43%, 11.79%, 10.72% respectively at heater pressure 2600 kPa for fluid R245fa and 12.43%, 14.04%, 10.99% respectively for fluid R123. Also, in this study various cases of Brayton cycle is analyzed such as simple Brayton cycle, with intercooling, with reheating and with both intercooler and re-heater. The study is done on fluids R123 and R245fa.

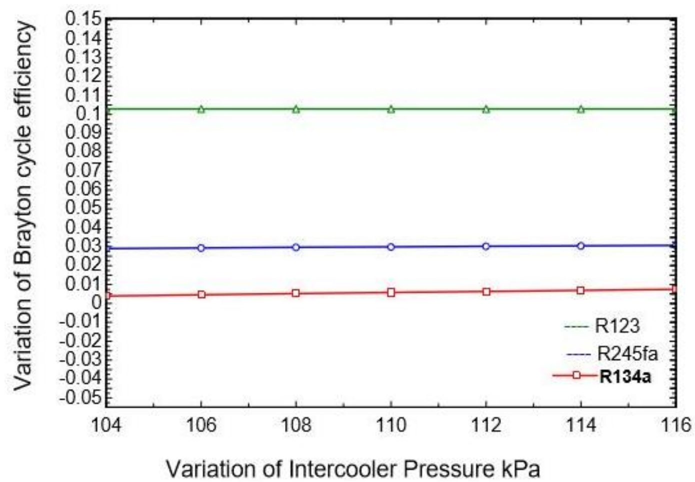

Figure 5: variation of cycle efficiency with intercooler pressure

Fig 5 shows the outcome of cycle efficiency by varying the intercooler pressure. As per the figure by increasing the intercooler pressure the cycle efficiency is also increasing. In this study analysis is done on three fluids i.e. R123, R245fa and R134a. From fig.5 the Brayton cycle efficiency at intercooler pressure 106kPa is 10.29%, 2.939% and 0.454% for fluid R123, R245fa and R134a respectively. Fig 6 shows the outcome of Brayton cycle efficiency by varying the maximum temperature of cycle. As per the figure by increasing the maximum cycle temperature the cycle efficiency is also increasing. In this study analysis is done on three fluids i.e. R123, R245fa and R134a. From fig.6 the Brayton cycle efficiency at temperature165 ºC is 10.29%, 3.023% and 0.6376% for fluid R123, R245fa and R134a respectively.

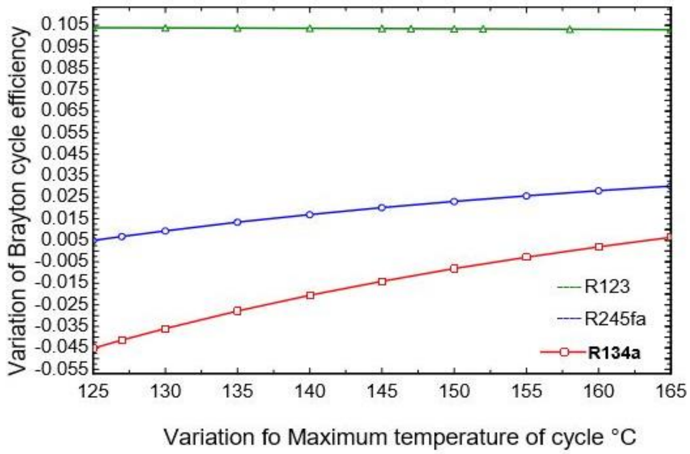

Fig 6 variation of cycle efficiency with maximum inlet temperature of turbine

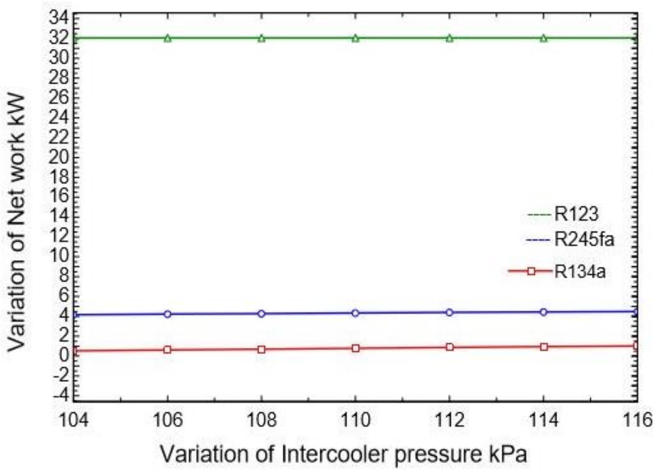

Fig 7 variation of net work of cycle with intercooler pressure

Fig 7 shows the outcome of net work by varying the intercooler pressure. As per the figure by increasing the intercooler pressure the net work is also increasing for R245fa and R134a but it is constant for R123. From fig.7 the Brayton cycle net work at intercooler pressure 106kPa is 32.04 kW, 4.217 kW and 0.6055 kW for fluid R123, R245fa and R134a respectively.

