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FACTORIAL ANALYSIS OF SURFACE CONDENSER FOR THERMAL POWER PLANT

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ABSTRACT
The thermal power plants, used to generate power, are designed based on required conditions (like a good quality of steam, pressure and temperature of steam etc.). This paper deals with the factors which reduced the efficiency of the condenser and power plant. In practical situations, actually inlet conditions are not as per the designed conditions, when power plants are installed. There are lots of constraints which conform with the second law of thermodynamics. This tends to reduce or increase output power and heat rate of thermal power plants. Due to these conditions, the designed power and heat rate are never achieved. Variations in the power outputs from plant are always a matter of disputes. So the parameters for power and heat rate are generated for different conditions of condenser pressure, flow rate of water through the condenser, temperature difference. On the basis of site measurement and design data collection performance of the condenser unit were evaluated. These evaluations indicate that if operating conditions vary, then power output and heat rate also vary.

KEYWORDS: Flow Rate, Condenser, Power Output, Vacuum, Energy Efficiency.

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1. INTRODUCTION

The condenser is a heat transfer device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In doing so, the latent heat is given up by the substance, and will transfer to the condenser coolant. Use of cooling water or surrounding air as the coolant is common in many condensers. The main use of a condenser is to receive exhausted steam from a steam engine or turbine and condense the steam. The benefit being that the energy which would be exhausted to the atmosphere is utilized .A steam condenser generally condenses the steam to a pressure significantly below atmospheric. This allows the turbine or engine to do more work. The condenser also converts the discharge steam back to feed water which is returned to the steam generator or boiler. In the condenser the latent heat of condensation is conducted to the cooling medium flowing through the cooling tubes. In practical situations, when power plants are installed there are lots of constraints. This tends to reduce or increase output power and heat rate of thermal power plants. Due to these conditions, the designed power and heat rate are never achieved.

Basically, a condenser is a device where steam condenses and latent heat of evaporation released by the steam is absorbed by cooling water. Thermodynamically, it serves the following purposes with reference to the P-V diagram shown in Figure 1. Firstly, it maintains a very low back pressure on the exhaust side of the turbine. As a result, the steam expands to a greater extent and consequently results in an increase in available heat energy. The shaded area shown in the P-V diagram exhibits the increase in the work obtained by fitting a condenser unit to a non-condensing unit for the same available steam properties. In the P-V diagram, line 4-5 is non-condensing line when the condenser unit is 4’-5’notisapplied condensing line when the condenser is used .Secondly, the exhaust steam condensate is free from impurities. Thermal efficiency of a condensing unit is higher than that of a non-condensing unit for the same available steam properties.

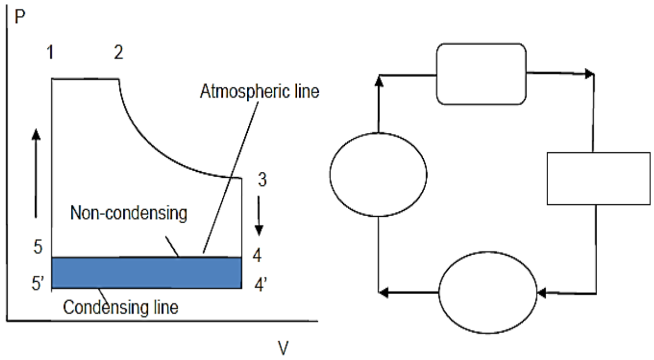

Figure 1: Key Components of a Thermal Power Plant working on a Rankine Cycle

Steam power plants use basically two types of cooling systems: open-cycle and closed cycle. Open-cycle or once-through cooling systems withdraw large amounts of circulating water directly from and discharge directly to streams, lakes or reservoirs through submerged diffuser structures or surface outfalls. An open-cycle system depends on the adequate cool ambient water to support the generation at full capacity. A closed-cycle cooling system transfers waste heat from circulating water to air drawn through cooling towers. (Arora and Domkundwa, 2006). Conventional wet cooling towers depend on evaporating heat exchange and require a continuous source of fresh water to replace evaporation losses. The ability of cooling towers to provide cold water to steam condensers of a thermoelectric unit decreases with increasing air temperatures and, in case of wet cooling tower, increasing humidity (Mirjana et al, 2010).

2. LITERATURE REVIEW

The percentage ratio of the exergy destruction to the total energy destruction was found to be maximum in the boiler system 86.27% and then condenser and stack gas 13.73%. In addition, the calculated thermal efficiency was 38.39 % while the exergy efficiency of the power cycle was 45.85% (Ankur et. al, 2013). Mirjana and Dejan (2010) focused on impact of cooling water temperature on energy efficiency of power plant, increasing pressure in the condenser of 1 kPa, efficiency decreases to 1.0-1.5% using Simulator based on IAPWS-IF97 .Considering that in this particular case the reduction is 1.2%, dependence of the energy efficiency in the function of the cooling water temperature rise is obtained. The condenser heat transfer rate and pressure in the condenser are given for variable cooling water temperature and flow rate, the specific heat rate change due to the change of condensing pressure, and the specific heat rate change due to the cooling water temperature change.

