Performance Evaluation of Condensers used in Thermal Plants - A Comparative Study of Condensers having various Types of Baffles

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Abstract— The Surface Condenser used in a thermal power plant is modeled and numerically analyzed in ANSYS FLUENT Flow Simulation. The temperatures obtained from the numerical analysis of the modeled condenser closely match with those of the working temperatures in the thermal power plant, which validates the model. Flower baffles are installed in the design of the shell-and-tube heat exchanger in order to improve the heat transfer performance. Three Sector angles 750, 900 and 1150 are considered for the analysis. The temperature distribution of the steam on the shell side is represented in the form of flow trajectories. The correlation of the overall heat transfer coefficient with varying angle is identified and is found that with increasing sector angle of flower baffles, the overall heat transfer coefficient increases. A comparative study of the condenser integrated with flower baffles to that of the condenser with segmental baffles is done. The effectiveness of the condenser is found to have increased with increasing baffle angles due to the induced turbulence. The heat transfer performance of the condenser with segmental baffles is higher than that of the condenser with flower baffles, but segmental baffles cause large pressure drop. The heat transfer coefficient on the shell side is calculated analytically and compared graphically.

Key words: Condenser, Shell-and-Tube Heat Exchanger, Heat Transfer Performance Thermal Power Plant

I. INTRODUCTION

A heat exchanger is a complex device that provides the transfer of thermal energy between two or more fluids, which are at different temperatures and are in thermal contact with each other. Heat exchangers are used either individually or as components of a large thermal system, in a wide variety of commercial, industrial and household applications, e.g. power generation, refrigeration, ventilating and air-conditioning systems, process, manufacturing, aerospace industries, electronic chip cooling as well as in environmental engineering. The improvements in the performance of the heat exchangers have attracted many researchers for a long time as they are of great technical, economical, and not the least, ecological importance. Performance improvement becomes essential particularly in heat exchangers with gases because the thermal resistance of gases can be 10 to 50 times as large as that of liquids which requires large heat transfer surface area per unit volume on gas side. The traditional methods of reducing the air-side thermal resistance are by increasing the surface area of the heat exchanger, or by reducing the thermal boundary layer thickness on the surface of the heat exchanger. Increasing the surface area is effective but it results in the increase in material cost and increase in mass of the heat exchanger. One of the methods to reduce boundary layer thickness is by the generation of passive vortices. In this technique the flow field is altered by an obstacle to generate a vortex oriented in the direction of the flow. The resulting change in the flow due to an obstacle alters the local thermal boundary layer. The net effect of this manipulation is an average increase in the heat transfer for the affected area. The present work is undertaken to compute the heat enhancement levels achievable in a plate-fin heat exchanger built-in vortex generators mounted on these fins in the form of rectangular winglets.

II. SYSTEM MODEL

A. Condensers

Condenser is a heat exchanger in which there is a phase change of vapor into liquid (condensation) and the heat rejected is absorbed by the cold fluid. Condensers may be classified into two types based on whether the condensate and coolant are separated by a solid surface or if they are mixed together. Those Condensers in which the condensate and the coolant remains as two different streams are subdivided into three main types: air-cooled condenser, shell-and-tube condenser and plate condenser. Steam turbine exhaust condensers are also called as surface condensers. Surface condensers are shell-and-tube condensers with cross flow arrangement.

B. Effectiveness of Condenser

Effectiveness of a heat exchanger is defined as the ratio of actual heat transferred for the given area of the HX (Qactual) to heat transferred when there is infinite heat transfer area (Qmax).
Or

It is the fraction of the maximum heat transferred through an infinite heat transfer area. Effectiveness of a heat exchanger is given by following expression in terms of number of transfer units (NTU).

