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Design of High Volume Heat Exchanger with CFD Analysis for Milk Dairy

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ABSTRACT

In dairy the heat exchanger calls for an in brilliance design for pasteurized high volume of milk in short time of span. The work presented in this paper shall focus on different design alternatives for the heat exchanger with support offered volume of about five thousand liters of milk per day. Mathematical modelling coupled with computational methodology shall be explored for ramping up the volume in excess of twenty thousand litters. ANSYS Fluent shall be deployed for finding solution while mathematical model shall offer alternative methodology for validating the solution. Conventional heat exchanger design method does not predict steady state uniform property performance well; and they are totally unable to predict the influences of time-dependence and varying properties or the consequent stresses in the shell and tubes. On the other hand, conventional CFD (computational fluid dynamics) techniques, with their emphasis on body-fitting grids and sophisticated turbulence models, can contribute only to small-scale phenomena such as the velocity and temperature distributions within the space occupied by a few-tube sub-section of a tube bank. Nevertheless, the practical importance of heat exchangers, including those which involve chemical reaction and phase change, is so great that engineers must find design tools which are both economically-affordable and more realistic in prediction than either of the just-mentioned extremes.

Keywords— **Heat Exchanger, turbulence, Material change, CFD Analysis.**

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I. INTRODUCTION

Shell & tube heat exchanger is one of the most widely used equipment in process industry like as in Oil refinery unit, milk dairy & also used in large chemical processes. Heat exchangers are used to transfer heat between two process streams. They are used for different applications such as heating, condensation, cooling and boiling or evaporation purpose. They give name according to their different application e.g. Heat exchanger is used for cooling are called as condenser and It used for heating or boiling are known as boiler. The required amount of heat transfer provides an insight about the capital cost and power requirement of heat exchanger. Basically there are two types of heat exchanger.

Direct contact heat exchanger – In that both media between which heat is exchanged are in direct contact with each other.

Indirect contact heat exchanger – In that both media are separated by a wall through which heat is transferred so that they never mixed.

Shell and tube heat exchanger is the indirect contact type of heat exchanger; here the series of tubes are used in which one of the fluid runs. The tube side and shell side fluids are separated by tube sheet. Thin baffles are used for diverting the flow, support the tube for rigidity and obtained higher heat transfer coefficient. Helical baffles give the better performance than the single segmental baffles, but their manufacturing, maintenance and installation cost is high.

Computational fluid dynamics is now industrial design tool having many advantages. CFD models of shell and tube heat exchanger is considered here. The flow structure and heat distribution is obtained by modelling the geometry. This software build a virtual prototype of the system or device before can be apply to real word physics and chemistry to the model and the software will provide with images and data, which predict the performance of that design.

After studying the Literature it can be concluded that a lot of work has been done in the field of Design & analysis of heat exchanger. An experimental analysis is carried out to study the heat transfer phenomenon in conical coil heat exchanger with cone angle 90 degree [1], The experimental investigation of the effect of wedge-shaped tetrahedral VGs (vortex generator) on a gas liquid finned tube heat exchanger was studied using irreversibility analysis [2], The statistical analysis is used as an invaluable tool for investigation of performance of a shell and tube heat exchanger under fouling condition [3], The non uniform distribution of liquid flow among the tubes of a shell and tube apparatus has to be taken into account in determining the efficiency of heat transfer. The authors of this paper have proposed a method for taking this non uniformity into account and for analysing its effect on the intensity of heat transfer [4], The heat transfer enhancement in the core flow, and with the analysis of the disturbance mechanism of longitudinal flow, a new type of high efficiency and low resistance heat exchanger with rod-vane compound baffler was designed and investigated numerically [5], The heat transfer rate of the external tube surface of the heat exchanger for a closed wet cooling tower can be divided into sensible and latent heat transfer rates. These in turn are expressed by heat and mass transfer coefficients [6], Minimization of the thermal surface area for a particular service involving discrete variables [7], The authors found the parameters such as effectiveness, heat transfer, energy extraction using CFD ANSYS 13.0 [8].

