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Steam Condenser Exergy Analysis of Steam Power Plant at Different Loads

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Conflicts of Interest
There are no conflicts to declare.

ABSTRACT

This paper presents steam condenser exergy analysis of 50 MW unit of the power plant by varying the ambient temperature from 5 C to 42 C at different loads. The performance parameters and the dependent variables are the exergy entering in the condenser, exergy out from the condenser, exergy efficiency of the plant, exergy destruction in the condenser and the exergy efficiency of condenser. Whereas the independent variables are ambient temperature and condenser pressure. It was seen that increases of exergy efficiency of the plant depends on combined effect of ambient temperature and condenser pressure as the sole variation of ambient temperature doesn't have much effect on the performance parameters. The varying of ambient temperature without altering the condenser pressure doesn't have any significant impact but by varying simultaneously the ambient temperature along with the changing of condenser pressure has profound effect on the performance parameters. As the Condenser pressure increases the heat loss is also increasing which shows the major portion of energy loss occurs in condenser. In comparison of heat loss in condenser the exergy destruction in condenser is very less. At the optimal condenser pressure 0.00804 MPa the exergy efficiency of the whole unit, exergy destruction in condenser, exergy efficiency of condenser, Heat loss (Q) in condenser and Wtotal are as 26.26%, 198.1KW, 99.72%, 81190 KW and 53.4 MW respectively and the optimal condition is attained at the full load(100%) or designed operating parameters.

Keywords: Condenser Pressure, Designed, Destruction, Exergy, Ambient temperature, Parameters.

1 Introduction

The condenser is an integral part of any steam power plant and it performs function of condensation where exhausted steam after expansion in turbine comes to the condenser to be converted back into the liquid by the help of cooling effect either through cooling water or by air circulation by transferring heat by the indirect mixing of two fluids [1,2]. Inside the steam condenser, pressure is quite lower than that of the atmospheric pressure (usually vacuum between 90 % and 95 %), so condenser operation also has an important impact on the low- pressure turbine process [3, 4]. Primary vacuum in the steam condenser is ensured with steam condensation process (significant decrease in the steam volume) after which the vacuum is maintained with steam ejectors, in most of the cases. Exergy technique is one of the most employed methods to determine the efficiency and losses in the energy systems and it is independent of heat transfer inside the condenser, number of condenser tubes or cooling water passages through the condenser, as well as condensation type which occurs on the condenser tubes are not essential elements. The exergy analysis can be carried out by just knowing the values of pressures, temperatures, mass flows of the entire fluid stream at the inlet and outlet of steam condenser [5]. In this paper are presented the results of the steam condenser exergy analysis at different loads. The analyzed steam condenser is a water-cooled condenser. As the exergy analysis is very dependable on the ambient temperature, at each condenser load the ambient temperature is varied in order to obtain steam condenser exergy losses and efficiencies at different ambient temperatures. Through the exergy analysis the parametric based exergy analysis was performed on the steam cooling tower effectiveness by performing energy, exergy balance and mass balance [6]. Through energy and exergy analyses the efficiency, losses and destructions were computed in the components of steam power plant and it was found that most of the exergy destruction happens in boiler (93.84%) and the lease exergy destruction occurs in condenser (0.306%) and condenser has highest exergy efficiency (94.89%)of all components [7]. Jamali,et al [8] carried out the energy and exergy analyses of the boiler and its parts furnace, economizer and superheaters and results showed maximum destruction in furnace and it was found that most of the exergy destruction occurs in furnace and it contributes to the loss of valuable energy thus losing major chunk of fuel as a wastage so there is need of overhauling and replacing the furnace with the latest and advanced one. Another important study was carried out in which the thermoeconomic with regression and optimization of 50 MW unit of Steam Coal Power plant was conducted which showed profound effect of condenser pressure on the performance parameters [9].

2 Steam condenser description

As the steam after expansion in turbine comes into condenser where the condensation takes place by the indirect mixing of cooling liquid especially water from cooling tower with the hot steam from turbine and heat transfer takes place where the cooling water takes out heat from exhausted steam and makes it saturated liquid which is again recirculated to the cycle for steam production through the pump as can be seen in figure 1 of Condenser working and operation. There are several types of condensation process which can occur on the condenser tubes [10]. After steam condensation, obtained condensate at the condenser bottom is taken by condensate pump [11] and delivered to condensate heating system