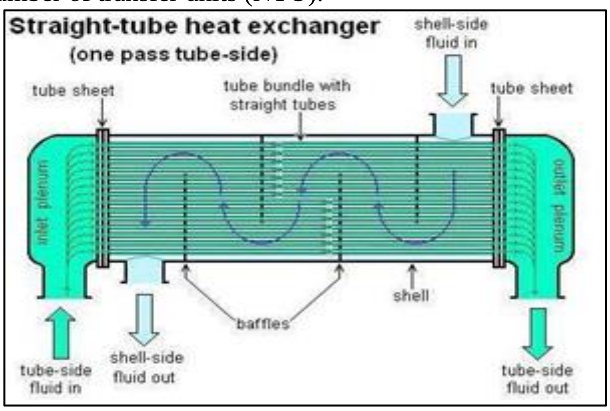

Fig. 1: Shell and Tube Heat Exchanger

C. Baffles

Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer co-efficient. The distance between adjacent baffles is called baffle spacing. The baffle spacing of 0.2 to 1 times of the inside shell diameter is commonly used. Baffles are held in position by means of baffle spacers. Closer baffle spacing gives greater transfer coefficient by inducing higher turbulence. The pressure drop is more with closer baffle spacing.

In case of cut segmental baffle, a segment (called baffle cut) is removed to form the baffle expressed as a percentage of the baffle diameter. Baffle cuts from 15 to 45% are normally used. A baffle cut of 20 to 25% provide good heat transfer with minimum pressure drop. The percentage cut for segmental baffle refers to the cut away height from its diameter.

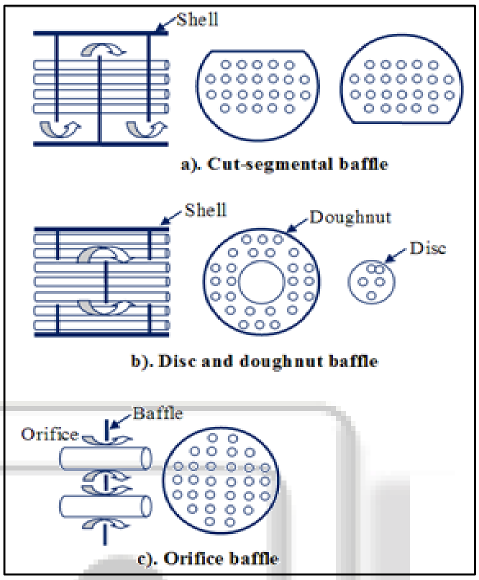

Fig. 2: Baffles

III. PROCESS DESCRIPTION

In this project I considered a condenser as heat exchanger and designed it using pro-engineering software and later imported it into ANSYS software and CFD analysis is used to determine the pressure drop, velocity and heat transfer rate. The temperatures obtained from the numerical analysis of the modeled condenser closely match with the working temperatures in the thermal power plant, which validates the model. Flower baffles are installed in the design of the shell-and tube heat exchanger in order to improve the heat transfer performance. Three Sector angles 750 , 900 and 1150 are considered for the analysis. The temperature distribution of the steam on the shell side is represented in the form of flow trajectories. The correlation of the overall heat transfer coefficient with varying angle is identified .The heat transfer coefficient on the shell side is calculated analytically and compared graphically with other condenser configurations

IV. PREVIOUS WORK

Xiang-hui Tan et.al[5] has performed numerical simulation on twisted oval tube heat exchanger. The heat transfer performance on the shell side of the heat exchanger under the influence of the geometrical parameters including twisted pitch length (P) and aspect ratio (A/B) is studied. The results reflect that both the Nusselt number and friction factor increase with increasing value of P and A/B. Considering only the influence of P alone, it firstly increases with increasing P and then decreases. It is concluded that the overall heat transfer performance on the shell side increases with increasing A/B. Spiral flows are found on the shell side when A=14mm, B=5mm. The spiral flow intensity becomes drastic with increasing A/B and decreasing P.

Experimental study for enhancing the heat transfer in a heat exchanger installed with helical baffles through blockage of triangle leakage zones is done by Simin Wang et.al.[6]. Fold baffles were used to block the triangle leakage zones between adjacent plain baffles. Although the pressure drop on the shell side increases, the pumping power penalty associated with the pressure drop is very low compared to the increment in heat flux..

