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Development of VB Based Software For Design And Analysis of Heat Exchangers

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Abstract

The exchange of heat is one of the most important processes in the mechanical industry and heat exchanger is the major equipment used to transfer heat from one medium to another. This project work on the Computer Aided Design (CAD) of shell and tube, double pipe and spiral coil heat exchanger aims to provide an easy way to design it. A case study question was taken and all the necessary calculations in the thermal design are carried out using standard method of heat exchanger design. The thermal design is then used as a guide to the computer aided design using computer codes.

The computer software program used is the Visual Basic called Visual Basic 6.0 (VB 6) because of its numerous advantages over the other software programmes. The result gotten from the computer aided design was compared to the result from the thermal design. The computer aided design software was equally used to test other problems on shell and tube, double pipe and spiral coil heat exchanger.

Because the computer aided design was found to be more accurate, quicker and more efficient, it was recommended for use in companies and industries.

Keywords: Heat Exchanger, Visual Basic 6.0, Design.

Introduction

Heat Exchangers are specialized devices that assist in the transfer of heat from one fluid to the other. In some cases, a solid wall may separate the fluids and prevent them from mixing. In other designs, the fluids may be in direct contact with each other. In the most efficient heat exchangers the surface area of the wall between the fluids is maximized while simultaneously mixing the fluid flow resistance. Fins or corrugation are sometimes used with the wall in order to increase the surface area and to induce turbulence. There are three primary flow arrangements with heat exchangers: Counter-flow, Parallel flow and Cross flow.

The most common type of heat exchangers used in the process, petroleum, chemical and HVAC industries intended for heating process fluids is Shell and Tube Heat Exchangers. Shell and tube heat exchangers are used when a process requires large amounts of fluids to be heated or cooled. Due to their design, they offer a large heat transfer area and provide high heat transfer efficiency. They consist of tubes and shells. The tubes act as the flow channels for one of the fluids in the heat exchanger, these exchangers are often parallel in order to provide a large surface area for the heat transfer. The shell on the other hand holds the tube bundle and acts as the channel for the fluid. The shell assembly houses the shell side connections and is the actual structure in to which the tube bundle is placed.

Shell and tube heat exchangers are used in applications where the pressure and temperature demands are high. They serve a wide range of applications in compressor system, hydraulic system, stationary engines, pain systems, air dryers and several marine applications.

A typical double-pipe heat transfer exchanger consists of one pipe placed concentrically inside another pipe of a larger diameter with appropriate fittings to direct the flow from one section to the next. One fluid flows through the inner pipe (tube side), and the other flows through the annular space (annulus). The inner pipe is connected by U-shaped return bends enclosed in a various series and parallel arrangement to meet pressure drop and LMTD requirements.

The major use of the double-pipe heat exchanger is for sensible heating or cooling of process fluids where small heat transfer areas (up to 50 m^2) are

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required. This configuration is also very suitable of one or both of the fluids at high pressure because of the smaller diameter of the pipes.

Spiral coil heat exchanger consists of spirally wound coils placed in a shell or designed as co-axial condensers ad co-axial evaporators that are used in refrigeration systems. The heat transfer coefficient is higher in a spiral coil than in a straight tube. Spiral heat exchangers are suitable for thermal expansion and clean fluids, since cleaning is almost impossible.

AIM: Design and development of software for solving shell and tube, double pipe and spiral coil heat exchanger.

OBJECTIVES:

- To design a one shell pass and two tubes pass, double pipe and spiral coil heat exchanger using Basic design Procedure and theory.
- To compare the design of above mention heat exchangers with each other.
- To develop software for solving shell and tube, double pipe and spiral coil heat exchanger.

SCOPE :- This study is proposed to focus on the design and development of software for solving heat exchangers. The index of studying the heat exchanger includes:

- The Basic design procedure and theory for the shell and Tube, double pipe and spiral coil heat exchanger.
- Solving problems of above mention heat exchanger using a software/ computer programming language Visual Basic (VB6).
- The factors affecting performance of heat exchangers and the pattern of flow of the streams/fluids in them.
- Their functions and general applications in Engineering.

SIGNIFICANCE OF THE STUDY:-Anyone who wants to use a heat exchanger faces a fundamental challenge, fully defining the problem to be solved which requires an understanding of the thermodynamic and transport properties of fluid. Such knowledge can be combined with some simple calculations to define a specific heat transfer problem and select an appropriate heat exchanger.

Heat exchangers serve as straight forward purpose controlling a system's or substance's energy. Although there are many different sizes, levels of sophistication and types of heat exchangers, they all use a thermally conducting tube or plate to separate two fluids such that one can transfer thermal energy to the other.

This study thereby necessitates the need for the design and development of software with minimum input data for which will lead to near maximum performance of a heat exchanger.

