Optimization in Area by Changing Number of Passage in Shell of Surface Condenser

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Abstract

Surface condenser is mostly used in thermal power plant, Process industries etc. Owing to the wide utilization of heat exchangers in industrial processes, their cost minimization is an important target for both designers and users. Traditional design approaches are based on iterative procedures which gradually change design parameters until a satisfying solution, which meets the design specifications, is reached. However, such methods, besides being time consuming, do not guarantee the reach of an economically optimal solution. In this paper a procedure for optimal design of shell and tube heat exchangers is proposed, which utilizes a aspen plus software to minimize the total cost of the equipment including capital investment and the sum of discounted annual energy expenditures related to pumping. With changes of different parameters like thermal conductivity, Heat transfer rate, flow rate, Inlet and outlet of cooling water required for cooling purpose, we can optimise the thermal design by reducing area of surface condenser. [1]

Keywords

Purpose of Condenser, Types of Design, Design procedure, MTD corrected factor, Software and codes used for design of condensers, Aspen Tech software for thermal analysis result.

1.0 Introduction

Condenser is a type of heat exchanger in which hot fluid becomes cold fluid. surface condenser is a commonly used term for a water-cooled shell and tube heat exchanger installed on the exhaust steam from a steam turbine in thermal power stations. These condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. Where cooling water is in short supply, an air-cooled condenser is often used. An air-cooled condenser is however significantly more expensive and cannot achieve as low a steam turbine exhaust pressure as a water-cooled surface condenser.
The condensation can occur on the outside or inside of the tubes. Each setup requires different Considerations as well as different heat transfer correlations. (See recommended readings from HEI standards).HEI means heat exchanger institute. The shell of condenser is made by carbon steel and tube material made by different higher thermal conductivity material. Physically, the steam will flow from top to bottom inside the shell while the Water will move counter currently in the tube area. There are many types of software available for condenser design like as Aspen plus, Compress, PVElite etc. [3]
Design on Aspen plus software is very similar to that of boiling design. Hand calculations will be needed again since Aspen has difficulty estimating condensation heat transfer coefficients accurately. On the other hand, the hand calculations can become very tedious

1.1. Purpose

In thermal power plants, the primary purpose of a surface condenser is to condense the exhaust steam from a steam turbine to obtain maximum efficiency and also to convert the turbine exhaust steam into pure water. The condenser provides a closed space into which the steam enters from the turbine and is forced to give up its latent heat of vaporization to
the cooling water. It becomes a necessary component of the steam cycle as it converts the used steam into water for boiler feed water and reduces the operational cost of the plant. Also, efficiency of the cycle increases 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. [11]

2.0 Design of surface condenser

For design of surface condenser following data required and necessary.[10]
- Ambient Pressure & Temperature
- Relative Humidity
- Design Conditions at different Gas Turbine Load Steam inlet (kg/s)
- Steam inlet (kg/s)
- Condensate Outlet Temperature (^{0}C)

2.1 Thermal Design

It's a primary design of heat exchanger in which we optimize the design by changing flow rate, material thermal conductivity etc. Also we optimized in process by changing design of two or three pass system. Turbine Condensers are designed as per HEI-standards for steam condensers (HEI means Heat Exchange Institute) Since 1933 - HEI is a non profit trade association committed to the technical advancement, promotion, understanding and education of industrial heat exchanger, vacuum system etc. HEI has developed and published Standard: journal article [4]

2.2 Mechanical Design [10]

Mechanical Design & Construction Code:
- ASME
- Sec VIII Div I, II, III
- Sec III
- Sec I
- TEMA
- IBR
- IS 2825

3. Data taken from Sikalbaha 225 MW ± 10% Combined Cycle (Dual Fuel) Power Plant Project Bangladesh [6]

Given Data
Ambient Pressure & Temperature
Relative Humidity
Design Conditions at different Gas Turbine Load
Steam inlet (kg/s)
Cooling Water Inlet, Condensate Outlet Temperature and fouling factor.