The paper presented by Jian-Feng Yang et al.[7] explains about the use of sealing strips to eliminate the bypass stream that exists between the tube bundle and shell. Shell and tube heat exchangers with discontinuous helical baffles (DCH-STHX) and continuous helical baffles (CH-STHX) with the same helix angle of 400 are investigated by employing sealing strips. It is concluded that, larger the width of sealing strips, the better is the heat transfer performance and also the sealing strips are more effective in improving the heat transfer characteristics of CH-STHX than that of the DCH-STHX, particularly at large mass flow rates.

V. MODEL OF HEAT EXCHANGER WITH SEGMENTAL BAFFLES

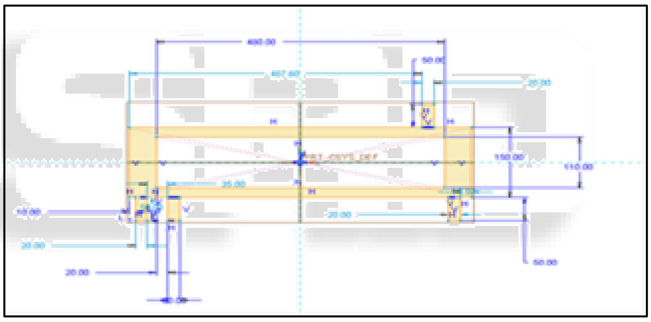

Fig. 2: Pro-Engineer 2D model

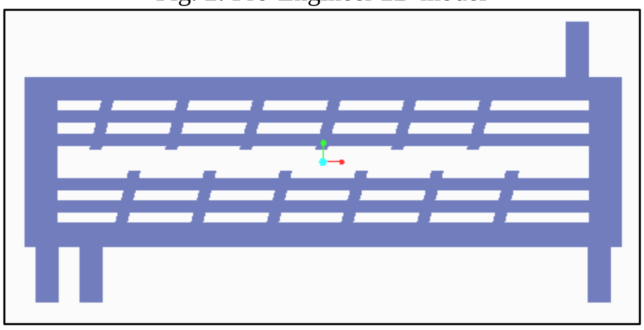

Fig. 3: 75 Degree Segment Baffle

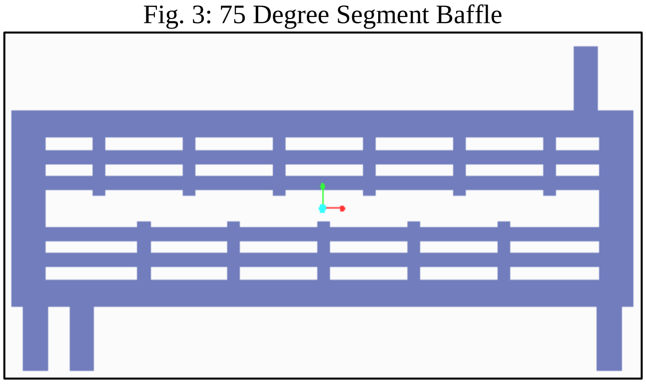

Fig. 4: 90 Degree Segment Baffle

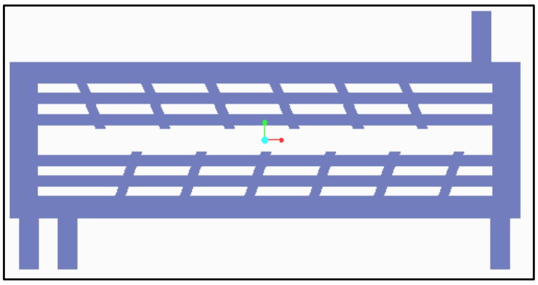

Fig. 5: 115 Degree Segment Baffle

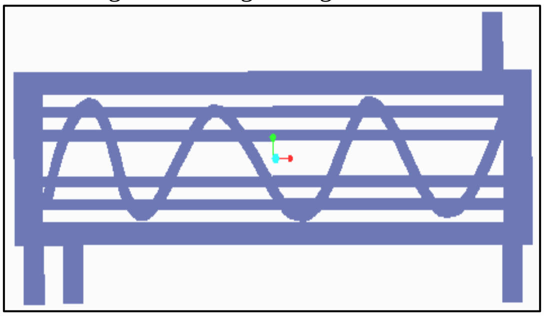

Fig. 6: Flower Baffle Segment Baffle

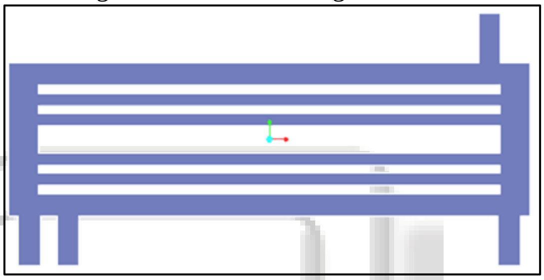

Fig. 7: Without Baffles Segment Baffle

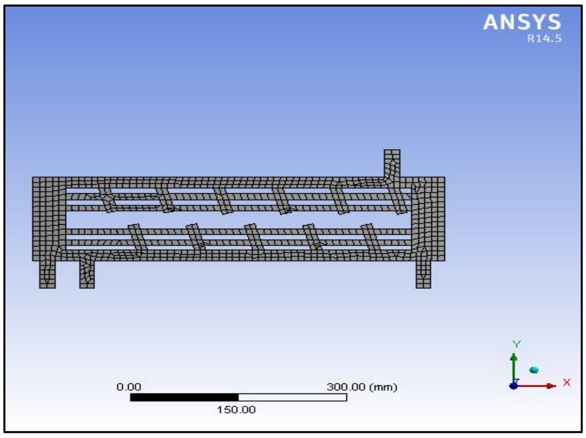

Fig. 8: Meshed Model

VI. CONCLUSION

Surface Condenser without baffles, Segmental baffles with three Sector angles 75^0, 90^0 and 115^0 and flower baffles are considered for the analysis and compared. The temperature distribution of the steam on the shell side is represented in the form of flow trajectories. 2D models are done using Pro/Engineer and CFD analysis is done using ANSYS. CFD analysis is done to determine the pressure drop, velocity and heat, the insertion of baffles causes the condensate to be sub cooled, which is not desirable. In order to avoid the sub cooling, the mass flow rate of the cooling water can be reduced. Heavy duty pumps are required to pump the water at high flow rates from the river. As the flow rates can be reduced, less pumping power is required and hence the use of baffles also adds to an economical advantage.