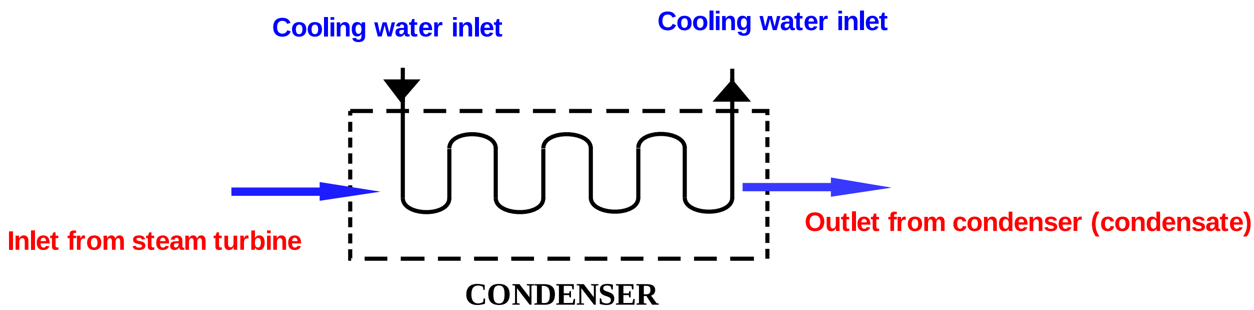


Figure 1 Condenser working and operation

3 Equations necessary for the exergy analysis

Exergy analysis of any system or a control volume is defined according to the second law of thermodynamics. The exergy balance equation for a control volume or a system in steady state, can be defined by following equation:

The main equations based on three fundamental principles are utilized for the model development, as given below. The conservation of mass, first law and second law of thermodynamics for a steady flow process reduces to the form given in Eqns. (1) to (3), respectively.

$$\sum \dot{m}_i = \sum \dot{m}_e \quad (1)$$

$$\dot{Q} - \dot{W} + \sum \dot{m}_i h_i - \sum \dot{m}_e h_e = 0 \quad (2)$$

$$\dot{Ex}_Q - \dot{Ex}_W + \sum \dot{m}_i ex_i - \sum \dot{m}_e ex_e - \dot{Ex}_D = 0 \quad (3)$$

In Eqn. (3) left hand side consists of exergy transfer due to heat and work, inlet and exit fluid physical exergy flow, and exergy destruction rate. The specific physical exergy flow of the fluid is given by Eq. (4).

$$ex = (h - h_0) - T_0(s - s_0) \quad (4)$$

The performance parameters are calculated using Eqns. (5) to (7).

$$\dot{W}_{net} = \dot{W}_t - (\dot{W}_{cp} + \dot{W}_{fwp} + \dot{W}_{LPHp} \quad (5)$$

$$EnE = \frac{\dot{W}_{net}}{\dot{Q}_f} \quad (6)$$

$$ExE = \frac{\dot{W}_{net}}{\dot{Ex}_f} \quad (7)$$

$$Qcondloss = mihi - moho \quad (8)$$

Energy balance on the control volume

$$m_{tur}h_{tur} + mct_{in} = m_{condensateout}h_{condensateout} + m_{ctout}h_{ctout} \quad (9)$$

$$\text{Exergy}_{\text{in condenser}} = e_{inlet\ from\ steam\ turbine} - e_{out\ as\ condesate} \quad (10)$$

$$\text{Exergy}_{\text{out from condenser}} = e_{outlet\ to\ cooling\ tower} - e_{inlet\ from\ cooling\ tower} \quad (11)$$

$$\text{Exergy}_{\text{destruction condenser}} = \text{Exergy}_{\text{in condenser}} - \text{Exergy}_{\text{out from condenser}} \quad (12)$$

$$\text{Exergy}_{\text{efficiency condenser}} = \text{Exergy}_{\text{out from condenser}} / \text{Exergy}_{\text{in condenser}} \quad (13)$$

4 Results and Discussion

By performing energy and exergy balance on through the main equations of balance by the help of Engineering Equation Solver (EES) the operating parameters relation against performance parameters was witnessed and different results were obtained which are given in table 1 and 2.

Table:1 Effect of varying Ambient temperature keeping condenser pressure constant (0.00804 MPa) on the performance parameters.

