DESIGN AND PERFORMANCE OF FINNED TUBE HEAT EXCHANGER IN HDH UNIT

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Objectives

- To study and understand the working of the Humidification-Dehumidification water desalination unit.
- To estimate the load of the finned tube heat exchanger that is used in the dehumidifier section.
- To design and install the finned tube heat exchanger in the existing HDH unit.
- To conduct experiments showing the effect of operating conditions on the performance of HDH unit.
- Perform numerical simulation on the fluid flow and heat transfer in cross-flow of air over tube bank for tandem and staggered configuration.

Abstract

Recently, many regions of the world have become in an urgent need of desalination systems. Humidification- dehumidification desalination plants are considered the most suitable choices for many countries. A parametric study to investigate the effect of air flow-rate, and hot water mass flow rate on the heat and mass transfer process in the humidifier is carried out experimentally. The air flow rate ranged from 4.12 to 4.85 kg/min and water mass flow rate ranged from 10 to 18 kg/min. The main part of the dehumidifier section is the finned tube heat exchanger. The key objective of the present work is to re-design the heat exchanger of the dehumidifier for the existing one. The existing heat exchanger is a radiator of dimension 180x180x40 mm. Analytic method is used to make a detailed design for the heat exchanger. Also, numerical simulation for heat transfer and fluid flow across a tube bank consists of 6 rows arranged in staggered and tandem configuration is carried out on a commercial CFD code. The simulation results showed that the staggered arrangement gives better heat transfer performance but with higher pressure drop.

