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Possibilities of intensifying heat transfer through finned surfaces in heat exchangers for high temperature applications

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ABSTRACT

High temperature heat transfer application actually represents the case of a heat exchanger operated within a process with high temperature. In every industrial domain, a different value of temperature may be considered "high". We are active in the field of chemical, petrochemical, waste-to-energy, power and process energy recovery heat transfer applications. Here, tube-fin exchangers are successfully used for gas or liquid and/or aggressive fluids with temperatures up to 350 and/or 400 °C. They are also frequently used in combustion systems with air preheating applications. Tubular heat exchangers, especially those with U-tubes, helical and straight tubes are most frequently used for high-temperature applications with temperatures above 650 °C.

Extended surfaces are used as an intensification approach to decrease the area requirements on flue gas side. Selection of an extended surface depends on the type of fuel being burned. Generally speaking, enhanced surfaces are used for gaseous media with low heat transfer coefficient. Fins substantially enhance the heat transfer area and consequently heat duty of the equipment.

This paper describes this "passive" technique to enhancement of heat transfer in more detail and presents novel types of longitudinally finned tubes intensifying heat transfer by increasing heat transfer area and heat transfer coefficient. This means that the fins not only increase heat transfer area but also make the fluid flowing around them change flow direction, i.e., they increase turbulence. This consequently increases film heat transfer coefficient on fin side.

1. Introduction

First, it is necessary to design the overall system with respect to the process in question [1] and only then one can consider heat exchanger networks (HEN) and heat exchangers as pieces of equipment. A novel design approach for HEN retrofits based on heat transfer enhancement is shown in Ref. [2]. The experience from industrial practice in terms of providing technical solutions increasing performance of heat exchangers through process enhancement technologies is presented in Ref. [3].

Heat exchangers perform satisfactorily only if they are correctly designed, installed, and operated. Selection of a suitable heat exchanger type, especially in case of high-temperature applications, is therefore of paramount importance.

1.1. Definition of "high temperature application"

High temperature application actually means that the equipment is operated within a process with high temperature streams. The problem, however, is how to define "high temperature". In every industrial domain, a different value may be considered "high", that is, a very different value will be denoted as such e.g. in cryogenics and in incineration. Even with respect to the human body, high temperature is understood in various ways. For example, normal human body temperature is approx. 37 °C and temperature around 38 °C is already a fever, while temperature above 40 °C is considered extreme, so-called hyperpyrexia. Burns may already occur upon touching a surface hotter than 45 °C (depending on the actual temperature and length of the touch). In food industry, temperatures above 80 °C are usually considered high. In electronics, high temperature is typically above 85 °C [4].

In any case, this paper is focused on the field of chemical, petrochemical, waste-to-energy, power, and process energy recovery heat transfer applications. In petrochemical industry, high

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temperature means values above 400 °C. A different situation arises considering combustion processes where high temperature flue gas is generated. There it is possible to classify as high-temperature any equipment with process stream temperatures above 650 °C (but then again, different sources give different values).

1.2. Suitable types of heat exchangers for high temperature applications

In general, it can be noted that for high temperature and highly fouled flue gas industrial applications heat exchangers with plain tubes or plate-type exchangers should be preferred wherever possible. These configurations allow easy cleaning of both outer and inner heat transfer surfaces. Tubular heat exchangers, especially those with U-tubes, helical, and straight tubes are most frequently used for high-temperature applications with stream temperatures above 650 °C [5].

In case of applications with low risk of fouling, the common approach is to use a conventional plate type heat exchanger with modular arrangement. Some types are described in Ref. [6], a review is given in Ref. [7], and the related equipment for power plants is discussed in Ref. [8]. Selected representatives of heat exchangers related to the range of temperatures in their applications are obvious from Fig. 1. However, these pieces of equipment have to be designed very carefully.

Authors of this article have an experience with such an application where a conventional plate type heat exchanger was originally used for high temperature purpose. Its plates were made of a special fire-proof chrome–nickel steel. Unfortunately, this heat exchanger was not designed correctly in terms of thermal expansion and the operating conditions specified in documentation were not respected either. Combination of these two facts resulted in distortion of the plates and complete destruction of the exchanger [9].

Finned tubes can also be used with success in case of low fouling applications. The actual temperature range in which finned tubes can be employed depends on the material they are made of. More on this topic can be found in Ref. [7]. According to Ref. [10], tube-fin exchangers are designed to cover the temperature range from low cryogenic temperatures to about 870 °C.

A typical example of application with finned tubes is a convection section of a fired heater. Convection section is located above the shield section and flue gas temperature there is between 500 °C and 700 °C. If there is no risk of fouling, usage of fins is possible. If there is any chance of fouling by flue gas, lower degree of heat transfer enhancement can be used, such as studded heat transfer surfaces [11].