Finally, the energy efficiency for the reference plant is given as the function of the change in condensing pressure. Ajeet et.al. (2013) Studied about the factors or parameters which reduced the efficiency of condenser Using Analysis of ATPS and finalized three causes which affecting the performance of condenser as deviation due to inlet temperature of cold water, deviation due to cold water flow, deviation due to air ingress /dirty tube, particular in this study the efficiency of a power plant will reduce to 0.4% by these deviation in condenser. Milan et. al. (2013) focused on the influence of cooling water flow rate and temperature on the condenser performance, and thus on the specific heat rate of the coal fired plant and its energy efficiency using Parametric Analysis Method. As cooling water flow decreases the vacuum inside the condenser. This increased condenser pressure will decrease the power output of LP turbine which is not advisable. From mathematical model and analysis author proved that energy efficiency of condenser reduces when cooling water inlet temperature increases.

Amir et.al. (2011) identified and quantified the sites having largest energy and exergy losses at cycle Using Energy and Exergy Analysis Method. In addition, the effect of varying the condenser pressure on this analysis will also be presented with the limits of turbine & condenser temperature and design, the minimum allowable condenser pressure should be chosen to produce maximum efficiency and output power. This pressure should be always controlled during the power plant operation. The maximum energy loss was found in the condenser where 60.86% of the input energy was lost to the environment. The exergy destruction in the condenser was 13.22 % and thermal and exergy efficiency 38.39 %, 45.85. Ankur and Khandwawala (2013) used Exergy Analysis Method for create relation between correction Curves for power & heat rate are generated for different condition of condenser back pressure. Prashant et. al, (2011) focused on Exergetic Optimization of Inlet Cooling Water Temperature of Cross Flow Steam Condenser, It is found that optimum cooling water temperature decrease with decrease of condenser pressure Using Exergo-economic Analysis Method for minimized the using the Exergy method. As the upstream mass flow rate increase, the optimum coolant temperature and exergy efficiency decreases, Pressure drop is also increased with increase of cooling water flow rate using MAT Lab program. With decrease of condenser pressure from 0.18 bars to 0.10 bar optimum cooling water temperature is also decrease from 34 to 21, and exergy destruction at 21 decreases from 41755 kW to 30263 kW. Operating temperature of cooling water cannot be increased more than 34. At this temperature, exergy destruction is 27350 kW and exergy efficiency is 37.1%.

Dutta et. al.(2013) had worked upon the Loss factor and Efficiency of surface condenser and result found out At a particular load and condenser pressure, with the decrease in temperature rise in cooling water the condenser efficiency decreases. Similarly, at higher temperature rise in cooling water the condenser offers higher efficiency. At a particular load and condenser pressure, Loss Factor (LF) increases with decrease in temperature rise in cooling water. At a particular load and condenser pressure, Loss Factor decreases with increase in efficiency. Vosough and Sadegh (2011) focused on Energy and Exergy Method for power plant Efficiency In the considered power cycle, the maximum energy loss was found in the condenser. Next to it was the energy loss in the boiler system. The major source of exergy destruction was the boiler system where chemical reaction is the most significant source of exergy destruction in a combustion chamber. Exergy destruction in the combustion chamber is mainly affected by the excess air fraction and the temperature of the air at the inlet.

3. MATERIALS AND METHOD

Well water is taken from the ground via six different sunk pumps delivering about 200 m^3 each to the filters which contains anthracites and sand as its filtering media. After filtration, water is sent to a storage tank of about 23000 m^3 capacity from which the cooling tower basing gets its make-up. There are two vertical circulating water pumps used for cooling system delivering cooling water to the condenser. Each pump having installed capacity of 14000 m^3/h at about 2.5 bar each. Steam is produced at the heat recovery steam generator HRSG via the exhaust gas of the gas turbine. This steam is supplied to a two stage steam expansion turbine with HP and LP turbine respectively. Extractions from both HP and LP steam lines are taken for the steam By-pass operations which includes the condenser system, vacuum pump or Ejector system, gland sealing system, recirculation to the Heat Recovery Steam Generator HRSG, Feed Water tank, and Steam sampling System. While designing the surface condenser all the steam extraction through the turbines cannot be considered because when ever any FWH is isolated or in maintenance, then bled steam of it will directly enter into the condenser. Finally, temperature and pressure gauges, flow transmitters, panel logic control, and turbine performance data base were used to generate information needed. Comparison of design and operating factors as in Table 1, shows the various key values which affect performance of a condenser.