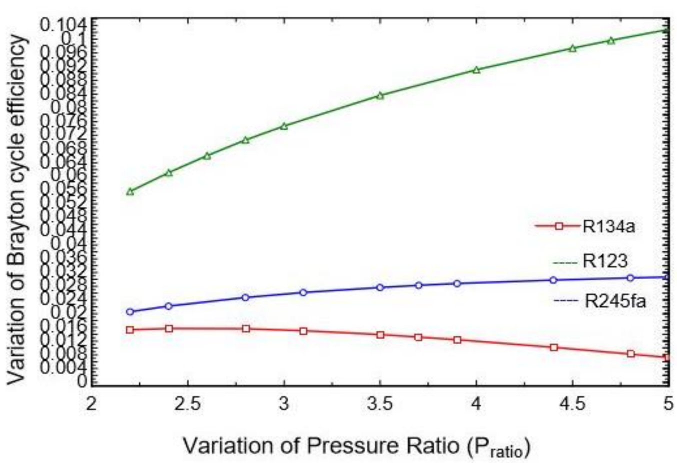

Fig 8 variation of cycle efficiency with pressure ratio

Fig 8 shows the outcome of cycle efficiency by varying the pressure ratio. As per the figure by increasing the intercooler pressure the cycle efficiency is increasing up to pressure ratio 3 and after thet it starts decreasing for R245fa while for R134a after pressure ratio 3 it decreases rapidly as compared to R245fa. It can be seen from the fig-8, on increasing of the pressure ratio efficiency is also increasing for R123.

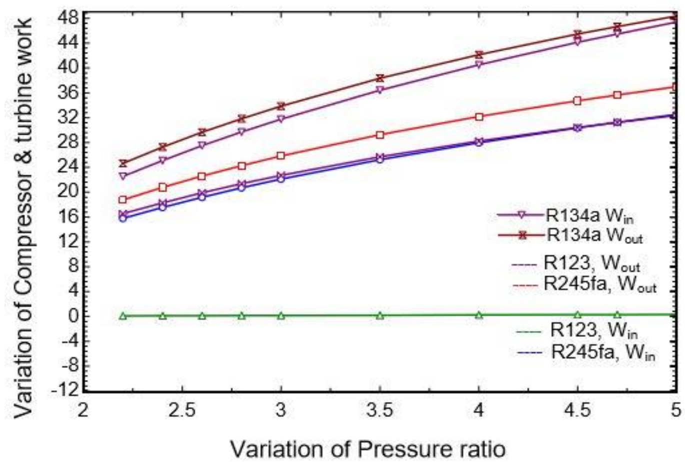

Fig 9 variation of compressor and turbine works with pressure ratio

Fig 9 shows the outcome of compressor and turbine work by varying the pressure ratio. As per the fig-9, by increasing the pressure ratio both compressor and turbine work is increasing for R123, R245fa and R134a.

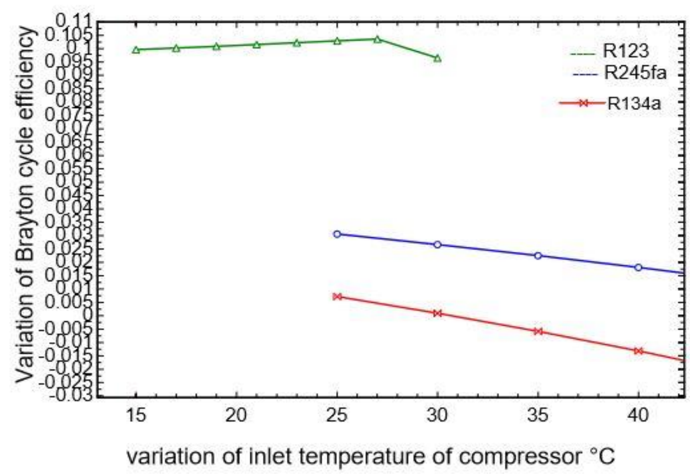

Fig 10 variation of Brayton cycle efficiency with inlet temperature of compressor

Fig 10 shows the outcome of cycle efficiency by varying the inlet temperature of compressor. As per the figure by increasing the inlet temperature of compressor the cycle efficiency is decreasing for R245fa and R134a while it is increasing for R123 upto 27ºC and after that it starts decreasing. From fig.10, the Brayton cycle efficiency at inlet temperature of compressor25ºC is 10.29%, 3.064% and 0.721% for fluid R123, R245fa and R134a respectively.

