Thermodynamic and exergy economic analysis combined heat power and cooling in a combined cycle with Ejector using solar energy

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ABSTRACT

Combined heat and power systems are used to renewable energies and reducing fossil fuels. In this work, investigated energy efficiency, exergy and exergy economic a Brayton cycle and refrigeration cycle with ejector that used solar energy as heat source. Inlet pressure turbine, outlet pressure turbine, inlet temperature turbine and temperature of evaporator are as variable parameters, when one of the parameters changes, the other parameters are kept constant, so that the thermodynamic analysis focuses on important parameters. Results showed that inlet pressure of initial flow in ejector and out let velocity of flow on ejector are increased with increasing outlet pressure of turbine. Storage tank had most exergy destruction rate among all components for high temperature difference that it's almost 29% from all of the exergy destruction rate. Also, the highest cost per unit power is related to the combine heat and power cycle that it's about 53% of the total cost.

KEYWORDS

Exergy, Combined heat power, ejector, solar energy

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1. Introduction

In combined cooling, heating and power (CCHP) systems can be generated simultaneously three different forms of energy such as cooling, heating and power. It's including various technologies, provide an alternative for the world to meet and solve energy-related problems, such as energy shortages, energy supply security, emission control, the economy and conservation of energy, etc [1]. the knowledge of CCHP back to more than 100 years ago but, its development has been very slowly and its limited to absorption chiller in large scale. Initial energy sources of CCHP are oil products, natural gas, coal, biomass and hydrogen and useful energy production are heat, cooling and power that mechanical power energy is often used to start generator [2]. A slight difference between CCHP and CHP is that thermal or electrical/mechanical energy is further utilized to provide space or process cooling capacity in a CCHP application. In some literature, CCHP systems are also referred to as trigeneration and building cooling heating and power (BCHP) systems. In this research, investigated a thermodynamic and exergy economic analysis combined heat power and cooling in a combined cycle with Ejector using solar energy. It studied a new cycle for generating power, heat and cooling simultaneously based on solar energy as energy source. Using solar energy is one of the method for decreasing electricity consumption. It's added a heat storage tank when there is no solar energy for decreasing pollution. In his system, used an organic Rankin cycle as primary stimulus and used hollow cylindrical collectors as solar energy collectors.

2. Geometry and mathematical equation

Diagram of the solar system with power cycle has been shown in Figure 1. It's investigated a control volume for each components of the cycle and all of the parameters are achieved by conservations mass, momentum and energy laws. Working fluid are water and carbon dioxide in solar cycle and combine cycle respectively. Inlet flow rate to collectors is 10 Kg/s. table 1 showed value of temperature and pressure on each component of cycle. First law of thermodynamic, conservation mass law and rate of useful heat rate received from the collector are achieved as follow [3]:

$$\Delta_{out}^{in}\left(\sum_i \dot{m}_i .h_i\right)+\Delta_{out}^{in}\left(\sum_j Q_j\right)+\Delta_{out}^{in}\left(\sum_k W_k\right)=0 \tag{1}$$

$$\Delta_{out}^{in}\left(\sum_i \dot{m}_i\right)=0 \tag{2}$$

$$Q_u = F_R WL[S-\frac{U_{lo}}{C}(T_{fi}-T_0)] \tag{3}$$

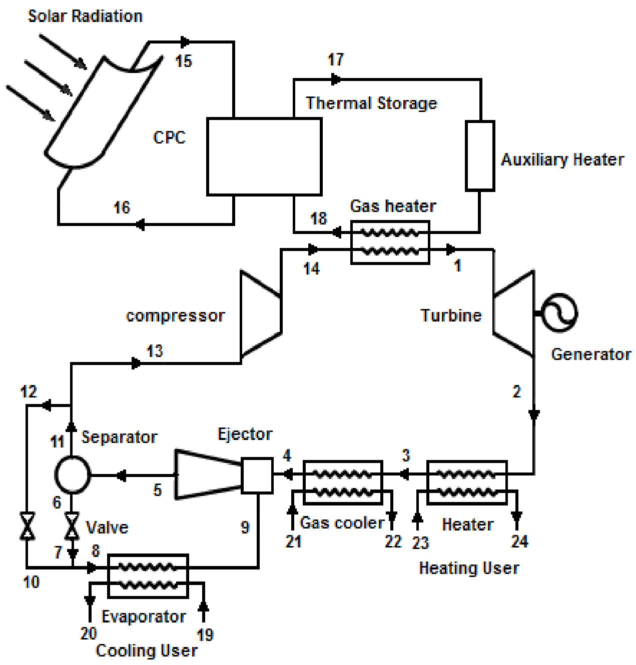

Figure 1. Diagram of the solar system with power cycle

3. Area heat transfer

For calculating heat transfer area used experimental equations. Pressure drop in heat exchanger is considered as one of the convergence conditions for calculating heat transfer area. Physical properties of heat exchanger and specification of stream is required for achieving heat exchanger area overall heat transfer coefficient. In this study, used parabolic collector due to high efficiency. In gas heater and gas cooler cycle used single-phase flow regime and in evaporator is used two-phase flow regime for modeling and achieving heat transfer coefficient and heat transfer area. Overall heat transfer is achieved as follow [4]:

$$Q_s = U_s A_s \Delta t_m \tag{4}$$

Where U_s overall heat transfer coefficient, A_s heat transfer area and Δt_m logarithmic difference temperature between hot and cold surface. Overall heat transfer coefficient is achieved follow:

$$\frac{1}{U_s}=\frac{1}{h_h}+\frac{\delta}{\lambda_m}+\frac{1}{h_c} \tag{5}$$

h_h and h_c convection heat transfer coefficient hot and cold respectively. Nusselt number is given as follow in heat exchanger

$$Nu = 0.724(\frac{6\beta}{\pi})^{0.646}\,\mathrm{Re}^{0.583}\,\mathrm{Pr}^{1/3} \tag{6}$$

4. Results

For validation of thermodynamic model, thermal and exergy efficiency this study has been compared with Wang [3] and shown in Table 1.

Table 1. Comparing results this work with Ref. [3]

	This work	Ref.[3]
Heat of collector (KW)	135.02	135.27
Power of Turbine (KW)	25	25.182
Power of compressor (KW)	24.71	25.07
Power of cooling (KW)	7.69	7.96
Power of Heating (KW)	63.3	63.54
Heating efficiency (%)	53.62	53
Exergy efficiency (%)	29.41	28.8
Cost on time ($/MJ)	139.8	

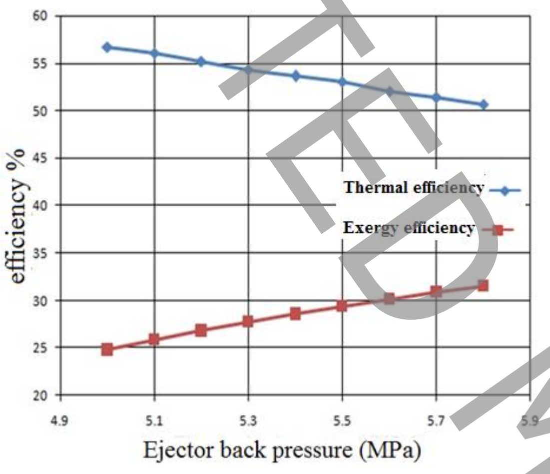

Figure 2. Effect of ejector back pressure on efficiency

Figure 2 showed effect of ejector back pressure on thermal and exergy efficiency. Drop of enthalpy is decreased with increasing of outlet pressure of turbine. To keep constant condition of inlet and outlet compressor, it's assumed that work of compressor is constant. Temperature of outlet turbine is increased with increasing outlet pressure of turbine, therefore, heat of heater is increased. Pressure of initial of inlet flow to jet pump is increased with increasing outlet pressure of turbine, also, mass flow of inlet saturated steam is decreased that quality of carbon dioxide input to the evaporator is decreased too. Therefore, difference of enthalpy is increased in evaporator. It's make that cooling in evaporator, thermal and exergy efficiency are increased. Figure 3 showed effect of turbine inlet pressure on area. Sum of heat transfer area is increased with increasing turbine inlet pressure. Also, mass flow of carbon dioxide is increased with increasing temperature. In other words, temperature of fluid is increased with increasing pressure. Therefore, for increasing heat transfer is required bigger heat transfer area for all of heat exchangers in the cycle.

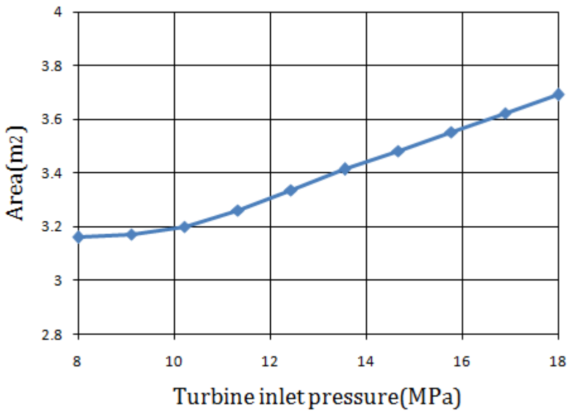

Figure 3. Effect of area on turbine inlet pressure

5. Conclusion

In this study, investigated a Brayton cycle and critical passage of carbon dioxide with jet pump using solar energy as heat source. Pressure of initial stream to jet pump and velocity of stream in outlet of nuzzle are increased with increasing outlet pressure of turbine. For high temperature difference, the reserve tank had most rate of exergy destruction in all of the component. Increasing temperature of evaporator had very little effect on thermal and exergy efficiency. The highest cost on power is related to outlet cooling form combined cycle that it's almost 53% of all of the costs.

6. References

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