Table No. 1. Comparison between Designing and Operating Factors

Parameter	Design	Operating
Condenser vacuum	698mmHg	612mmHg
Condenser TTD	4.9^{o}C	19.8^{o}C
Condenser Effectiveness	63.50%	30.76%
C.T Range	8^{o}C	8.9^{o}C
C.T Approach	6^{o}C	5.4^{o}C
Cooling water rate	1850 m^3/h	1536.45 m^3/h
Cycle Efficiency	37.70 %	34 %
Evaporation Losses	21.33 m^3/h	20.03 m^3/h
Make up water consumption	4.2776 m^3/h	4.006 m^3/h
Turbine back pressure	0.1 bar	0.21 bar
Turbine work	958.6 kW	885.9KW
Specific Steam Consumption	28.05 TPH	30.53 TPH
Steam Rate	3.78	4.069 kg/kWh

	kg/kWh	
Heat Rate of Turbine	9720.3 kJ/kWh	10566.22kJ/kWh
Fuel Consumption	5806 kg/h	6300 kg/h

4. RESULT AND DISCUSSION

Cooling Water Parameters Influence on the Condenser Performance

Condenser heat transfer rate strongly depends on condensing pressure, cooling water flow rate and temperature. In an ideal situation, when the venting system properly removes air from the steam condenser, the achievable condensing pressure is determined by temperature of the cooling water, as it is mentioned above. For the steam power plant with closed cycle cooling system, cooling water temperature is determined by natural water source or ground temperature. This means that cooling water temperature is changing with weather conditions in particular region, and cannot be changed in order to achieve better condenser performances (*i. e.* higher vacuum in the condenser). Still, cooling water temperature directly affects condenser performances. Suitable parameter for on-line control is cooling water flow rate, and it can be varied in a wide range, with appropriate circulation pumps.

During plant operation the objective is to operate at the optimum cooling water flow rate, which depends on cooling water temperature and power demand. In that manner, cooling water temperature and flow rate are considered variable parameters in the simulation of the plant operating conditions.

Condensing Pressure and Cooling Water Temperature

With cooling water temperature rise, the mean temperature difference in the condenser decreases, and condenser heat transfer rate for the same condensing pressure will also decrease. It means that this particular condenser is designed at its maximum heat transfer rate and with increased cooling water temperature it cannot achieve required value. In this way, the question of the valid designed parameters is opened. Increasing of cooling water flow rate will increase the condenser heat transfer rate for the given cooling water temperature.

Condensing pressure dependence on cooling water temperature is obtained for the given water flow rate and steam load of the condenser. Steam load is considered constant, in order to obtain a clear illustration of this dependence, as it is shown in Fig. 2. It is obvious that with cooling water increasing, pressure in the condenser will also increase.

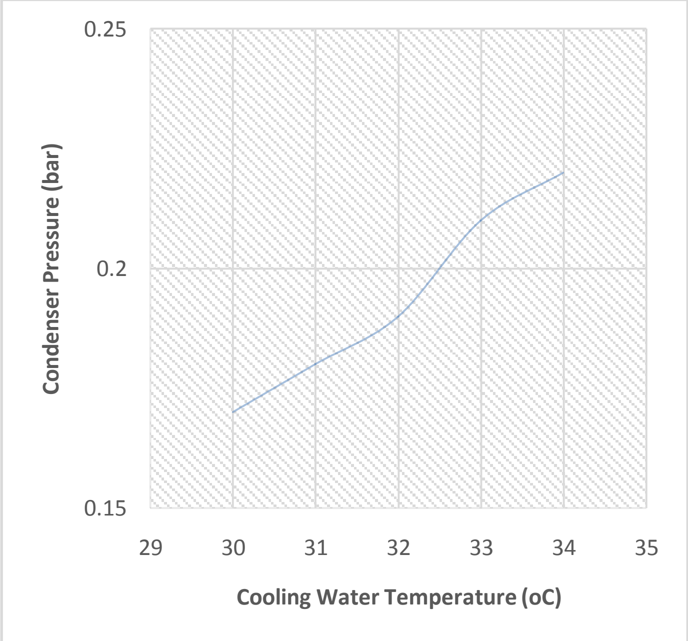

Fig. 2: Variation of Condenser Pressure with Cooling Water Temperature

Steam Load of the Condenser

With cooling water temperature increasing, in order to maintain designed heat transfer rate of the condenser, condensing pressure will increase. As this plant is working under turbine-follow mode, the turbine governor will increase the throttle and exhaust flows in order to set the generated power at the designed level, but with increasing of heat rate, Those results are identical to experimental results for similar plant given in literature (Mirjana et al, 2010), the steam load of the condenser dependence on condensing pressure, at a constant cooling water temperature as for different values of cooling water flow rate.

