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FUNDAMENTALS OF MATHEMATICAL MODELING OF FLOW STRUCTURE IN HEAT EXCHANGE DEVICES

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Abstract. Heat can flow only from the hotter to the cooler fluid. In a heat exchanger there is no direct contact between the two fluids. The heat is transferred from the hot fluid to the metal isolating the two fluids and then to the cooler fluid. Geothermal technologies are used to generate electricity and heat and cool buildings. To develop accurate models for heat and mass transfer applications involving fluid flow in geothermal applications or reservoir engineering and petroleum industries, a basic knowledge of the rheological and the transport properties of the materials involved, especially in high-temperature and high-pressure environments, are needed.
Key words: mathematical modeling, heat transfer, geothermal engineering, physical model.

Introduction. In this Special Issue, all aspects of fluid flow and heat transfer in geothermal applications, including the ground heat exchanger, conduction, and convection in porous media, are considered. The emphasis here is on mathematical and computational aspects of fluid flow in conventional and unconventional reservoirs, geothermal engineering, fluid flow and heat transfer in drilling engineering, and enhanced oil recovery (hydraulic fracturing, steam-assisted gravity drainage applications. I would like to thank all the authors who contributed to this Special Issue. A brief outline of each paper is given below. In manufacturing and industrial fields used heat exchanger to control of temperature weather as a boiler or cooling system. This system is not stable as the temperature output can easily disturb by noise and other disturbance such as surrounding temperature. To improve the heat exchanger system performance, the mathematical model's needed.

Materials and methods. The heat exchanger mathematical model in this case is constructed using dynamic modelling based on real parameters of the heat exchanger. The simulation result shows almost similar trend of responses with the experiment result, it means they are can used as a model of the heat exchanger.