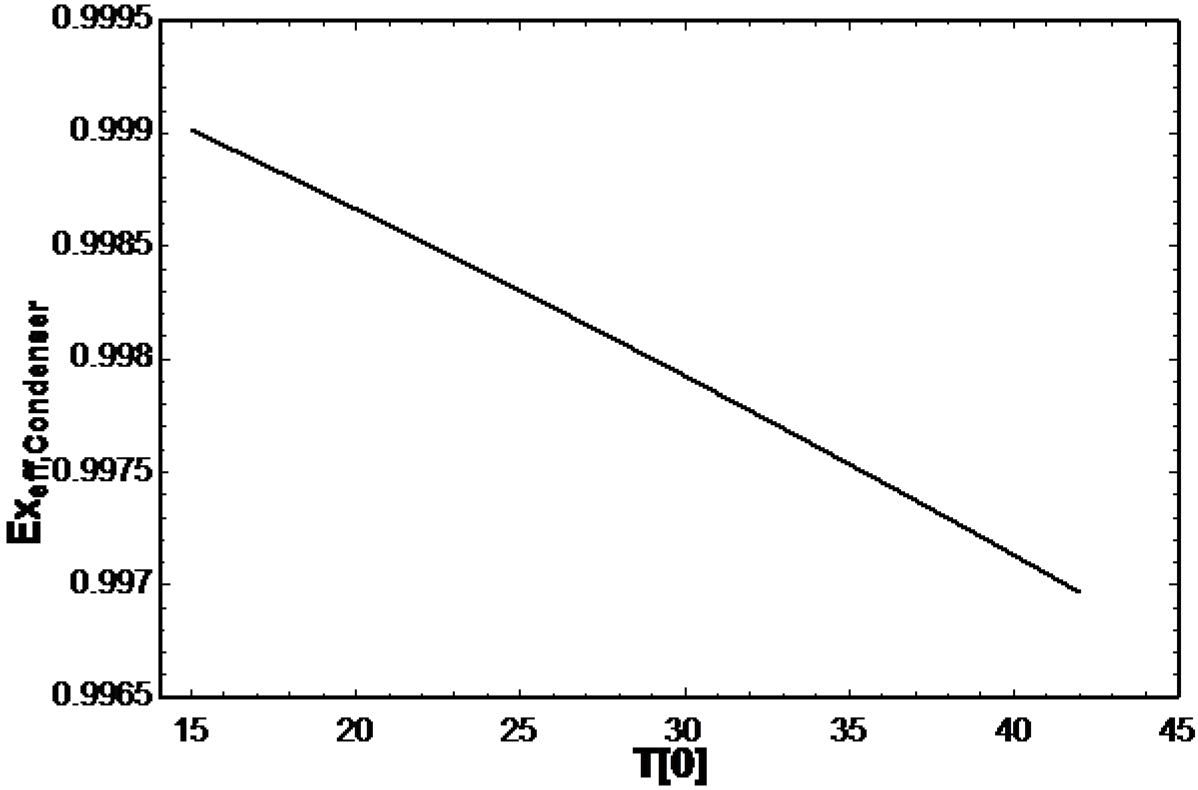
Ambient Temperature (C)	Exergy Destruction in Condenser (KW)	Exergy out from condenser (KW)	Exergy entering in condenser (KW)	Exergy efficiency of Condenser
15	76.2	77244	77321	0.999
18	91.44	76455	76547	0.9988
21	106.7	75666	75773	0.9986
24	121.9	74877	74999	0.9984
27	137.2	74088	74225	0.9982
30	152.4	73299	73452	0.9979
33	167.6	72510	72678	0.9977
36	182.9	71721	71904	0.9975
39	198.1	70932	71130	0.9972
42	213.4	70143	70356	0.997

Table:2 Effect of varying Ambient temperature by also changing condenser pressure on the performance parameters.