Finally, the data obtained from this procedure give us comparison between all above mention heat exchanger and we can select appropriate heat exchanger according to their application.

Literature Survey

In physics and thermodynamics, heat is the process of energy transfer from one body or system due to thermal contact, which in turn is defined as an energy transfer to a body in any other way than due to work performed on the body. [1] When an infinitesimal amount of heat Q is transferred to a body in thermal equilibrium at absolute temperature T in a reversible way, then it is given by the quantity Tds, where S is the entropy of the body. A related term is thermal energy, loosely defined as the energy of a body that increases with its temperature.

Energy transfer by heat can occur between objects by radiation, conduction and convention. Temperature is used as a measure of the internal energy or enthalpy, which is the level of elementary motion giving rise to heat transfer.[1]

Heat transfer is a path function (process quantity), as opposed to a point function (state quantity). Heat flows between systems that are not in thermal equilibrium with each other; it spontaneously flows from the areas of high temperature to areas of low temperature.

Similarly some modern, brief definitions of heat are as follows.

- In a thermodynamics sense, heat is never regarded as being stored within a body. Like work, it exists only as energy in transit from one body to another; in thermodynamics terminology between a system and its surroundings. When energy in the form of heat is added to a system, it is stored not as heat, but as kinetic and potential energy of the atoms and molecules making up the system.[1]
- Heat as an interaction between two closed systems without exchange of work is a pure heat interaction when the systems, initially isolated and in a stable equilibrium, are replaced in contact. The energy exchanged between the two systems is the called heat.[2]
- Heat is the transfer of energy between substances of different temperatures.

Internal Energy

Heat is related to the internal energy μ of the system and work W done by the system by the first law of thermodynamics:

$$\Delta\mu = Q - W$$

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This means that the energy of the system can change either via work or via heat flows across the boundary of the thermodynamic system. In more detail, Internal energy is the sum of all microscopic forms of energy of a system.

Heat Capacity

For a simple compressible system such as an ideal gas inside a piston, the changes in enthalpy and internal energy can be related to the heat capacity at constant pressure and volume, respectively. Constrained to have constant volume, the heat Q, required to change its temperature from an initial temperature, to a final temperature, T_f is given by.[5]

$$Q = \int_{To}^{Tf} CvdT = \Delta\mu$$

Removing the volume constraint and allowing the system to expand or contract at constant pressure.

$$Q = \Delta\mu \int_{To}^{Tf} Pdv = \Delta H = \int_{To}^{Tf} CpdT$$

For incompressible substance, such as solids and liquids the distinction between the two types of heat capacity disappears, as no work is performed. Heat capacity is an extensive capacity and as such is dependent on the number of molecules in the system. It can be represented as the product of mass, m, and specific heat capacity, Cs according to:

Cp = MCs

Or is dependent on the number of moles and the molar heat capacity, Cn according to:

Cp = nCn

The molar and specific heat capacities are dependent upon the internal degrees of freedom of the system and not on any external properties such as volume and number of molecules.

Heat Transfer Mechanism

Heat tends to move from a high-temperature region to a low temperature region. This heat transfer may occur by the mechanisms of conduction and radiation. In engineering, the term convective heat transfer is used to describe the combined effects of conduction and fluid flow and is regarded as a third mechanism of heat transfer.[1]

Conduction:-Conduction is the most significant means of heat transfer in a solid. On a microscopic scale, conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighbouring atoms and molecules, transferring some of their energy (heat) to these neighbouring atoms. In insulators the heat flux is carried almost entirely by photon vibrations.

Convection:-Convection is usually the dominant form of heat transfer in liquids and gases. This is a term used to characterize the combined effects of conduction, enthalpy transfer occurs by the movement of hot or cold portions of the fluid together with heat transfer by conduction.

Radiation:-Radiation is the only form of heat transfer that can occur in the absence of any form of medium i.e. through a vacuum. Thermal radiation is a direct result of the movement of atoms and molecules in a material. Since these atoms and molecules are composed of charged particles (protons and electrons), their movements result in the emission of electromagnetic radiation which carries energy away from the surface. At the same time, the surface is constantly bombarded by radiation from the surroundings, resulting in the transfer of energy to the surface. [1]

Heat Dissipation:-In cold climates, houses have their heating systems. In spite of efforts to insulate such houses to reduce heat losses to their exteriors, considerable heat is lost or dissipated from them, which can make their interiors uncomfortably cool or cold. For the comfort of its inhabitants, the interior of a house must be maintained out of thermal equilibrium with its external surroundings.