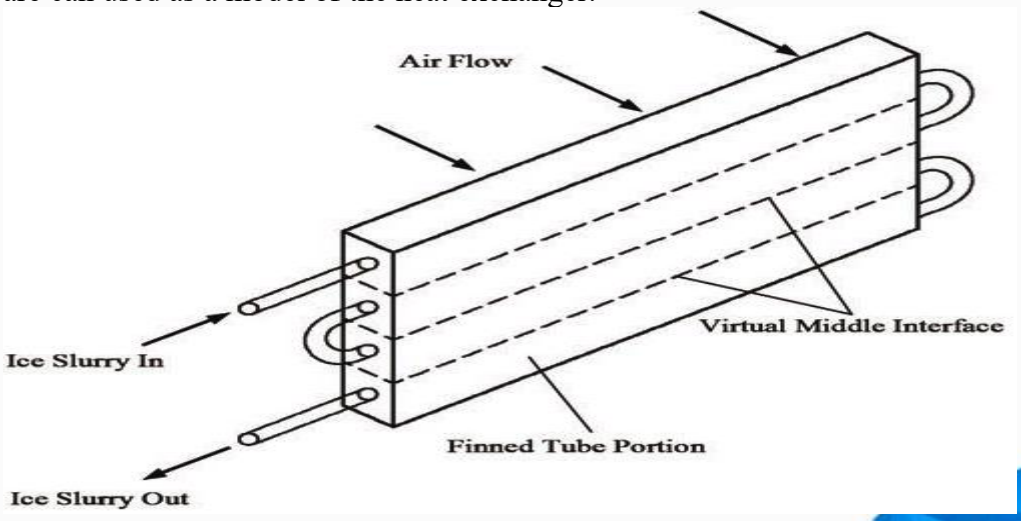


Figure 1. Physical model of the ice slurry finned tube heat exchange

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The high demand for compact heat exchangers has led researchers to develop high-quality and energy-efficient heat exchangers at a lower cost than conventional ones. To address this requirement, the present study focuses on improvements to the tube/shell heat exchanger to maximize the efficiency either by altering the tube's geometrical shape and/or by adding nanoparticles in its heat transfer fluid. The involved transport equations are solved numerically by the finite-element-based computing tool. The results are presented using the streamlines, isotherms, entropy generation contours, and Nusselt number profiles for various nanoparticles volume fraction $0.01 \leq \varphi \leq 0.04$ and Reynolds numbers $2400 \leq Re \leq 2700$ for the different shaped tubes of the heat exchanger. The results indicate that the heat exchange rate is a growing function of the increasing nanoparticle concentration and velocity of the heat transfer fluid. The diamond-shaped tubes show a better geometric shape for obtaining the superior heat transfer of the heat exchanger. Heat transfer is further enhanced by using the hybrid nanofluid, and the enhancement goes up to 103.07% with a particle concentration of 2%. The corresponding entropy generation is also minimal with the diamond-shaped tubes. The outcome of the study is very significant in the industrial field and can solve many heat transfer problems. Solar energy has become the energy of the times and the only solution for the poor to replace petroleum products. Heat exchangers are used in diverse fields of application such as in water heating systems in solar collectors, solar thermal energy storage systems, and other compact heat exchanger applications. The efficiency of heat exchangers is related to metallic and non-metallic materials such as aluminum, iron, copper, steel, bronze, ceramic and glass PTFE, and graphite. The heat transfer coefficient varies from one material to another. Therefore, by increasing the heat transfer coefficient, the heat exchange capacity increases. This is accomplished by modifying the geometric shape of the heat exchangers. The importance of heat exchangers differs from field to field with increasing demand; the purpose of using them is to save energy and reduce the cost. Thus, the heat exchanger is an essential element of any energy management policy and therefore of environmental protection. Indeed, a large part of the energy used in the various sectors passes at least once through a heat exchanger, which makes it a key device for thermal engineers and essential in energy management. With the development of science and technology, energy guidance has become a major goal for scientists due to their urgent need to provide natural energy sources. Where many companies and factories compete to rationalize energy consumption through regenerative heat exchangers, it is a weapon of the times that saves large amounts of wasted energy. Thanks to it, it can capture as much waste heat as possible and use it to heat the cold gases that are usually heated in thermal furnaces and engines that use fossil fuels to warm up. Thus, these motors use less energy and therefore consume valuable fossil fuel. Underground heat exchangers have also been used underground to take advantage of geothermal heat from the earth in cooling and heating fluids for industrial, residential, and agricultural uses. These devices are specially designed to activate the vital act of various thermal and chemical processes through the transfer of heat from one liquid to another at different temperatures. The design of these heat exchangers with reliable operation of the systems is mainly adopted for the transfer of heat in spite of the problems of this reactor such as cooling of the components of the system to reuse and avoid burning it and to intensify these exchanges to improve the production rate. To improve the heat transfer using convection as a cooling method, the researchers conducted numerical and experimental tests about the nature of the systems in which they occur and the properties of the fluids involved.