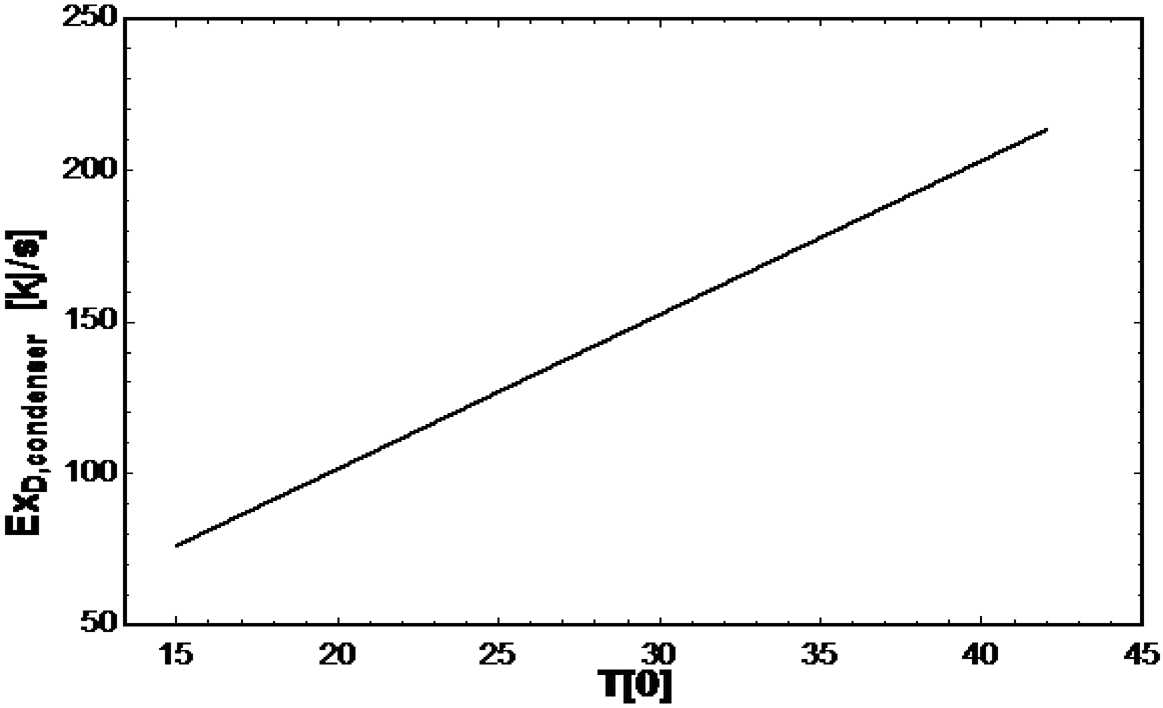
Ambient Temperature(C)	Condenser Pressure (MPa)	Exergy efficiency of the plant Unit of 50MW (%)	Exergy Destruction in condenser (KW)	Exergy out from condenser (KW)	Exergy entering in Condenser (KW)	Heat loss (Q) in Condenser (KW)	Wtotal of plant (KW)
15	0.095	19.87	687.3	79922	80609	84002	40483
18	0.09	20.05	807.8	79053	79861	83946	40838
21	0.086	20.2	925.9	78193	79119	83899	41134
24	0.072	20.76	984.5	77204	78189	83711	42274
27	0.055	21.58	983.1	76124	77107	83418	43944
30	0.041	22.44	943.4	75016	75960	83090	45685

33	0.024	23.89	744.5	73660	74404	82475	48628
36	0.009	26.06	246.3	71839	72085	81323	53043
39	0.00804	26.26	198.1	70932	71130	81190	53441
42	0.0071	26.47	134.8	70013	70148	81043	53844

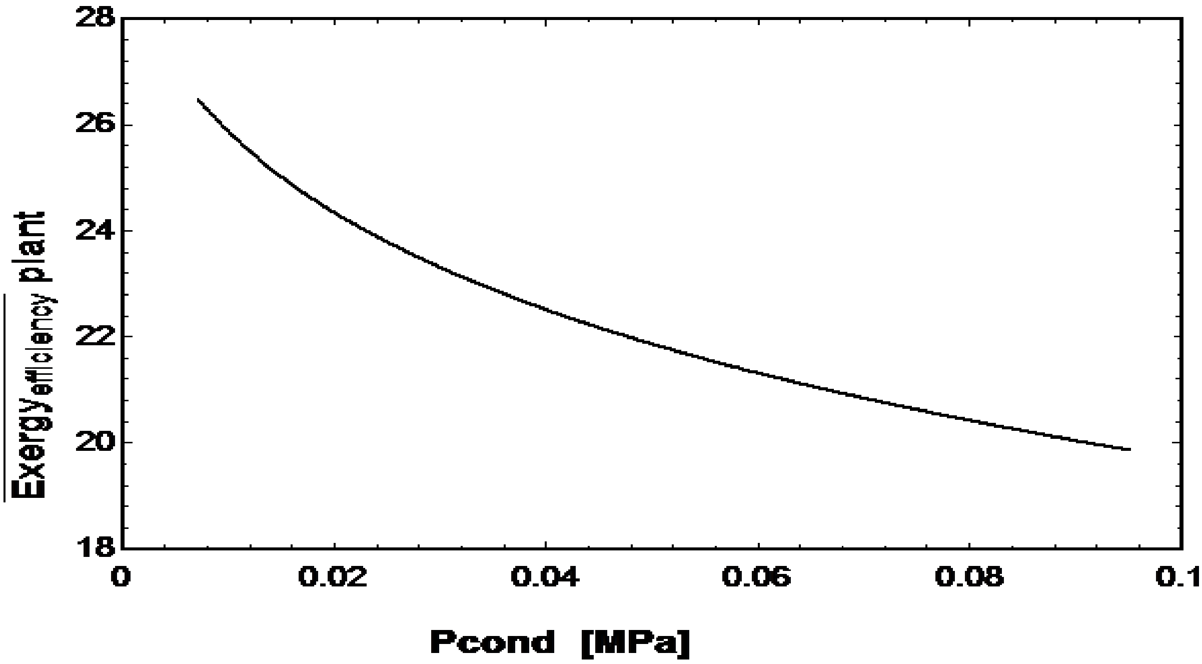
It is witnessed from the above table 1 that sole although ambient temperature has little effect on the exergy efficiency and destruction whether it be of condenser or whole plant unit yet the combined and cumulative effect of condenser pressure and ambient temperature has profound effect on the efficiency, destruction and losses of the system. In the below graphs 1,2,3, 4, 5,6,7,8 and 9 various effects are observed at different conditions. It is observed that with the reducing of condenser pressure the power output, exergy efficiency and energy efficiency is increased significantly. It is completely confirmed that by the lowering of condenser pressure the exergy efficiency increases significantly but due to limitation and constraints the further lowering of condenser pressure isn't possible and also the exergy destructions and the heat loss in condenser reduces to a great extent by lowering the condenser pressure so condenser pressure plays vital and significant role in enhancing the efficiency and reducing the losses and if this major component of the power plant is fixed and maintained properly the losses of fuel, water and energy can be minimized and the cheap power production will occur which will benefit ultimately the consumer who are the end users of power significantly and will also boost trade and business therefore this will have trickle-down effect on the economy.