Methodology

1-Experimental Setup


Test-Rig


Hot water tank


Water spray



Humidifier-Dehumidifier

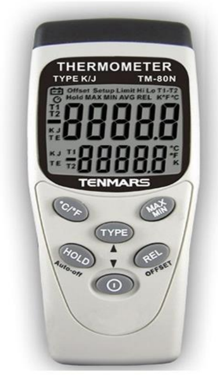

Cold water tank


Water pump

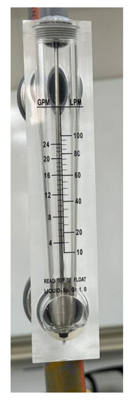

Air blower


Electric heater

Instrumentation



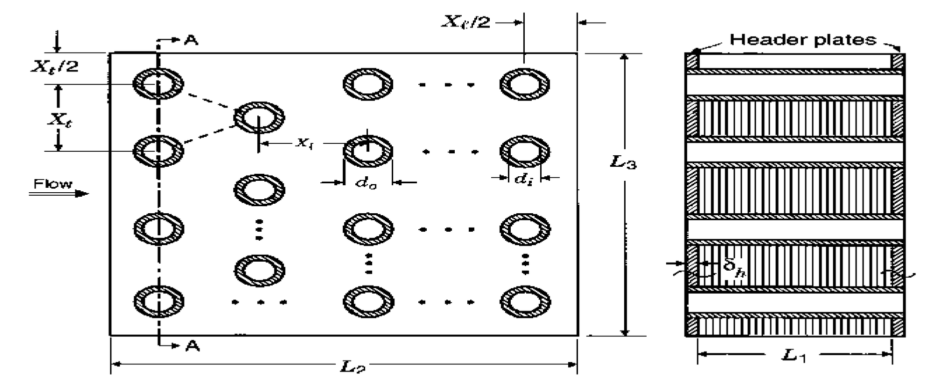
Digital Thermometer


Water flow-meter

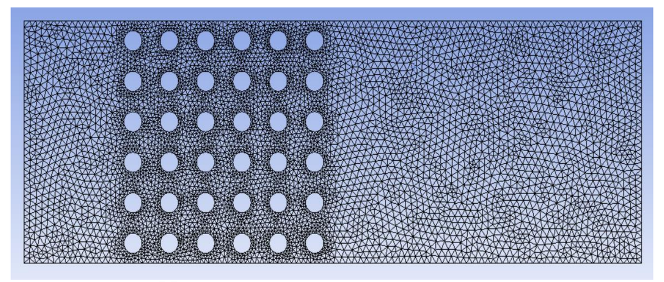

Air flow-meter

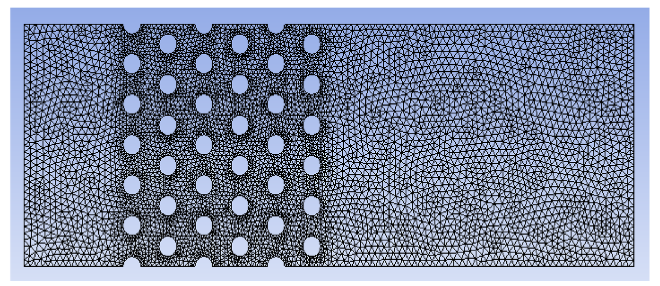
2-Analytic Method for Heat Exchanger Design:

1. Determine the heat exchanger's dimensions, such as tube length, diameter, and fin height.
2. Choose the tube material and fin material based on their thermal conductivity and corrosion resistance.
3. Calculate the heat transfer area A, and the number of tubes N required to achieve the desired heat transfer rate.
4. Perform design calculations based on the thermal analysis of heat exchangers.



3- CFD Simulation


Inline arrangement


Staggered arrangement

Model Validation

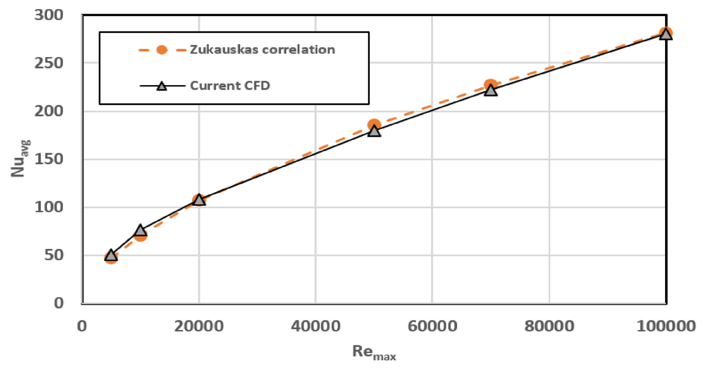
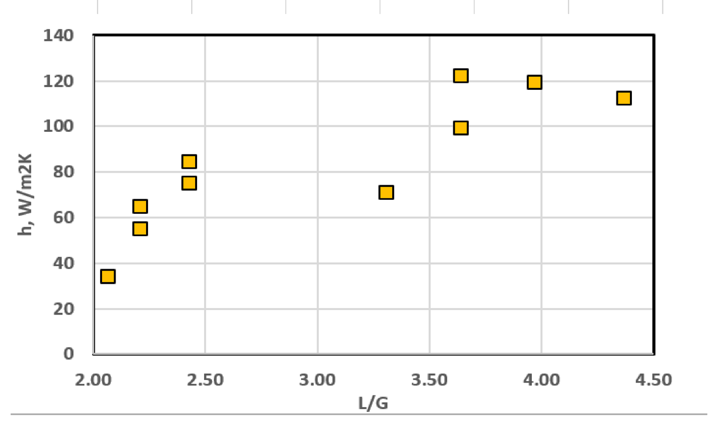
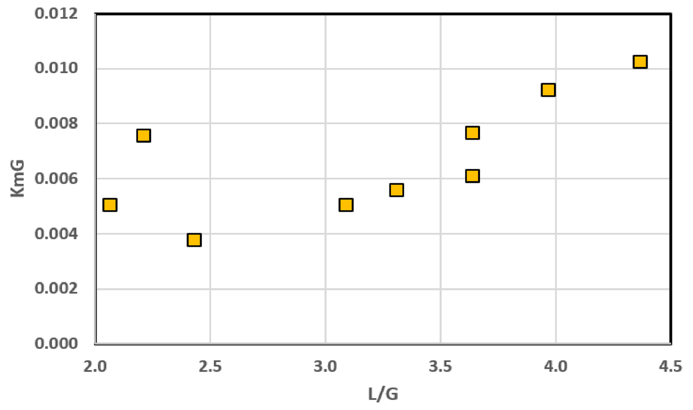