First part of furnace convection section is followed by the second part where flue gas temperature reaches 300 °C–500 °C. Based on our extensive experience, we can state that there it is possible to fully utilize the potential of enhanced solutions (with respect to fouling properties of flue gas).

Finned tubes are also frequently used in combustion systems with air preheating equipment. These applications are probably the areas with the highest potential for application of enhanced solutions associated with increasing significance of heat recovery in this temperature range.

According to the above-mentioned information, it can be noted that for high-temperature and highly fouled flue gas industrial applications heat exchangers with plain tubes or plate-type ones should be preferred. Such configurations allow easy cleaning of both outer and inner heat transfer surfaces.

For very high gas temperatures (above 500 °C) and low risk of fouling one can safely use heat exchangers with enhanced heat transfer surfaces (with respect to limits posed by material of the

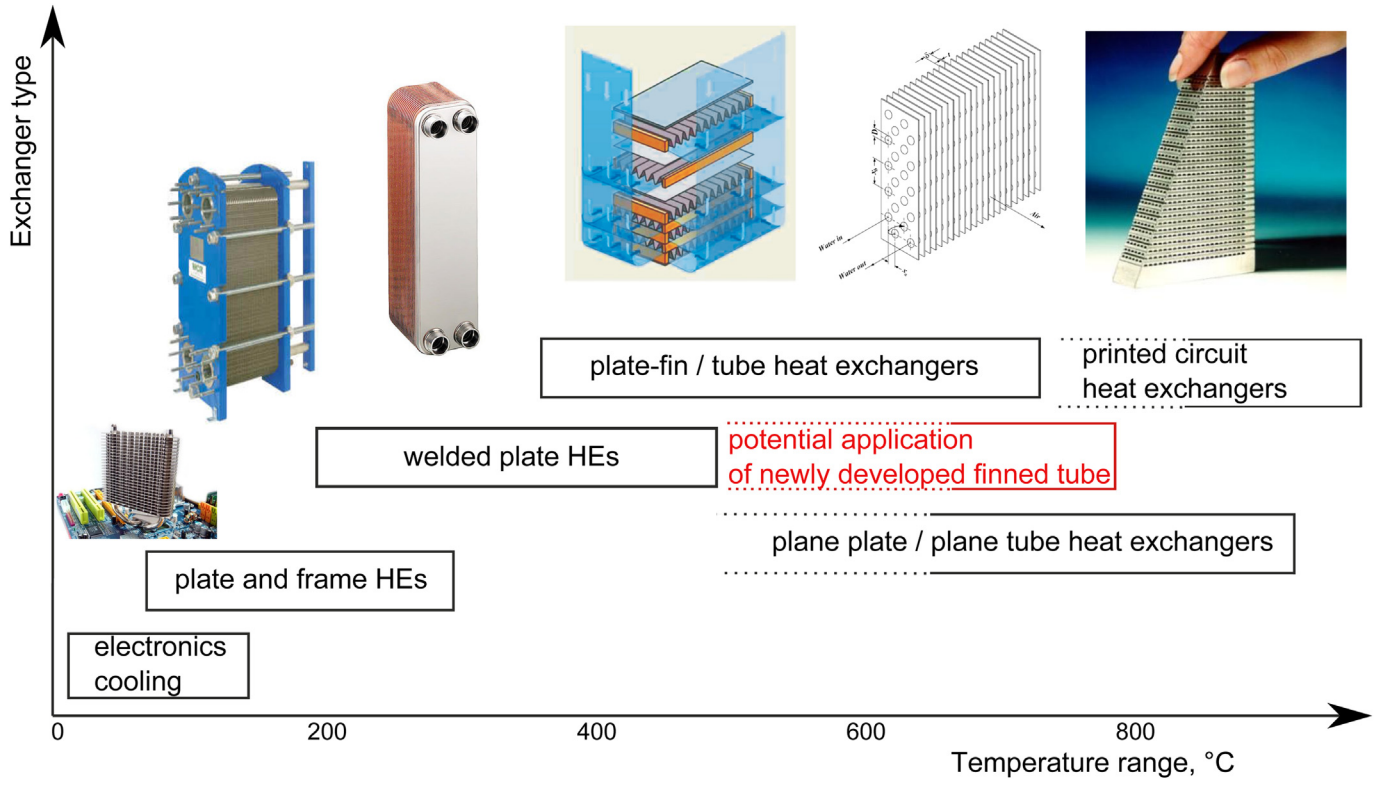

Fig. 1. Types of compact heat exchangers and their typical temperature limits [9].