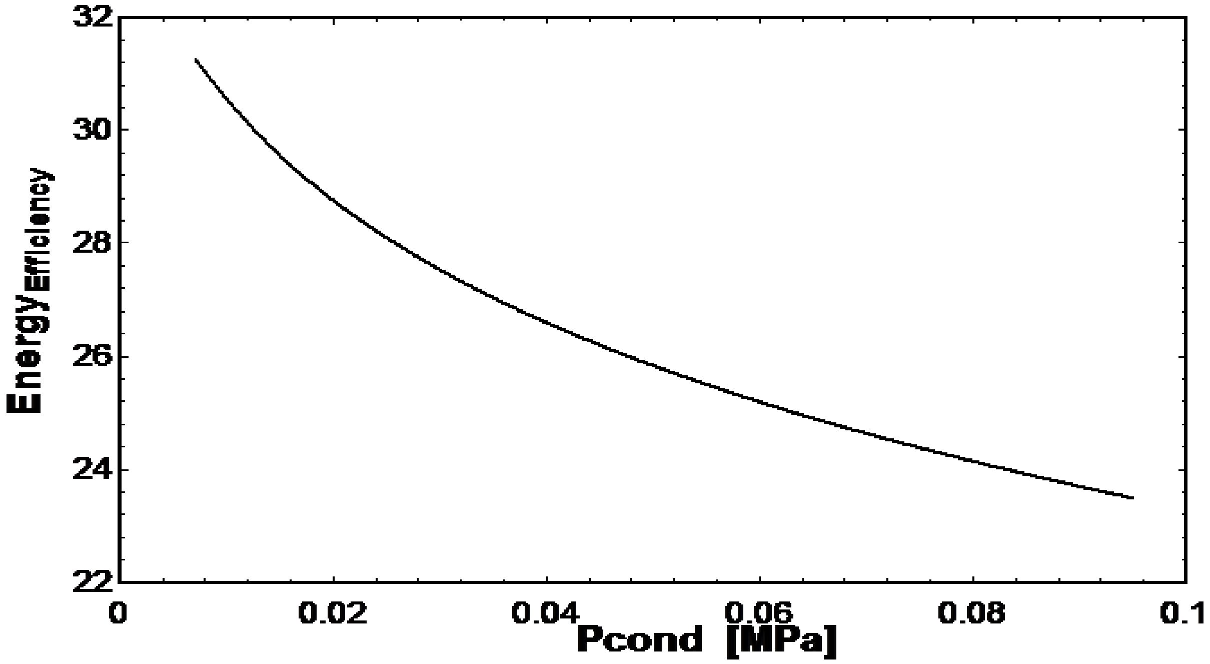
Graph :01 shows Ambient temperature effect on the Exergy efficiency of Condenser.