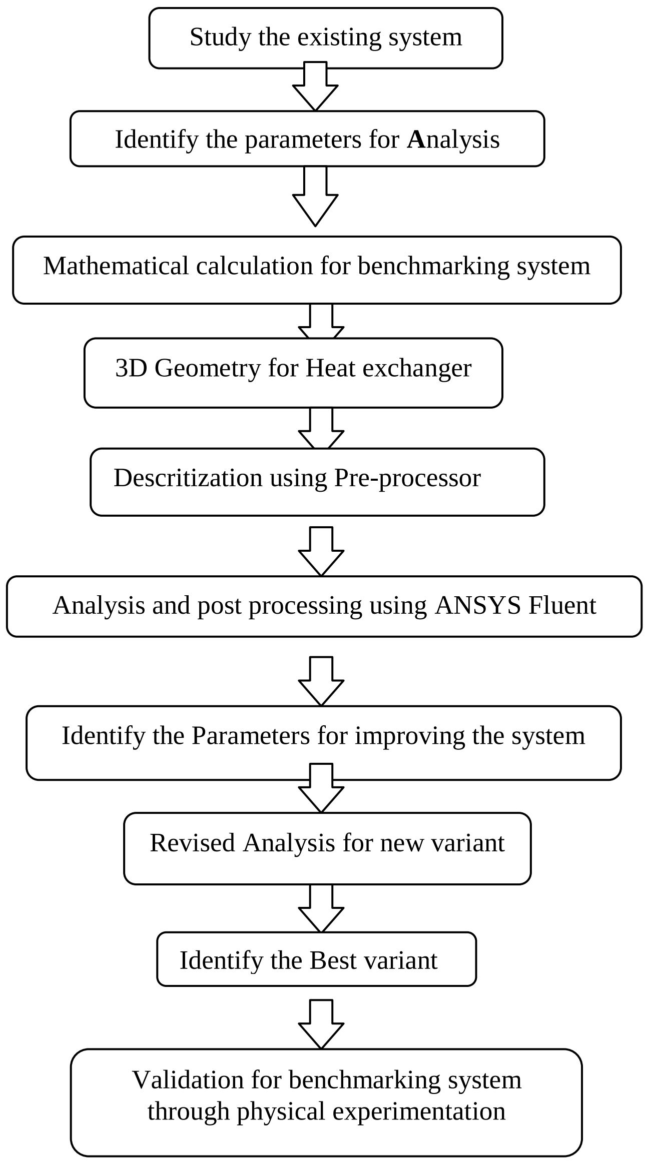
A. Problem statement

The collection center at a typical dairy processing unit records around twenty thousand liters of milk in a day. The same needs to be processed immediately upon receipt from the vendors since the perishable nature of milk makes it mandatory to pasteurize the same on priority. The volume dictates the nature of heat exchanger to be engaged for processing needs. Smaller volumes have been handled in the past using shell & tube heat exchanger with tubes made of steel. The existing heat exchangers pose limitations for handling the increased volume of the milk. Multiplying the units of the current design of heat exchanger does not seem to offer an efficient solution to the problem.

B. Objective

- Review current process and design aspects of the heat exchanger.
- Benchmark the performance for reference, the same shall be validated with mathematical modeling.
- Propose design alternative/s for the type or construction of heat exchanger.
- Analyze the proposed variant/s using CFD software.
- Recommend the solution.

C. Methodology



II. MODELLING OF SHELL AND TUBE HEAT EXCHANGER

There are various types of modelling software available like CATIA, Pro-E, and Solid Works. Here, 3D model of shell and tube heat exchanger is prepared in CATIA because in ANSYS it's very difficult to model the part.