Figure 3.14 Comparison between the present model prediction and Zukauskas correlation

Results and Discussion

Experimental Results





CFD Results

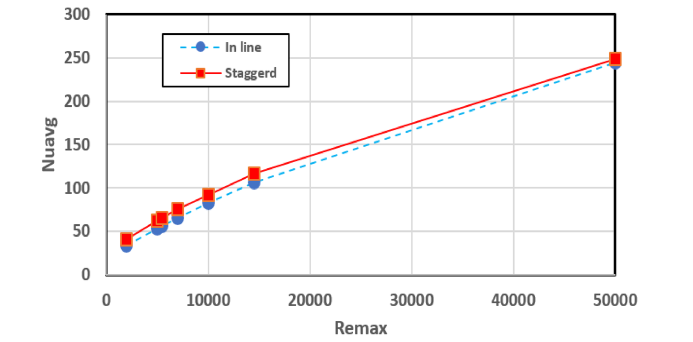


Figure 5.9 average Nusselt number vs. maximum Reynolds number for the staggered and inline arrangement

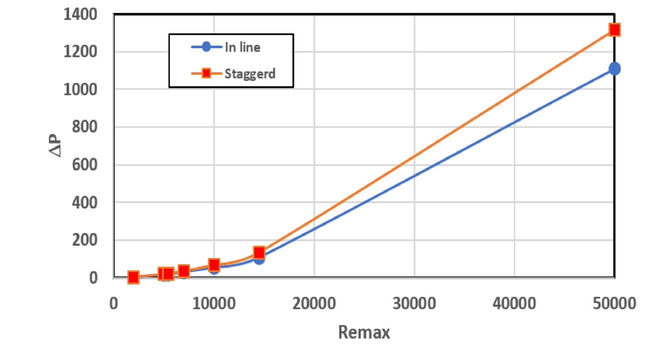
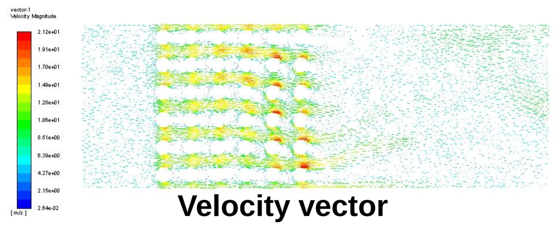
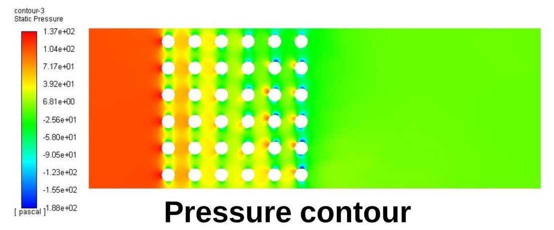
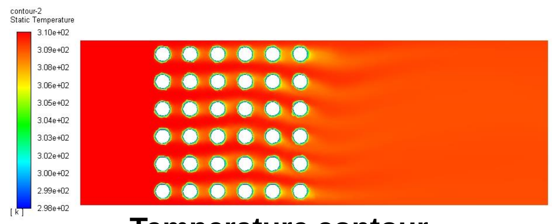


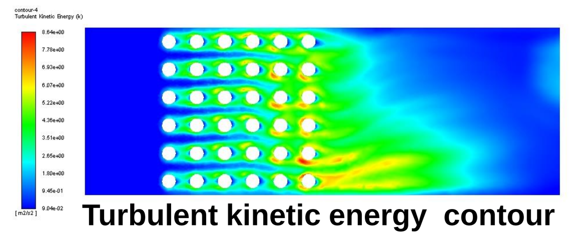
Figure 5.10 pressure drop vs. maximum Reynolds number for the staggered and inline arrangement