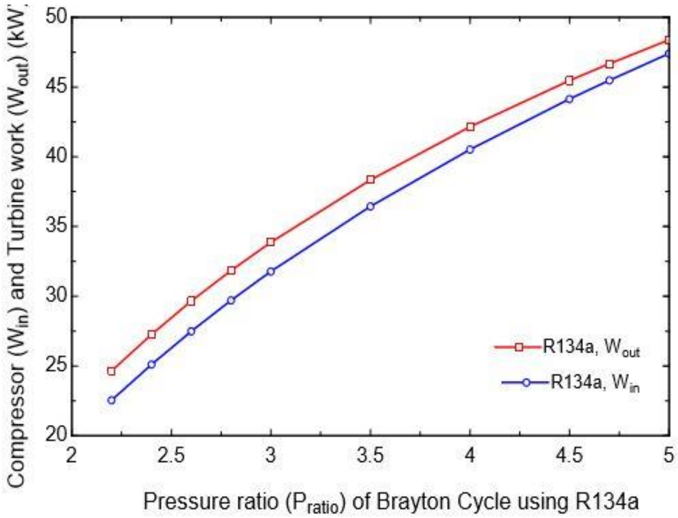

Fig 11 variation of compressor and turbine works with pressure ratio using R134a

Fig 11 shows the outcome of compressor and turbine work by varying the pressure ratio. As per the figure by increasing the pressure ratio the compressor and turbine work is also increasing for R134a. From fig.11, compressor and turbine work is 31.77 kW and 33.87 kW respectively at pressure ratio 3.

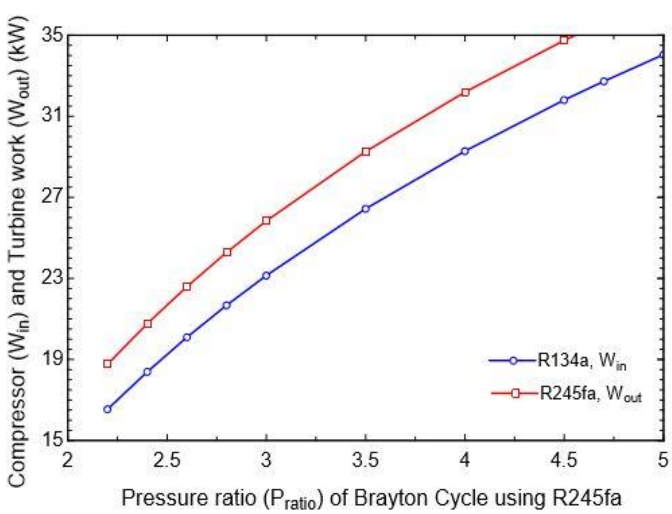

Fig 12 variation of compressor and turbine works with pressure ratio using R245fa

Fig 12 shows the outcome of compressor and turbine work by varying the pressure ratio. As per the figure by increasing the pressure ratio the compressor and turbine work is also increasing for R245fa. From fig.12, compressor and turbine work is 23.14 kW and 25.83 kW respectively at pressure ratio 3.

Fig 13, shows the outcome of compressor and turbine work by varying the pressure ratio. As per the figure by increasing the pressure ratio the compressor and turbine work is also increasing for R123. From fig.13, compressor and turbine work is 40.51 kW and 42.15 kW respectively at pressure ratio 4.

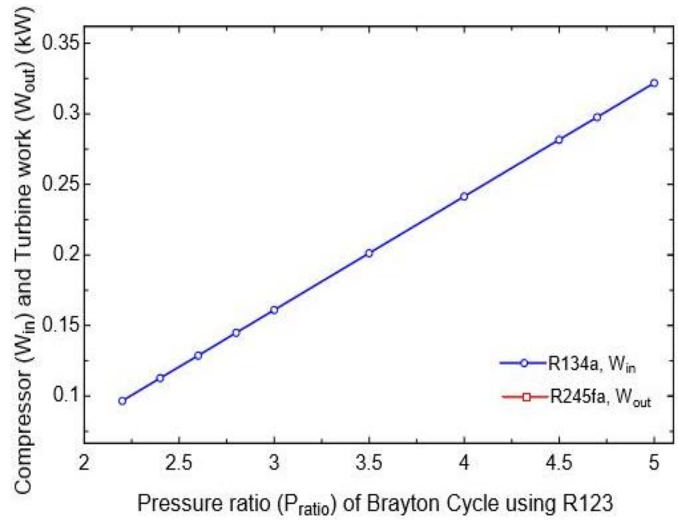

Fig 13 variation of compressor and turbine works with pressure ratio using R123

4. Conclusions

The following conclusion has been made from the above results

(i) As pressure ratio increases, the turbine & compressor work are increasing.