From the above data calculated velocity by Thermal analysis as shown in below table

Table-1 Given data for 225 MW power plant operating at different load on Turbine [6]

Steam Flow Rate (kg/s)	Pressure (bar)	Steam Inlet Temp Thi (^{0C})	Steam Outlet Temp Tho (^{0C})	Water Inlet ti (^{0}C)	Water Outlet to (^{0}C)
41.1	0.093	44.3	41.21	37.5	42.2
43.3	0.095	44.8	41.64	37.7	42.6
51.8	0.103	46.5	43.15	38	43.9
53	0.105	46.7	43.5	38.1	44.1
60.2	0.165	56	52.38	46.2	53.1
63	0.115	48.6	44.26	38.5	45.5
63.2	0.044	30.7	26.99	20.1	27
93.2	0.215	61.6	56.84	46.7	57.2
96	0.078	41	37	24.5	35.6
98.8	0.161	55.5	50.94	39.8	50.7

4. Calculation Procedure for Area and Power for Surface Condenser [4] & [10]

Power (P) = Pressure (N/m^2) × Velocity (m/s) × Area depend on Shell Passes (m^2)

$$A = \frac{Q}{U \times MTD}$$

$$MTD = LMTD \times F$$

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

$$= \frac{(T_{hi} - T_{ci}) - (T_{hi} - T_{co})}{\ln(T_{hi} - T_{ci}) / (T_{hi} - T_{co})}$$

Where

T_{hi} and T_{ho} - Inlet and Outlet Temperature of Shell
t_i and t_o -Inlet and Outlet Temperature of Tube
P and R- temperature ratio
F-Correction factor
LMTD-Logarithmic mean Temperature Difference
MTD-Mean temperature difference

$$P = \frac{t_o - t_i}{T_i - t_i}$$

$$R = \frac{T_i - T_o}{t_o - t_i}$$

From the chart find out value Of F for one shell Pass and Two shell passes

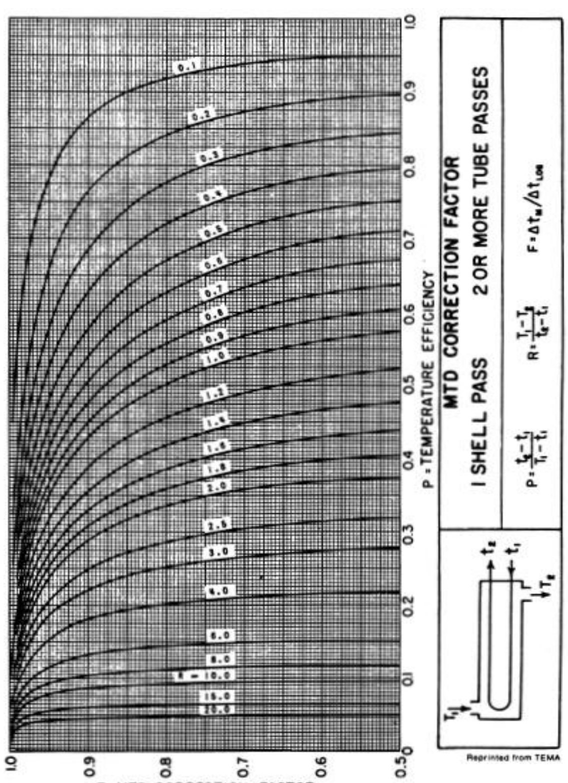

Figure 1.MTD correction factor for one Shell pass in Surface condenser. [4]

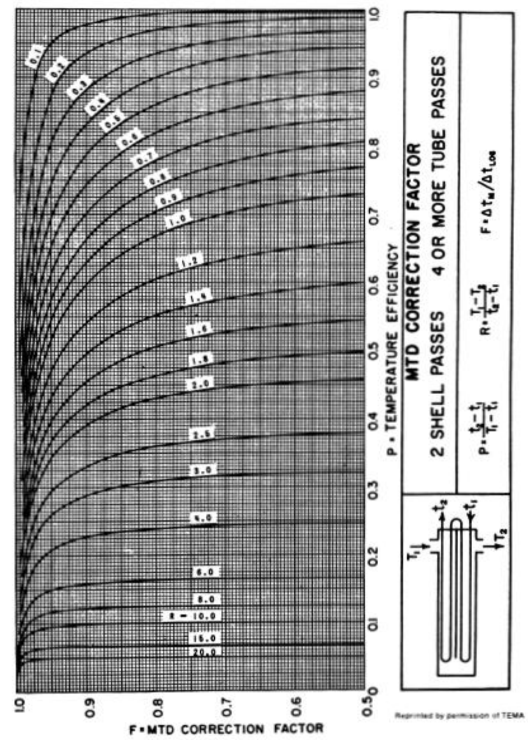

Figure 2. MTD correction factor for two Shell pass in Surface condenser. [4]

