A Review on Thermal Analysis and Optimization of Heat Exchanger Designed for Co-Generation Units

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Abstract-*A heat exchanger is a heat transfer device that is used for transfer of internal thermal energy between two or more -fluids available at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally, they do not mix. Heat exchangers are used in the process, power, petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, alternate fuels, and other industries. Common examples of heat exchangers familiar to us in day-to-day use are automobile radiators, condensers, evaporators, air preheaters, and oil coolers. Heat exchangers can be classified into many different ways.*

Keywords: CFD, Co-generation, ANSYS, Efficiency, Heat exchanger

1. INTRODUCTION

A heat exchanger consists of heat-exchanging elements such as a core or matrix containing the heat transfer surface, and fluid distribution elements such as headers or tanks, inlet and outlet nozzles or pipes, etc. Usually, there are no moving parts in the heat exchanger; however, there are exceptions, such as a rotary regenerator in which the matrix is driven to rotate at some design speed and a scraped surface heat exchanger in which a rotary element with scraper blades continuously rotates inside the heat transfer tube. The heat transfer surface is in direct contact with FLuids through which heat is transferred by conduction. The portion of the surface that separates the fluids is referred to as the primary or direct contact surface. To increase heat transfer area, secondary surfaces known as ns may be attached to the primary surface

2. USES

Refrigerators and air-conditioners, for example, use heat exchangers in the opposite way from central heating systems: they remove heat from a compartment or room where it's not wanted and pump it away in a fluid to some other place where it can be dumped out of the way.

In power plants or engines, exhaust gases often contain heat that's heading uselessly away into the open air. That's a waste of energy and something a heat exchanger can certainly reduce (though not eliminate entirely—some heat is always going to be lost). The way to solve this problem is with heat exchangers positioned inside the exhaust tail pipes or smokestacks. As the hot exhaust gases drift upward, they brush past copper fins with water flowing through them. The water carries the heat away, back into the plant. There, it might be recycled directly, maybe warming the cold gases that feed into the engine or furnace, saving the energy that would otherwise be needed to heat them up. Or it could be put to some other good use, for example, heating an office near the smokestack.

In buses, fluid used to cool down the diesel engine is often passed through a heat exchanger and the heat it reclaims is used to warm cold air from outside that is pumped up from the floor of the passenger compartment. That saves the need for having additional, wasteful electric heaters inside the bus. A car radiator is another kind of heat exchanger. Water that cools the engine flows through the radiator, which has lots of parallel, aluminum fins open to the air. As the car drives along, cold air blowing past the radiator removes some of the heat, cooling the water and heating the air and keeping the engine working efficiently. The radiator's waste heat is used to heat the passenger compartment, just like on a bus.

3. BEST MATERIALS FOR A HEAT EXCHANGER

Heat exchangers can be made of metals ceramics, composites (based on either metals or ceramics), and even plastics (polymers). All these materials have their advantages. Ceramics are a particularly good choice for the kind of high-temperature applications (over 1000C or 2000F) that would melt metals like copper, iron, and steel, though they're also popular for use with corrosive and abrasive fluids at either high or low temperatures. Plastics generally weigh and cost less than metals, resist corrosion and fouling, and can be engineered to have good thermal conductivity, though they tend to be mechanically weak. Although not generally suitable for high-temperature applications, plastic exchangers could be a good choice for something like a swimming pool or shower, operating at every day, room-temperatures. Composite heat exchangers combine the best features of their parent materials—say, the high thermal conductivity of a metal with the reduced weight and better corrosion resistance of a plastic.

4. COGENERATION

Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time. Trigeneration or combined cooling, heat and power (CCHP) refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or a solar heat collector. The terms cogeneration and trigeneration can be also applied to the power systems generating simultaneously electricity, heat, and industrial chemicals – e.g., syngas or pure hydrogen.

Cogeneration is a technique for producing heat and electricity in one process that can save considerable amounts of energy. Cogeneration is often associated with the combustion of fossil fuels but can also be carried out using some renewable energy sources and by burning wastes. Cogeneration often reduces energy use cost-effectively and improves security of energy supply. Cogeneration helps overcome the main drawback of conventional electrical and thermal systems: the significant heat losses that detract greatly from efficiency. Heat losses are reduced and efficiency is increased when cogeneration is used to supply heat to various applications and facilities. Energy and exergy analyses of cogeneration-based district energy systems are described in this chapter. Relative to conventional systems, such integrated systems can be complex in that they often carry out the provision of electrical, heating, and cooling services simultaneously.