Segmental Baffles	**75^0angle**	3.50	1.77	3.53	8.87	33.47	0.101
	90^0angle	3.48	1.80	3.53	7.57	21.432.	0.138
	115^0angle	3.49	1.76	3.53	7.23	21.03	0.116
Flower baffles		3.39	1.82	3.53	8.06	36.29	0.366
Without baffles		3.43	1.70	3.53	8.95	74.14	0.42
Models		**Pressure KPa (KPa)**	**Velocity (Km/s)**	**Temperature (K)**	**Heat transfer co-efficient (KW/m^2K)**	**Heat transfer rate (KW)**	**Mass flow rate (Kg/s)**

Table 1: Conclusion

By observing the analysis of the results, the overall heat transfer coefficient with varying angle is identified and is found that with increasing sector angle, the overall heat transfer coefficient decreases. The heat transfer coefficient is more for segmental baffles with 75^0 than flower baffles but less when compared with that of without baffles. The heat transfer rate of the condenser with flower baffles is higher than that of the condenser with segmental baffles and without baffles. Segmental baffles also cause large pressure drop and flower baffles cause less pressure drop. So it can be concluded that surface condenser with flower baffles yields better results than condenser without baffles and with segmental baffles. The manufacture of the flower baffles is also easier and in fact, less material is required for the manufacture. Hence, the material cost can be reduced. As the baffle angle increases, the flower baffles offer more flow resistance, which may even reduce the heat transfer performance. This may cause more pressure drop just as in case of segmental baffles. The flower baffles with higher sector angles can be considered as segmental baffles. Therefore, with increasing sector angle of flower baffles, the thermal performance of the condenser gets reduced.

The pressure drop on the shell side of the condenser with flower baffles is found to be much less than that in condenser with segmental baffles. Also, the thermal performance of condenser with flower baffles is close to that of the condenser with segmental baffles. Hence, flower baffles can be preferred to be installed in a condenser than the segmental baffles.