5.Result Table

In table 2 shown as below generated result from Table and from Thermal Analysis on Aspen Tech Software

Table 2. Effect of number of number of Shell Passage on Area and Power for Surface condenser [6],[8] &[9]

Velocity of Steam for one shell paas (m/s)	Velocity of Steam for two shell paas (m/s)	Heat Exchanged for one/two shell pass Q (Mw)	Overall Heat Transfer Coeff. for one shell U (W/m^2K)	Overall Heat Transfer Coeff. for two shell U (W/m^2K)	MTD Corrected (^0C) for one/two Shell Pass	Area for 1shell pass (m^2)	Area for 2 shell pass (m2)	Power for one shell pass (kW)	Power for Two shell pass (kW)
230.01	313.94	99.4	1197.9	1531.3	275.68	300.0	235.5	6.42	6.88
236.39	322.35	104.68	1208.6	1544.8	275.78	314.1	245.8	7.05	7.53
188.9	351.12	125.05	989.4	1542.6	276.5	457.1	260.0	8.89	9.40
189.54	352.27	127.9	985.8	1540.3	276.7	468.9	300.1	9.33	11.10
131.55	248.08	143.98	971.5	1509.1	277.25	534.6	344.1	11.60	14.09
202.01	378.17	151.77	995.6	1557.5	277.52	539.3	351.1	12.53	15.27
537.16	815.69	154.7	984.7	1914.2	278.13	549.3	290.8	12.98	10.44
156.92	302.9	221.63	1040.1	1485.9	280.24	760.4	532.3	25.65	34.66
459.91	888.84	232.9	1001.7	1631.9	281.6	899.5	506.8	32.27	35.14
219.05	424.93	236.41	980.6	1521	280.81	858.9	553.5	30.29	37.87

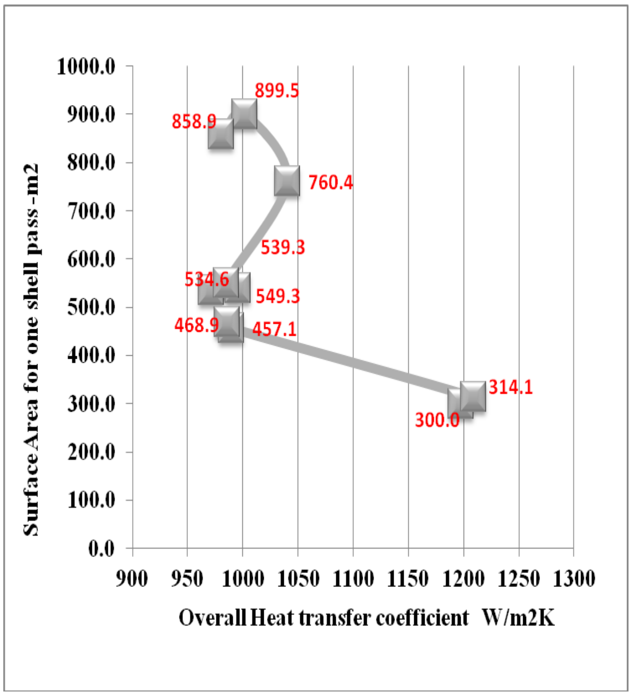

Figure 3 Graph of Surface area for one shell pass v/s Overall Heat transfer Coefficient.