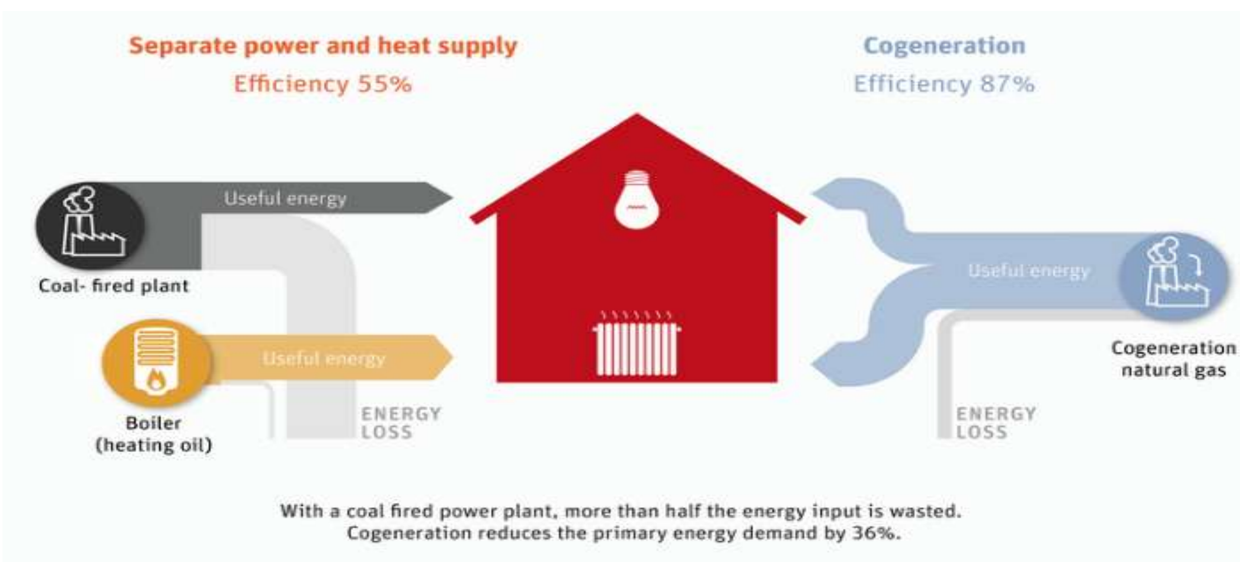

Fig. 1. Cogeneration

5. HOW TO MAKE A HEAT EXCHANGER MORE EFFICIENT

Heat exchanger efficiency can be defined in many ways, in terms of thermal performance there are several key factors to consider;

Temperature differential - The difference between the hot fluid and coolant is very important when designing a heat exchanger. The coolant always needs to be at a lower temperature than the hot fluid. Lower coolant temperatures will take more heat out of the hot fluid than warmer coolant temperatures. If you had a glass of drinking water at room temperature for example, it is much more effective to cool it down using ice rather than just cool water, the same principle applies to heat exchangers.

Flow rate - Another important factor is the flows of the fluids in both the primary and the secondary side of the heat exchanger. A greater flow rate will increase the capability of the exchanger to transfer the heat, but a greater flow rate also means greater mass, which can make it more difficult for the energy to be removed as well as increasing velocity and pressure loss.

Installation - Generally speaking the most efficient way to install a heat exchanger is with the fluids flowing in a counter-current arrangement (so if the coolant is travelling left to right, the hot fluid travels right to left) and for shell and tube heat exchangers the coolant should enter at the lowest inlet position to ensure that the heat exchanger is always full of water. For air cooled heat exchangers, it is important to consider the air flow when installing a cooler, any part of the core which is blocked will compromise cooling capacity.

6. PAST STUDIES

Macháčková et al (2018) presented the ever increasing environmental awareness introduces the trend of increasing the efficiency of power plants via implementing waste heat recovery. Milani et al (2017) presented the Response Surface Methodology (RSM) and two phase mixture model are proposed to investigate the sensitivity analysis of heat transfer and heat exchanger effectiveness in a double pipe heat exchanger filled with Al_2O_3 nanofluid. Banakar et al (2017) presented a Fresnel lens collector was incorporated in a thermoelectric solar system for combined heat and power (CHP) generation. Two passive (heat pipe thermo-siphon) and active (pumped circulation) cooling systems were used for transferring heat from the cold side of thermoelectric generators to a thermal energy storage. Experimental results from the solar thermoelectric (STE) CHP system equipped with passive cooling showed that the maximum output power of the thermo-siphon from the thermoelectric generators (TEGs) was 70 W/m2. Bojko et al (2016) presented application of numerical simulations based on the CFD calculation when the mass and heat transfer between the fluid flows is essential component of thermal calculation. In this article the mathematical model of the heat exchanger is defined, which is subsequently applied to the plate heat exchanger, which is connected in series with the other heat exchanger (tubular heat exchanger). Lythcke et al (2016) presented an FMG (flexible multi-generation system) consists of integrated and flexibly operated facilities that provide multiple links between the various layers of the energy system. Milani et al (2016) presented a 2-D numerical simulation and sensitivity analysis carried out on turbulent heat transfer and heat exchanger effectiveness enhancement in a double pipe heat exchanger filled with porous media. The Darcy–Brinkman–Forchheimer and the k–ε turbulent models are employed to achieve heat transfer and heat exchanger effectiveness in the presented model. Macháčková et al (2015) presented possibilities of application of a secondary exchanger for use of flue gas waste heat produced by small microturbines. The investigated heat transfer system consisted of two consecutively positioned heat exchangers with various construction designs. Chen et al (2015) presented an equivalent thermal circuit to represent the heat transfer process in a heat exchanger, and then analyze the temperature variations of all the working fluids in each heat exchanger to establish the equivalent thermal circuits for such three basic layouts of HENs as multiple-loop, series, and parallel.

7. PRESENT WORK

In this work, Research on the heat exchangers for the co-generating units was carried out to obtain the best design, by comparing the efficiency and the concepts used by different heat exchangers. The system was designed based on three basic parameters optimization: number of coolant tubes, diameter of the coolant tube and inlet velocity of the cold gases. These three variables were optimised in order to investigate heat transfer performances, as well as, effects of heat transfer fluids and efficiency.

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