Condenser Operating Conditions Influence on the Plant Performances

After data analysis result is show that with increasing of condensing pressure and flow rate of the cooling water, steam flow through the condenser, and thus through the low-pressure turbine is increasing. This will increase net power output. This increasing of the net power output, however, is correlated to the increasing of the heat rate.

Specific Heat Rate

Specific heat rate change due to condensing pressure change, those results are identical to experimental results for similar plant given in literature (Mirjana et al, 2010). With decreasing of the pressure in the condenser, specific heat rate decreases. With pressure decreasing to bellow the point where the exhaust annulus becomes choked, excessive condensate sub-cooling will result, tending to reduce the improvement in heat rate resulting from the lower condensing pressure. Condensate sub-cooling is defined as the saturation temperature corresponding to the pressure in the condenser minus the condensate temperature in the hot well.

Energy Efficiency

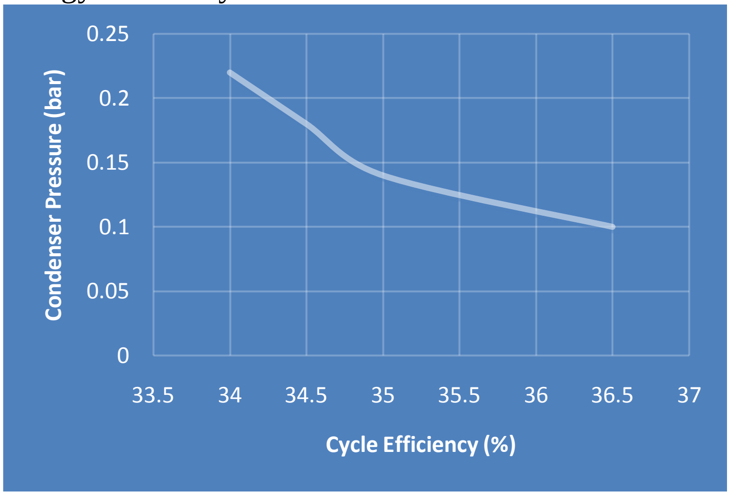

Figure 3.Variation of Cycle Efficiency with Condenser Pressure

Using the known assumption, from the literature (Mirjana et al, 2010), that with increasing pressure in the condenser of 0.11 bar, efficiency decreases to 2.0 - 2.7% and considering that in this particular case the reduction is 2.7%, dependence of the energy efficiency in the function of the cooling water temperature rise is obtained and is shown in Fig. 3.

Cooling water temperature rise causes the reduction of energy efficiency and power of steam power plants. The problem is more severely set for plants with closed-cycle cooling system in comparison to the plant with an open cycle cooling system. Dry bulb temperature, the wet bulb temperature, the atmospheric pressure, flow rate of the circulating water , the characteristic of cooling tower fill, the resistance coefficient of the parts in a tower, and the working condition of a water distribution system and so on, can affect the outlet water temperature of the cooling tower (Mirjana et al, 2010). It means that cooling water temperature is changing in a much wider range in one day in comparison to once-through cooling system.

Condenser TTD and Cooling Water Temperature

The analysis is show that condenser TTD is function of water temperature, in the figure-4 show that the condenser TTD is increase with increasing the temperature of inlet cooling water in condenser and reduce the condenser performance.

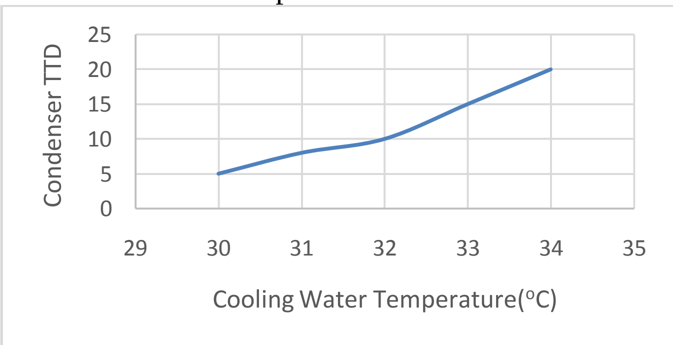

Fig. 4: Variation of Condenser TTD with Cooling Water Temperature

5. CONCLUSION

In this paper, causes which affects the performance of condenser are deviation due to cooling water inlet temperature, deviation due to water flow rate and deviation due to condenser pressure in energy efficiency of plant are considered .Eventually this paper finds that total efficiency of a power plant will reduce to 2.7% by all these deviation in the condenser, but overcoming these three reasons; the performance of power plant can be risen to a good level.

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