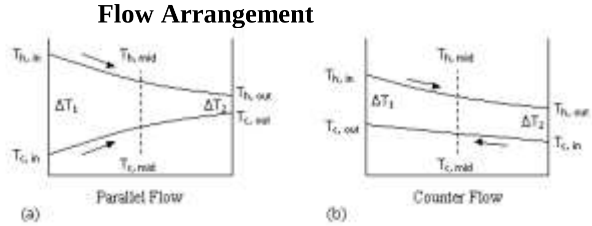
In such a house, a thermostat is a device capable of starting the heating system when the house's interior falls below a set temperature, and of stopping that same system when another (higher) set temperature has been achieved. Thus the thermostat controls the flow of energy into the house, that energy is eventually being dissipated to the exterior.

Heat Exchanger

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media are separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigerator, air conditioning, power plants, chemical plants, petroleum refineries and natural gas processing.

One common example is the radiator in a car, in which the heat source, being a hot engine cooling fluid, water, transfer heat to air flowing through the radiator i.e. the heat transfer medium.

Flow Arrangement



(a) Parallel Flow (b) Counter Flow

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Heat exchanger may be classified according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers, the fluids enter the exchanger from opposite ends. The counter current design is most efficient, in that it can transfer the most heat from the heat transfer medium. [7]

In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of the fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. The driving temperature across the heat transfer surfaces varies with position, but an appropriate mean temperature can be defined. In most simple systems this is the Log Mean Temperature Difference (LMTD) but NTU methods are mostly used due to non-availability LMTD direct knowledge.[5]

Applications

- **Industry**

Heat exchangers are widely used both for cooling and heating large scale industrial processes. The type and size of heat exchanger used can be tailored to suit a process depending on the type of fluid, its phase, temperature, density, viscosity, pressures, chemical composition and various other thermodynamics properties. Other industries that use heat exchangers are

- Waste water treatment, refrigeration systems, wine-brewing industry, and petroleum industry.

- **In Air Craft**

In commercial aircraft, heat exchangers are used to take heat from the engine's oil system to heat cold fuel. This improves fuel efficiency, as well as reduces the possibility of water entrapped in the fuel freezing in components. In early 2008, a Boeing 777 flying as British Airways flight 38 crashed just short of the runway. In early 2009 Boeing-update sent to aircraft operators, the problem was identified as specific to the Rolls-Royce engine oil-fuel flow heat exchanger. Other heat exchangers or Boeing 777 aircraft are not affected by the problem.

- **In Nature**

The human lungs also serve as an extremely efficient heat exchanger due to their large surface area to volume ratio. In species having external testis such as humans, the artery to the testis is surrounded by a mesh of veins called the pampiniform plexus. This cools the blood heading to the testis, while reheating the returning blood.

In Animals, "Counter Current" heat exchangers occur naturally in the circulation system of fish and whales. Arteries to the skin carrying cold blood cause the warm arterial blood to exchange with the cold venous blood. This reduces the overall heat loss in cold waters.

Fluids in Heat exchangers

- **Fluid Fundamentals**

How heat gets transferred from one fluid to another depends largely on the physical characteristics of the fluids involved, especially their density, specific heat, thermal conductivity and dynamic viscosity.

- **Density (P)**

Density is a fluid's mass per unit volume measured in kg/m3. Density can be used to convert a measurement from a mass flow rate, to the more common volumetric units, such as gallons per minute for liquids or cubic feet per minute for gases.

- Specific heat relates the quantity of the transferred heat to the temperature change of the fluid while passing through the heat exchanger.
- Thermal conductivity (k) represents the ability of a fluid to conduct heat.
- Dynamic viscosity indicates a fluid's resistance to flow. A fluid with high dynamic viscosity produces a high pressure loss because of shear resistance.

- **Fluid Flow**

Inside a heat exchanger, the fluid flow is either turbulent or laminar. Turbulent flow produces better heat transfer, because it mixes the fluid. Laminar flow heat transfer relies entirely on the thermal conductivity of the fluid to transfer heat from inside a stream to a heat exchanger wall.[1]

An exchanger's fluid flow can be determined from its Reynolds number (N_{Re}):

$$N_{re} = \frac{e_x V_x \delta}{\mu}$$

Where V is the flow velocity and ∂ is the diameter of the tube in which the fluid flows. The units cancel each other, making the Reynolds number dimensionless. If the Reynolds number is less than 2000, the fluid flow will be fully laminar. The transition region between turbulent and laminar flow produces rapidly increasing thermal performance as the Reynolds number increases. The type of flow determines how much pressure a fluid losses as it moves through a heat exchanger. This is important because higher pressure drops require more pumping power.

- **Balance and Effectiveness**

The characteristics of fluids contribute to a fundamental property of heat exchangers – the heat-transfer rate. The heat is transferred from the hotter fluid, according to the following equation:

Q = [M x CP x (Tout - Tin] cold

Q = - [M x CP x (Tout - Tin] heat

Where Q represents the mass flow per unit time. So the heat transferred per unit time equals the product of mass flow per unit time, specific heat and temperature change. An exchanger's effectiveness is the ratio of the actual heat transferred to the heat that could be transferred by an exchange of infinite size. Effectiveness is the best way to compare different types of heat exchangers.