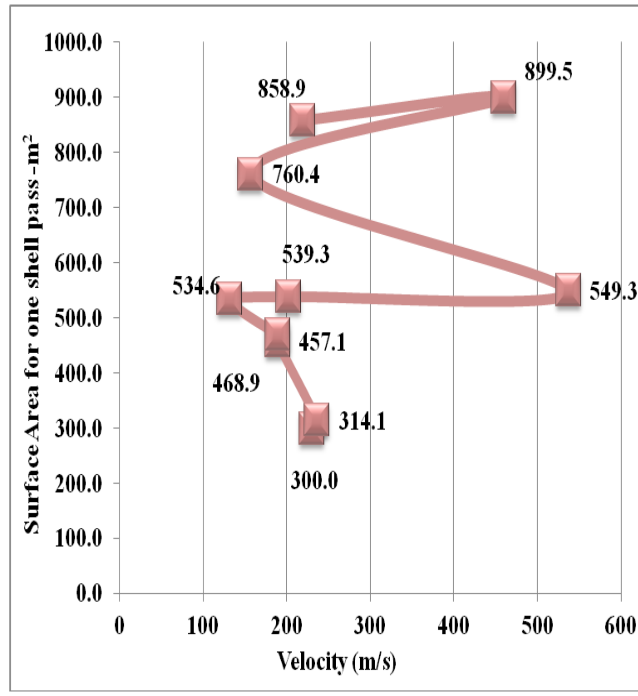

Figure 4 Graph of Surface area for one shell pass v/s Velocy of steam

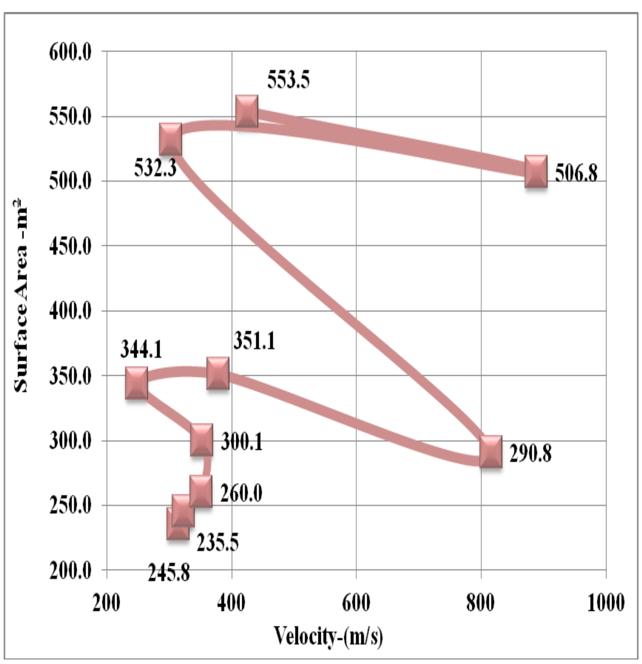

Figure 3 Graph of Surface area for two shell passage v/s Overall Heat transfer Coefficient.

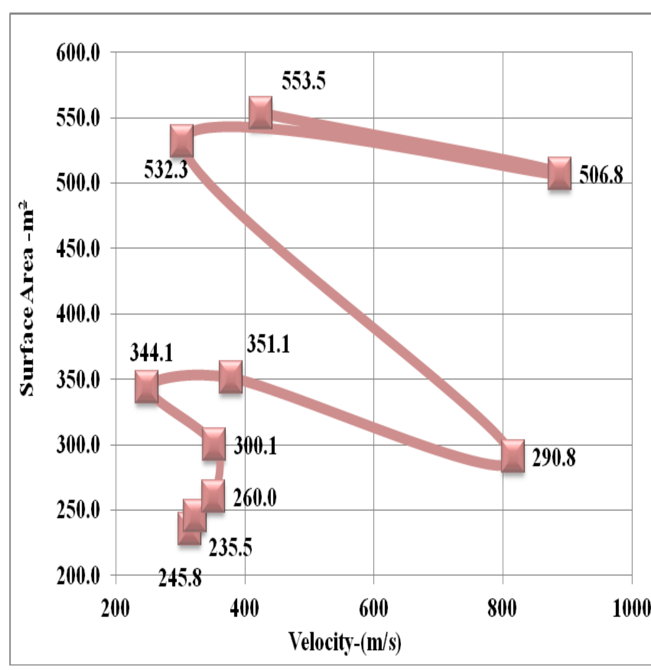

Figure 5 Graph of Surface area for two passage in shell v/s Velocity of steam.

7.0 CONCLUSION

Surface area of condenser is depending on number of Shell passage. If velocity increases power consumption by pump also increases. In 225 MW power plant when we use two passage in shell at that time we get optimised result as shown below.

Steam Flow Rate (kg/s)	Pressure (bar)	Velocity of Steam for one shell paas (m/s)	Velocity of Steam for two shell paas (m/s)	Overall Heat Transfer Coeff. for one shell U (W/m^{2}K)	Overall Heat Transfer Coeff. for two shell U (W/m^{2}K)	Area for 1shell pass (m^2)	Area for 2 shell pass (m2)	Power for one shell pass (kW)	Power for Two shell pass (kW)
63.2	0.044	537.1	815.69	984.7	**1914.2**	549.3	**290.8**	12.98	**10.44**

Here power consumption is less because of higher heat transfer rate less area required and Power depend on area.

Also Area in two passages in shell type condenser occurs a counter flow that is most effective than single pass so again area is less required as compared to single passage.

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