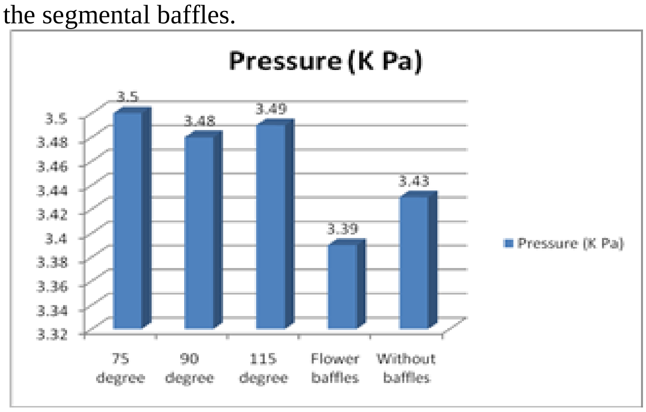

Fig. 9: Comparison of Pressure Values for All Models

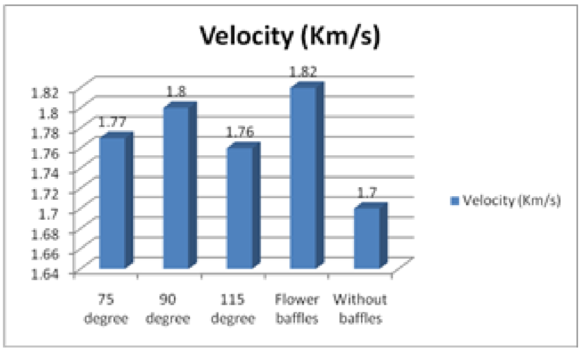

Fig. 10: Comparison of Velocity Values for All Models

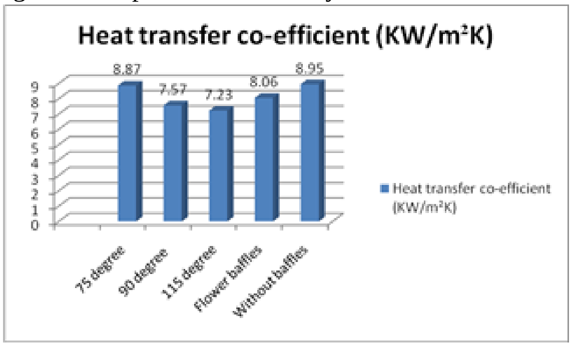

Fig. 11: Comparison of Heat Transfer Coefficient Values for All Models

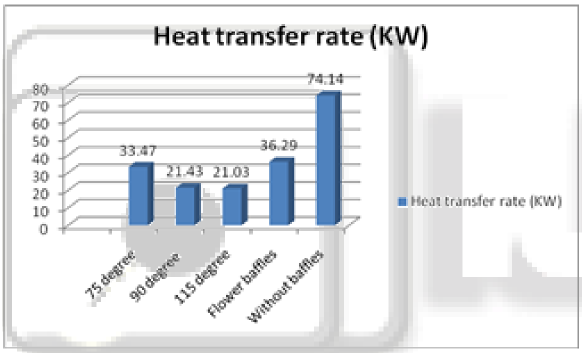

Fig. 12: Comparison of Heat Transfer Rate Values for All Models

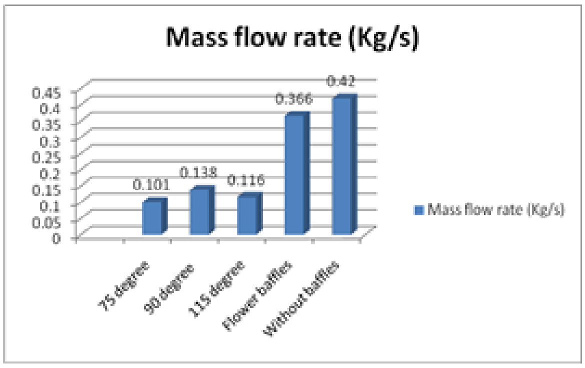

Fig. 13: Comprison of Mass Flow Rate Values For All Models

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