Inline configuration

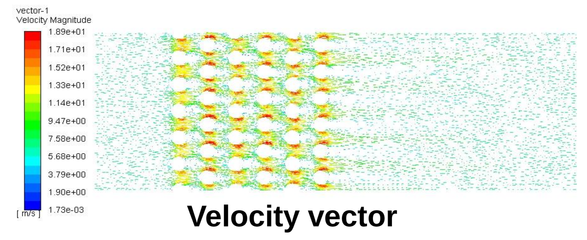

Velocity vector


Pressure contour


Temperature contour


Turbulent kinetic energy contour

Staggered configuration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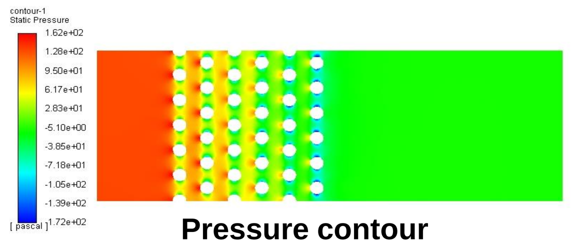
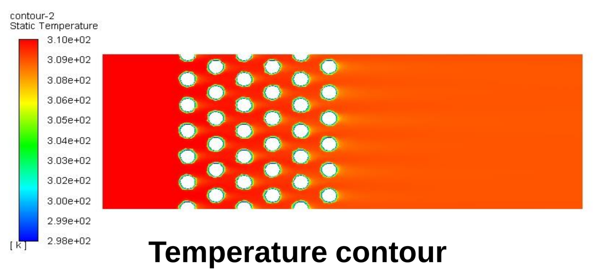
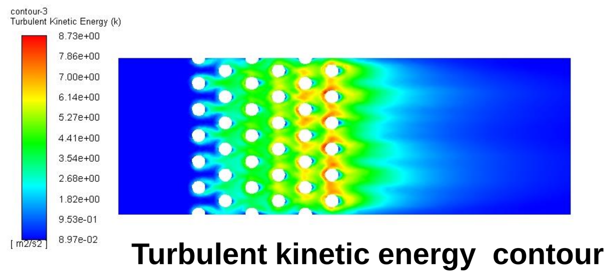

Pressure contour


Temperature contour


Turbulent kinetic energy contour

Re=14500

Conclusions

- ❑ Both the heat transfer coefficient and the mass heat transfer coefficient in the humidifier increase with the increase of the mass of water to mass of air ratio.
- ❑ The staggered arrangement gives better heat transfer performance than the in-line arrangement but with higher pressure drop due to higher turbulence level.
- ❑ When selecting a heat exchanger, consider the following factors: cost, pressure limits, thermal performance, temperature ranges, product mix, pressure drops, fluid flow capacity, cleanability, materials required for construction, and ease of future expansion. By considering these factors, you can ensure that the selected heat exchanger meets your specific needs and provides efficient and reliable heat transfer performance

References

1. Bergman, A.A.; Incropera, F.P. Fundamentals of Heat and Mass Transfer; John Wiley & Sons: Hoboken, NJ, USA, 2011.
2. Shah, R.K.; Sekulic, D.P. Fundamentals of Heat Exchanger Design; John Wiley & Sons: Hoboken, NJ, USA, 2003.
3. Hesselgreaves, J.E.; Law, R.; Reay, D. Compact Heat Exchangers: Selection, Design and Operation, 2nd ed.; Butterworth-Heinemann: Oxford, UK, 2016
4. A.E., Kabeel; M.H., Hamed; Z.M., Omara; S.W., Sharshir "Water Desalination Using a Humidification-Dehumidification Technique-A Detailed Review," *Natural Resources*, pp. 286-305, 2013.

Acknowledgments

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