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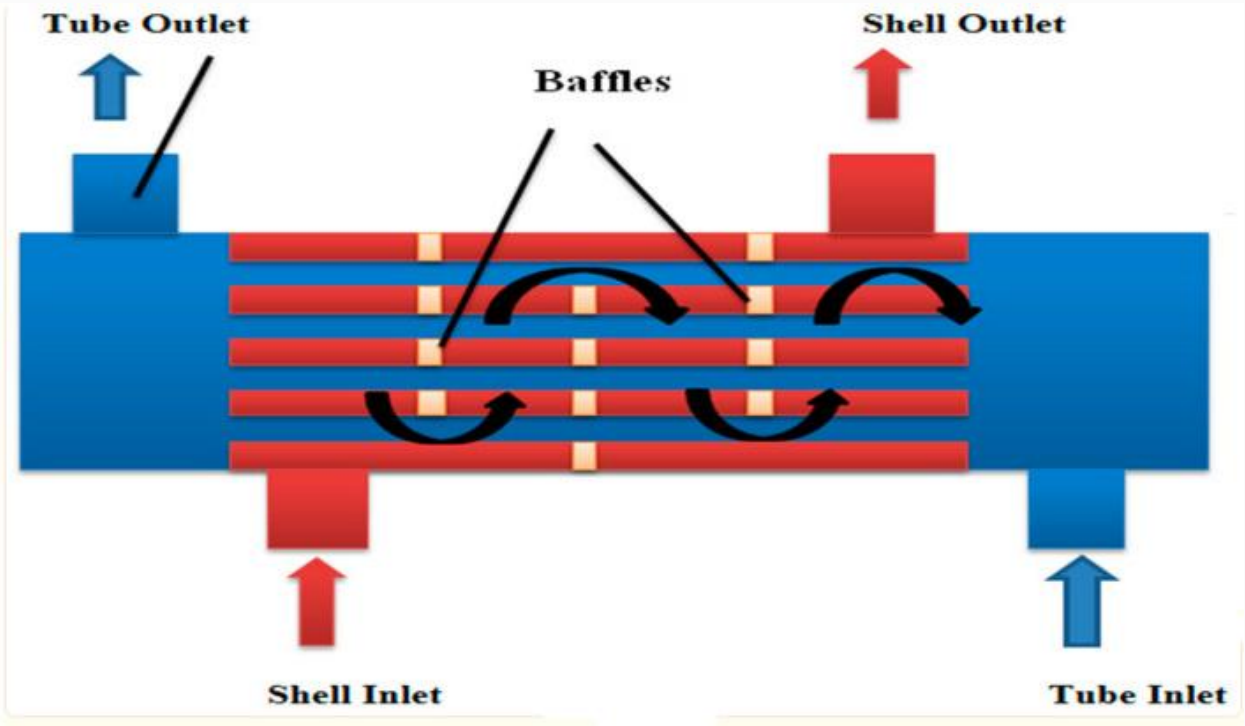


Figure 2. Schematic representation of a conventional tube/shell heat exchanger.

Counter flow heat exchangers use flows in the opposite direction of each other. Shell and tube, and double pipes heat exchangers are examples of common exchangers using counter flow configurations. The best design for shell and tube and double-pipe exchanger is counter flow configuration, and the heat transfer between the fluid is the maximum. In counter flow, the efficiency is higher than the parallel, and temperature in the cooling fluid outlet can exceed the warmer fluid inlet temperature. In the figure below, we can see the position of inlets and outlets. As it is illustrated in the counter flow heat exchanger, the fluids flow in the opposite direction, and at the heads, there is a maximum temperature difference between them. We have an inlet for hot fluid and the exit pipes of cold fluid at the left head, while cold fluid inlets and the hot fluid outlet are on the right head. The baffle is a key structural part of heat exchangers. On the one hand, it can affect the flow resistance and heat transfer performance of the heat exchanger by changing the flow curve of shell side fluid. On the other hand, baffles can support the tube bundle and play a significant role in the stress and stability of the solid structure of a heat exchanger. Segmental baffle heat exchangers are the most adaptable and most widely used heat exchangers, which are simple in structure and convenient in manufacturing. As the fluid is heated from below, the concentration of the isotherm lines is clustered at the bottom and fades as it spreads vertically toward the outlet of the flow passage. Heat is absorbed by the working fluid from the bottom and dissipates as it rises to an outlet as it begins to spread upwards with the passage of time. At the lower flow regime (Re = 2600), the convection fluxes are very weak, and uniformly distributed temperature lines occupy the entire domain. Therefore, the thermal conduction modes dictate the thermal behavior. The values of the isothermal lines gradually increase from the hot wall to the cold wall. This topology is the thermal stratification, where thermal diffusion causes heat transfer. With the progress in time, the isotherm contours distribute uniformly over the flow passage, and such uniformity is more with the diamond-shaped tube bundle compared to all other shapes of the tubes.

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Conclusion. In general, the outcome of the study is very significant in the industrial field and can solve many heat transfer problems. However, the present study could be extended for further research to incorporate three-dimensional models, other geometries, and flow-controlling parametric ranges and boundary conditions for unsteady or turbulent fluid flow, which are limited in the present study.

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