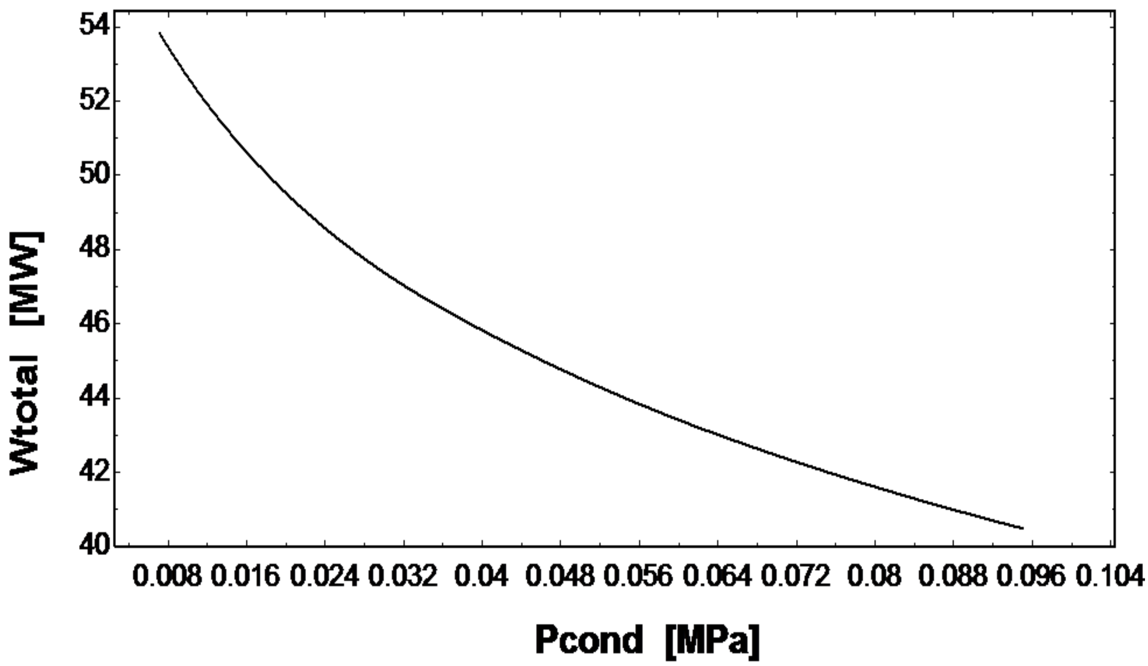
Graph :02 shows Ambient temperature effect on the Exergy destruction (KW) in Condenser.



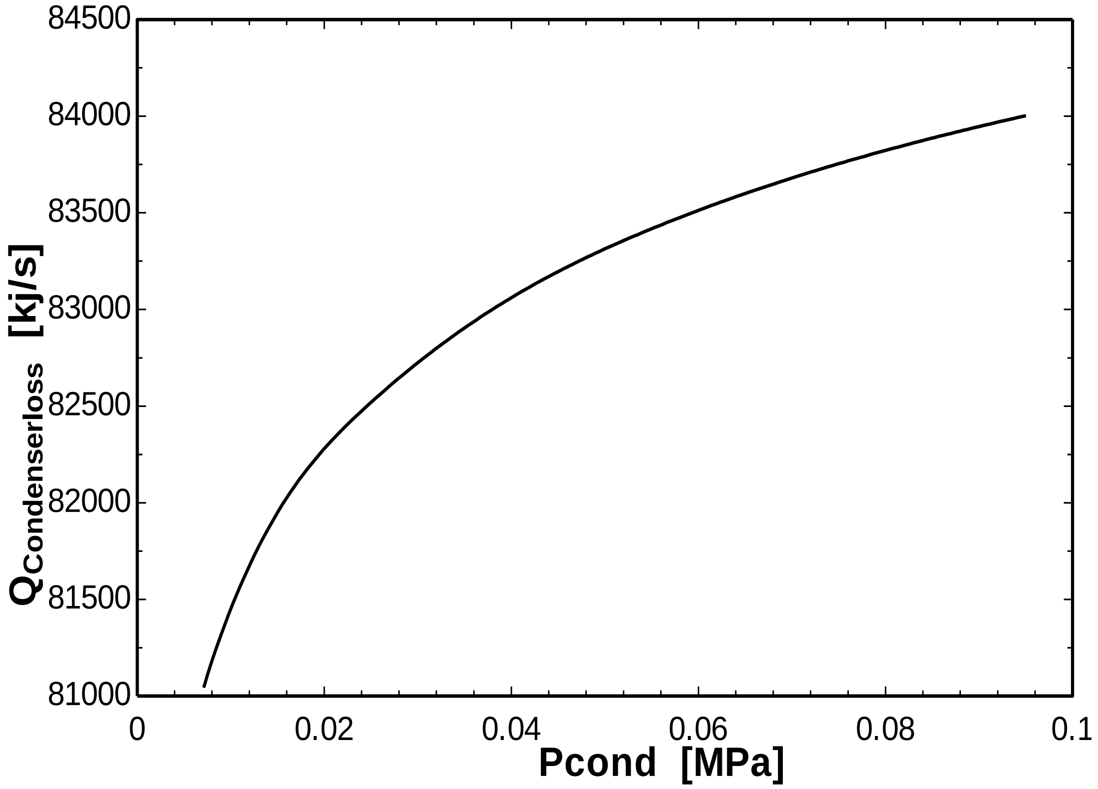
Graph :03 shows Effect of Condenser pressure on the Exergy efficiency of unit of 50MW of plant.