(ii) As intercooler pressure increases the cycle efficiency increases.

(iii) R123 is giving better performance than R245fa and R134a

References

[1] Serrano J.R., Dolz V., Novella R., Garcia A., 2011. HD Diesel engine equipped with a bottoming Rankine cycle as a waste heat recovery system. Applied Thermal Kevinj Engineering 36(2011), 279-287.

[2] Wang X. D., Zhao L., Wang J.L., Zhang W.Z., Zhao X.Z., W.Wu. 2009, Performance evaluation of low temperature Solar Rankine Cycle System utilizing R245fa. Solar Energy 84(2010), 353-364.

[3] Di GenovaKevinj., Botros Barbara B, Brisson J.G., 2012 Method for customizing on Organic Rankine cycle to a complex heat source for efficient energy conversion, demonstrated on Fischer Tropsch Plant. Applied Energy 102(2013) 746-754.

[4] Wang Dongxiang, Ling Xiang, PengHao, 2012. Performance Analysis of double organic Rankine cycle for discontinuous low temperature waste heat recovery. Applied thermal Engineering 48(2012) 63-71.

[5] Larjola J., 1994. Electricity from industrial waste heat using high speed organic Rankine cycle. International journal of Production Economics 41(1995) 227-235.

[6] Li Jing., Pei Gang, Li Yumhuli, JiJie., 2012. Evaluation of External heat loss from small scale expander used in organic Rankine cycle. Applied Thermal Engineering 31(2011) 2694-2701.

[7] Quilin S., Orosz M.,Hemond H., Lemort V., 2012. Performance and design optimization of Low cost solar organic Rankine cycle for remote power generation. Solar Energy 85(2011) 955-966.

[8] Herberle Florian, Bruggemann Dieter, 2010. Exergy based fluid selection for geothermal organic Rankine cycle for combined heat and power generation. Applied Thermal Engineering 30(2010) 820-880.

[9] Liu Bo., Riviere Philippe, Coquelet Christopher, Gicquel Renaud, David Frank, 2012. Investigation of a two stage Rankine cycle for Electric power Plants. Applied energy 100(2012) 285-294.

[10] Borsukiewiz- Gozdur Aleksandra, 2012. Pumping work in organic Rankine cycle. Applied thermal engineering 51(2013)781-786.

[11] Clemente Stefno, Michel Diego, Mauro Reini, TaccaoniRodolf, 2012. Energy Efficiency analysis of organic Rankine cycle with scroll expander. Appplied energy 97(2012) 792-801.

[12] Garcia Lourdes Rodriguez, Austin M.Delgado-Torres, 2006. Solar powered Rankine cycle for fresh water production. Desalination 212(2007) 319-327.