- **Exchanger Equation**

The heat transfer rate of a given exchanger depends on its design and the properties of two fluid streams. This characteristic can be defined as:

$Q = UA\Delta T$ log mean

where U is the overall heat-transfer coefficient or the ability to transfer heat between the fluid streams, A is the heat-transfer area of the wall that separates the two fluids and ΔT log mean is the average effective temperature difference between the two fluid streams over the length of the heat exchanger. [7]

A heat exchanger's performance is predicted by calculating the overall heat transfer coefficient U and the area A.

- **Selection of a Heat Exchanger**

Due to the many variables involved, selecting optimal heat exchangers is challenging. Hand calculations are possible, but much iteration is typically needed. As such, heat exchangers are most often selected via computer programs, either by system designers, who are typically engineers, or by equipment vendors.

In order to select an appropriate heat exchanger, the system designers would first consider the design limitations for heat exchanger type. Although cost is the first criterion evaluated, there are several other important selection criteria which include:

- High/low pressure limits
- Thermal performance
- Temperature range
- Product mix (liquid/liquid particulates, or high solids liquid).
- Pressure drops across the exchanger.
- Fluid flow capacity
- Clean ability, maintenance and repair
- Materials required for construction
- Ability and ease of future expansion

Choosing the right heat exchanger (HX) requires some knowledge of the different heat exchanger types, as well as the environment in which the unit must operate. [7]

- **Application of Computer – Aided Design (CAD):** Is the use of computer technology to aid in the design and drafting of any part or type of product for any discipline or technical field. CAD is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and type of software in question.

The emergence of Computer Aided Design (CAD) and Rapid prototyping technologies has had a major impact on mapping, design, and manufacturing, thereby reducing design effort, testing and prototype work. This has resulted in significantly reducing costs and improved productivity.

In this design the computer help in speeding up the design, Based on the problems and features needed to accomplish in this design work and also considering the time constraint, visual Basic 6.0 programming language was chosen. V.B. is a programming environment, which is a program specifically designed to facilitate the creation of new program.

-VISUAL BASIC (VB.6)

VB is the third-generation event-driven programming language and integrated development environment (IDE) from Microsoft for its COM programming model. VB is also considered relatively easy to learn and use programming language, because of its graphical development features and BASIC heritage.

Visual Basic was derived from BASIC and enables the rapid application development (RAD) of graphical user interface (GUI) applications, access to database using Data Access Objects DAO, Remote Data Objects RDO, or ActiveX Data objects ADO, and creation of ActiveX controls and objects. Scripting languages such as VBA and VBScript are syntactically similar to Visual Basic, but perform differently.

A programmer can put together an application using the components provided with Visual Basic itself. Programs written in Visual Basic can also use the Windows API, but doing so requires function declarations.

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3. Problem Statement: - Designing and development of software which ease the selection of heat exchanger along with the complete design of the selected heat exchanger with minimum fundamental characteristic inputs.

Methodology

BASIC DESIGN PROCEDURE INVOLVES THE FOLLOWING STEPS:-

1) Define the duty: Heat-transfer rate, fluid flow rates and temperatures.

2) Collect together the fluid physical properties required: Density, viscosity and Thermal conductivity.

3) Assume value of overall coefficient μ o

4) Decide number of shell and tube passes, calculate DTLMTD, correction factor f, and DTm.

5) Determine heat transfer area required: Ao = q/ μ oDTm

6) Decide type, tube side, material layout assign fluids to shell or tube side.

7) Calculate number of tubes.

8) Calculate shell diameter.

9) Estimate tube-side heat transfer coefficient.

10) Decide baffle spacing and estimate shell-side heat transfer coefficient

11) Estimate tube and shell side pressure drops.

12) Estimate cost of exchanger

13) Accept design and develop a software for it (Visual Basic Version 6.0 was used).

4. Results & Discussion

The following outputs are expected from this study:-

1. Welcome page
2. Manu of selection of required heat exchangers from among the Shell and tube, double pipe and spiral coil heat exchanger.
3. Input data form
4. Design form
5. Result form.

Conclusion

It was seen in the paper that there are might be slight variations between the results from the computer design.

The VB 6.0 software computes the values mostly between 8-16 digit decimal places while the manual design computes the values with 3 digit decimal places. So this makes the VB6.0 software more accurate and reliable than the manual design. The software also takes lesser time in computation of the design value compared to the hours used in the manual design.

By which we can say that the software can show accurately and effectively design of any heat exchanger which will be there in menu, with the input parameters feed in correctly at the specified unit.

I will recommend that this program be developed to increase its accuracy and to build up an available database so as to reduce the number of required input data.

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