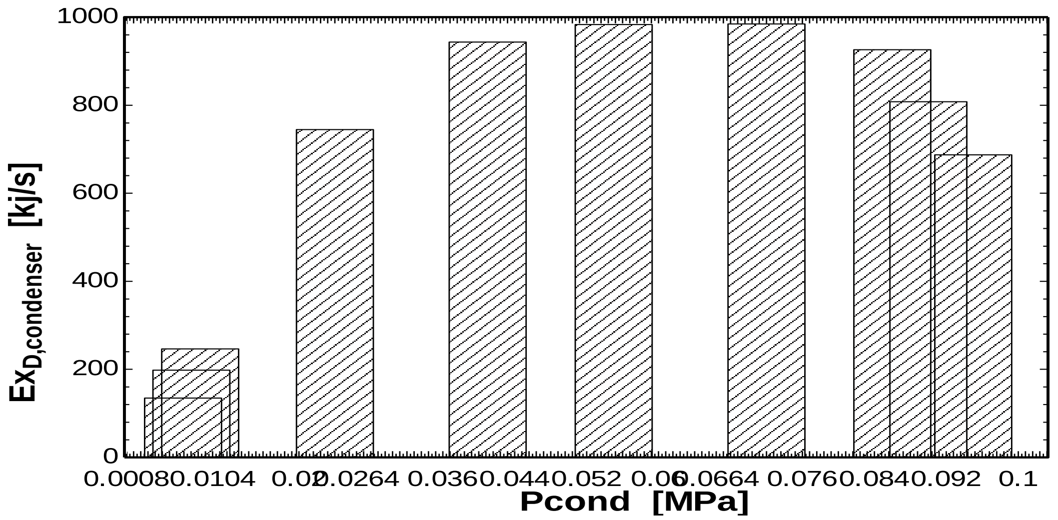
Graph :04 shows Effect of Condenser pressure on the Energy efficiency of unit of 50MW of plant.



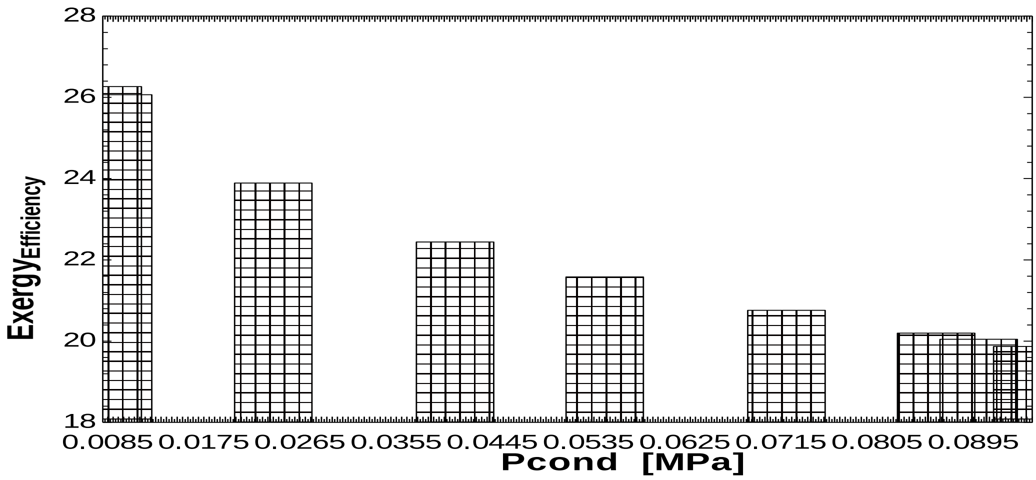
Graph :05 shows Effect of Condenser pressure on the Work output of unit of 50MW of plant.