[13] Sprousell Charles, Depicl Christopher, 2012. Review of organic Rankine cycle for internal combustion engine Exhaust waste heat recovery. Applied Thermal Engineering 51(2013) 711-722.
[14] Herberle Florian, Bruggemann Dieter, 2010. Exergy based fluid selection for Geothermal Organic Rankine cycle for combined heat and power generation. Applied Thermal Engineering 30(2010) 1326-1332.
[15] Algieri Angelo, MorronePietropaolo, 2011. Comparative energetic analysis of high temperature sub-critical and transcritical organic Rankine cycle. Applied Thermal Engineering 36(2012) 236-244.
[16] Hui-tao Wang, Hu Wang, Zhu-ming Zhang, 2011. Optimization of low temperature exhaust gas waste heat fuelled organic Rankine cycle. Journal of Iron and Steel Research, International 2012,19(6), 30-36.
[17] Kosmadakis G, Manolakos D, Papadakis G, 2009. Parametric Theoretical study of a two stage solar organic Rankine cycle for RO desalination 2009, Renewable Energy 35(2010) 989-996.
[18] P.J. Mago, K.K. Srinivasan, L.M. Chamra, C. Simayaji, An examination of exergy destruction in organic Rankine cycles, Int. J.Energy Res 32(2008) 926-938.
[19] W. Li, X. Feng, L.J. Yu, J. Xu, Effects of evaporating temperature and internal heat exchanger on organic Rankine cycle, Appl. Therm. Eng. 31(2011) 4014-4023.
[20] Y.P. Dai, J.f. Wang, L. Gao, Parametric optimization and comparative study of organic Rankine cycle (ORC) for low grade waste heat recovery, Energy Convers, Manag. 50(2009) 576-582.
[21] Karellas S, Schuster A., Supercritical fluid parameter in organic Rankine cycle Applications. International Journal of Thermodynamics, 2008. 11(3), 1018.
[22] V. Lemort, S. Quoilin, C. Cuevas, J. Lebrun, Testing and modeling a scroll expander integrated into an organic Rankine cycle, Appl. Therm. Engg. 29(2009) 3094-3102.
[23] A. Schuster, S. Karellas, E. Kakaras, H. Spliethoff, Energetic and economic investigation of organic Rankine cycle applications, Appl. Therm. Eng. 29(2009) 1809-1817.
[24] F. Heberle, D. Bruggemann, Exergy based fluid selection for a geothermal organic Rankine cycle for combined heat and power generation, Appl. Therm. Eng. 30(2010) 1326-1332.
[25] J.P. Roy, M.K. Mishra, A. Mishra, Parametric optimization and performance analysis of a waste heat recovery system using organic Rankine cycle, Energy 35(2010) 5049-5062.
[26] J. Li, G. Pei, Y.Z. Li, J. Ji, Evaluation of external heat loss from a small-scale expander used in organic Rankine cycle, Appl. Therm. Eng. 31(2011) 2694-2701.
[27] S. Quoilin, R. Aumann, A. Grill, A. Schuster, V. Lemort, H. Spliethoff, Dynamic modeling and optimal control strategy of waste heat recovery organic Rankine cycle, Appl. Energy. 88(2011) 2183-2190.
[28] N. Yamada, M.N.A. Mohammad, T.T. Kien, Study on thermal efficiency of low to medium temperature organic Rankine cycles using HFO-1234yf, Renew. Energy 41(2012) 368-375.
[29] F.A. Al-Sulaiman, I. Dincer, F. Hamdullahpur, Thermo-economic optimization of three tri-generation systems using organic Rankine cycles: part 1 – formulations, Energy Convers. Manag. 69(2013) 199-208.
[30] F.A. Al-Sulaiman, I. Dincer, F. Hamdullahpur, Thermo-economic optimization of three tri-generation systems using organic Rankine cycles: part II – applications, Energy Convers. Manag. 69(2013) 209-216.
[31] World Energy Outlook 2013. 2013; International Energy Agency]. Available from: http://www.iea.org/.
[32] Horuz, I. and B. Kurt, Absorption heat transformers and an industrialapplication. Renewable Energy, 2010. 35(10): p. 2175-2181.
[33] Klein, S.A. and F. Alvarado, Engineering Equation Solver, version 9.237, FChartSoftware. Middleton 2012.
[34] Kim, Y.M., C.G. Kim, and D. Favrat, Transcritical or supercritical CO2 cyclesusing both low- and high-temperature heat sources. Energy, 2012. 43(1): p.402-415.
[35] Institute, P. Energy Source: Solar Energy. Renewable Energy. . 2011;Available from: http://www.pembina.org/re/sources/solar.
[36] Chen, H., The Conversion of Low-Grade Heat into Power Using SupercriticalRankine Cycles, in Chemical and Biomedical Engineering. 2010, Universityof South Florida.
[37] Stijepovic, M.Z. and P. Linke, Optimal waste heat recovery and reuse inindustrial zones. Energy, 2011. 36(7): p. 4019-4031.
[38] R.S. Mishra &Manish Kumar [2018] Thermodynamic models for combined cycle power plants used in organic Rankine&Brayton Cycles, International Journal of research in Engineering and innovation (IJREI) e-ISSN: 2456 -6934 , Vol: 02, Issue: 04 ,2018, 449-463
[39] R.S. Mishra &Manish Kumar [2018]Thermodynamic analysis of modified rankine cycle used for power generation, International Journal of research in Engineering and innovation (IJREI) e-ISSN: 2456 -6934, Vol: 02, Issue: 01, 2018, 33-40.
[40] R.S. Mishra &AakashBehl [2018]Thermodynamic analysis of combined cycle power plant with trans-critical cycle integrated with solar system for power generation for space heating and cooling, International Journal of research in Engineering and innovation (IJREI) e-ISSN: 2456 -6934, Vol: 02, Issue: 04, 2018, 423-441

Cite this article as: R.S. Mishra, Manish Kumar, Thermodynamic analysis of brayton cycle for power generation, International Journal of Research in Engineering and Innovation Vol-3, Issue-4 (2019), 282-290.