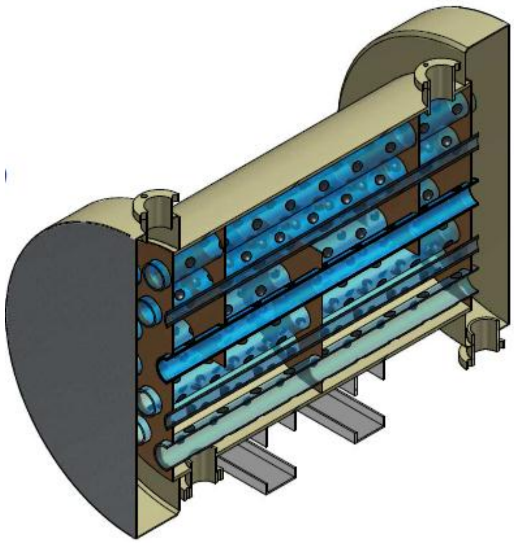


Fig. 2 Cut section of shell & tube heat exchanger

Bellow shows the dimensioning details of different part of shell and tube heat exchanger.

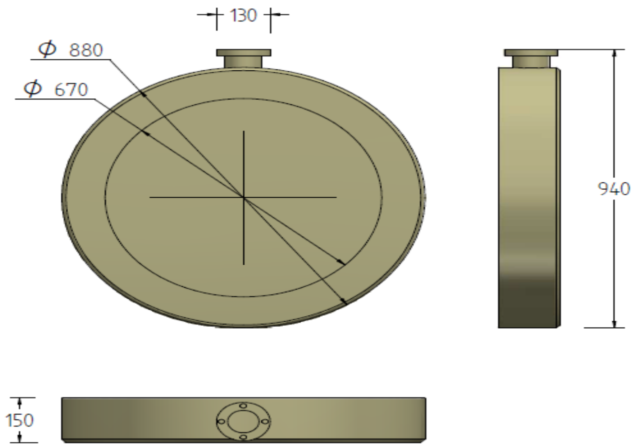


Fig. 3 Dimensioning details of housing end plate

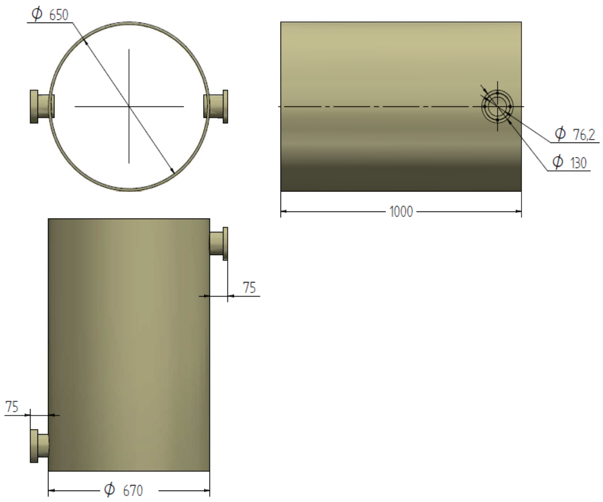


Fig. 4. Dimensioning details of housing

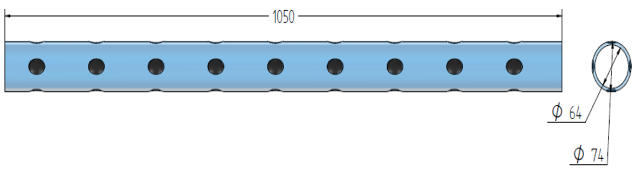


Fig.5. Dimensioning details of tubes

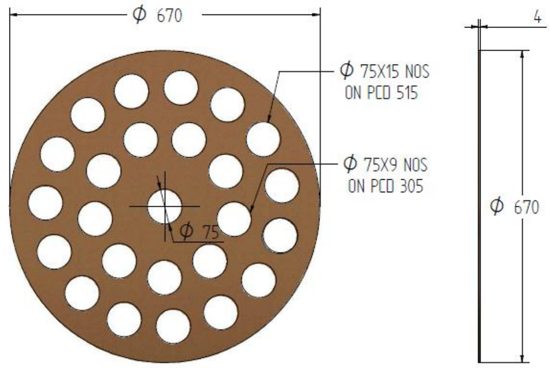


Fig.6. Dimensioning details of end plate

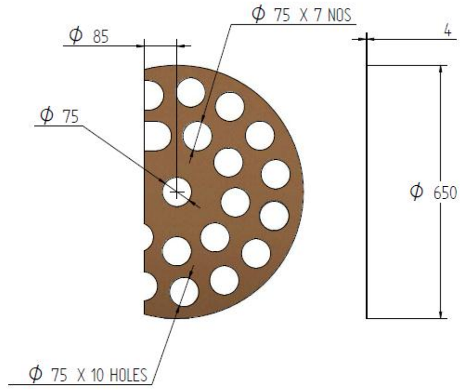


Fig.7. Dimensioning details of Baffle plate

III.EXPERIMENTATION

Upon reviewing the ‘Analytical results’ for the benchmark (existing) facility of the shell and tube heat exchanger, an experiment is planned to validate these results. The analytical results for the existing setup shall be compared vis-à-vis the experimental results for the same benchmark (existing) setup. Thermocouples shall be deployed for measuring temperature, while suitable instruments like ‘flow meter’ shall be used for assigning the requisite mass flow rate of the working fluid and the milk. The temperature shall be recorded at a steady state expected in about an hour from the assignment of correct operating conditions as per the input data used for problem solving in the mathematical model and/or the analytical/computational solution.

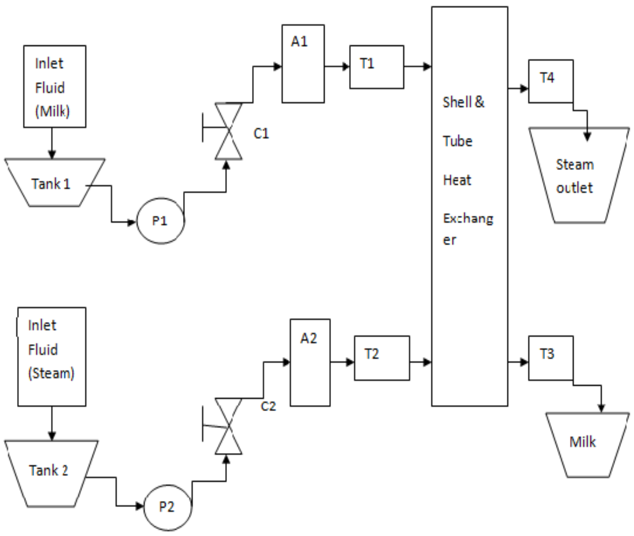


Fig.8. Schematic of experimental set up

Where,
P1, P2- Inlet pump, C1,C2- Flow control valve,T1,T2,T3,T4- Inlet /outlet temperature.

IV. CONCLUSION

The study over the topic reveals that the rate of heat transfer can be enhanced using alternative material or incorporating a change in the geometry of the tube. The provision of fins or protrusions to increase the surface area of contact can result in enhanced performance. This work shall mainly focus on arrangement of tubes while varying with pitch and/or the diameter. The requisite mass flow rate shall be calculated to achieve the given temperature (72^0C) in the specified time. The actual variation to be done shall be discussed upon securing the existing configuration of the shell and tube heat exchanger.

V. FUTURE SCOPE

Input data in the form of CAD geometry for the current heat exchanger shall be secured from the Sponsoring Company. The scope outlined for this work shall encompass activities involving the pre-processor for 'Analytical' software followed for solving and post-processor. The material properties for the working fluid and the input conditions applicable for the problem case shall be administered while working on the CAD interface. Mathematical modeling is considered for alternative methodology to validate the results obtained by computational techniques.

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