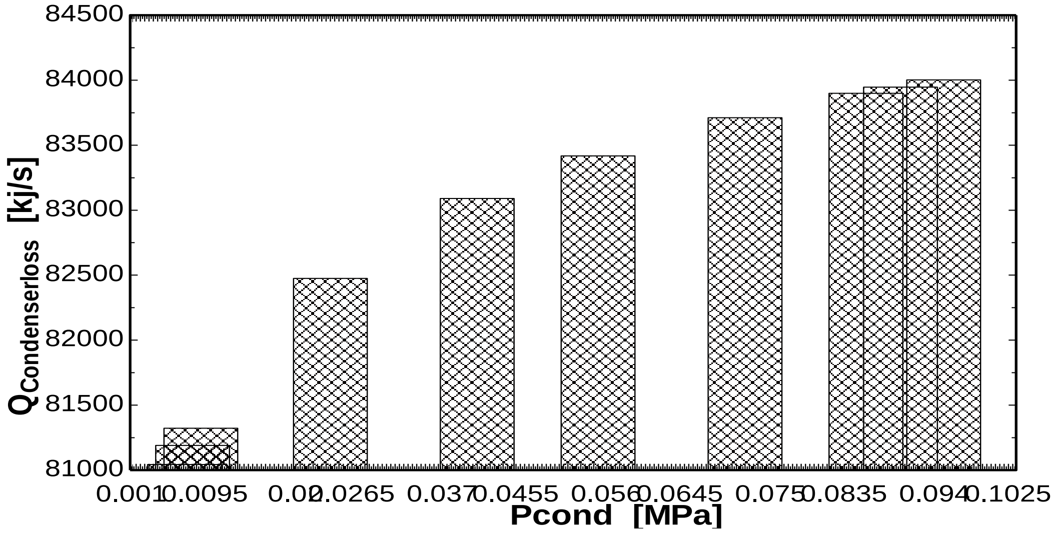
Graph :06 shows Effect of Condenser pressure on the Heat loss KW (Q) in condenser.



Graph :07 shows Effect of Condenser pressure on the Exergy destruction (KW) in condenser.



Graph :08 shows Effect of Condenser pressure on the Exergy efficiency of the unit of plant.



Graph :09 shows Effect of Condenser pressure on the Heat rejected KW (Q) in condenser.

Conclusion

The performance parameters and the dependent variables are the exergy entering in the condenser, exergy out from the condenser, exergy efficiency of the plant, exergy destruction in the condenser and the exergy efficiency of condenser. Whereas, the independent variables are ambient temperature and condenser pressure. It was seen that increases of exergy efficiency of the plant depends on combined effect of ambient temperature and condenser pressure as the sole variation of ambient temperature doesn't have much effect on the performance parameters. The varying of ambient temperature without altering the condenser pressure doesn't have any significant impact but by varying simultaneously the ambient temperature along with the changing of condenser pressure has profound effect on the performance parameters. As the Condenser pressure increases the heat loss is also increasing which shows the major portion of energy loss occurs in condenser. In comparison of heat loss in condenser the exergy destruction in condenser is very less. At the optimal condenser pressure 0.00804 MPa the exergy efficiency of the whole unit, exergy destruction in condenser, exergy efficiency of condenser, Heat loss (Q) in condenser and Wtotal are as 26.26%, 198.1KW, 99.72%, 81190 KW and 53.4 MW respectively and the optimal condition is attained at the full load(100%) or designed operating parameters.

Nomenclature

Ct	*Cooling tower*
ex	*Specific exergy flow (kW)*
e	*Physical exergy*
Ex_D	*Exergy destruction rate (kW)*
h	*Specific enthalpy (kJ/kg)*
$\dot{m}$	*Mass flow rate (kg/s)*
P	*Pressure (kPa or MPa)*
$\dot{Q}$	*Heat flow rate (MW)*
S	*Specific entropy (kJ/kg.K)*
T	*Temperature (^oC)*
$\dot{W}$	*Power (MW)*

ABBREVIATION

Cp	*Condenser pump*
FBC	*Fluidized-Bed Combustion*
Fwp	*Feedwater pump*
EnE	*Energy efficiency*
ExE	*Exergy efficiency*

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