Studies on Heat Exchangers Efficiency

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Abstract: - This paper contains notions about manufacturing process, and capability indices of a heat exchanger. In addition, it can be remark the classification of heat exchangers. The case study consists of estimation of process capability indices for normal distribution using Monte-Carlo simulation. The very limited and specific field of process capability indices is, in this respect, quite typical, though some early ideas and methods appear to remain important and useful.

Key-Words: - heat exchangers, capability indices, manufacturing process capability.

1 Introduction

The heat exchanger efficiency is defined as the ratio of the heat transferred in the actual heat exchanger to the heat that would be transferred in the ideal heat exchanger. The concept of heat exchanger efficiency provides a new way for the design and analysis of heat exchangers and heat exchanger networks.

The concept of efficiency is used in many areas, particularly engineering, to assess the performance of real components and systems. Efficiency is a comparison between the actual (real) and ideal (best) performances and is typically defined to be less than or at best equal to 1. The ideal behavior is generally known from modeling, and the limitations dictated by physical laws, particularly the second law of thermodynamics. Knowing the ideal performance, the actual performance can be determined if expressions for the efficiency as a function of the system characteristics and the operating conditions are known. Efficiency provides a clear and intuitive measure of a system's performance by showing how close an actual system comes to the best that it can be and if further improvements are feasible and justified. Despite much effort, the application of the second law to heat exchangers has not yielded a consistent method for assessing the performance of heat exchangers [1].

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. One common example of a heat exchanger is the radiator in a car, in which the heat source, being a hot engine-cooling fluid, water, transfers heat to air flowing through the radiator (i.e. the heat transfer medium).

2. Heat Exchangers Construction

The most important criteria for the classification of heat exchangers are:

The nature of the agent that makes the refrigerant heat transfer:
- Gas (usually air);
- Liquid (usually water).

Their role and type of shift:
- Vaporizers
- Cooling the air (or gas);
- Cooling water (or other liquid).
- Capacitors
- Water-cooled (or other liquid);
- Cooled air (or gas).

Operating conditions that characterize the most important mode of work of refrigeration heat exchangers are:

- Temperature and pressure of the inlet and outlet of exchanger (for cooling and humidity of air is important);
- The minimum temperature difference between the two agents;
- The refrigerant supply (especially for vaporizers);
- This heat accumulation (case evaporators ice batteries).

Thermal loads of heat exchangers, which are fundamental to the design of these devices sizes.

The geometrical characteristics of heat exchangers that is:

- Arrangement of pipes;
- Length of pipe;
- Pipe size (diameter outside and inside, outside diameter and thickness);
- Number of rows of pipes (pipe horizontal) and number of sections (vertical pipe).

Functional characteristics are what define the thermal performance of heat exchangers and fluidodinamice. Among these the most important are:

- Overall heat transfer coefficient;
- Loss of pressure on the circuits the two agents;
- How to automate the operation (by controlling the pressure of the refrigerant, the Ice, or water composition, etc.).

Necessary maintenance operations is another important feature, and some examples are:

- Purge (condensable gas, oil, etc.).
- Cleaning, de-icing, de-dusting, descaling;
- Auxiliary treatments.

2.1. Construction of heat exchangers

Modular exchangers are mainly constructed from a bundle of pipes, installed in two plates and enclosed in a tubular jacket provided with lids, as we can see in figure 1.

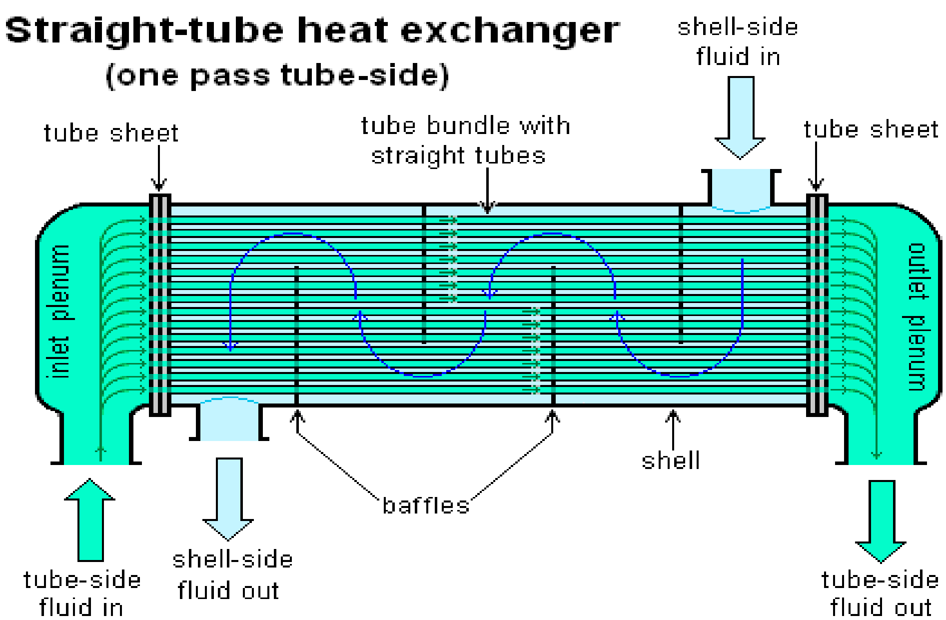

Figure 1

Generally tubes are rolled and heat exchangers designed specifically for construction. The materials used are:

- medium and low temperature steels;
- copper;
- copper-nickel alloys in various compositions (eg 70/30% or 90/10%);
- copper-aluminum alloys in various compositions (eg 93 / 7%, or 91 / 9%);
- different types of alloys with zinc between 22 and 40%;
- stainless steel.

In figure 2 are presented spiral ribbed pipes, which are mainly used in the construction of evaporators.

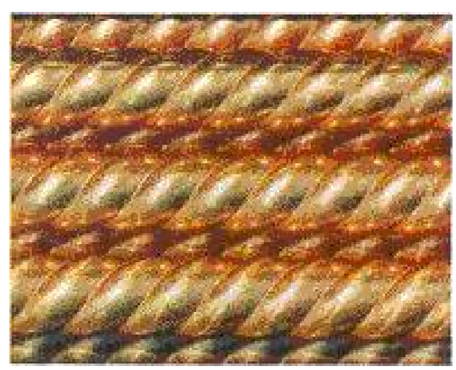

Figure 2

Pipes star-shaped core may be 14 ... 19 mm diameter and thickness of 1 mm. The ratio of inner and outer surface is 2 to 5 cores if rays and 2.7 for cores with 10 rays.

Figure 3

2.2. Plate heat exchangers

These devices are made by combining the tiles that they made between spaces through which agents that change the heat. These agents occupy alternative spaces between the heat exchanger plates, so as not to interfere with each other. Consequently, the spaces between tiles must be sealed from outside and from other areas in which gang agents. The system also must allow passage sealing agents in a space to another, sometimes passing space for other agents. The exchange must have at least two boards, as with some types of vaporizers.

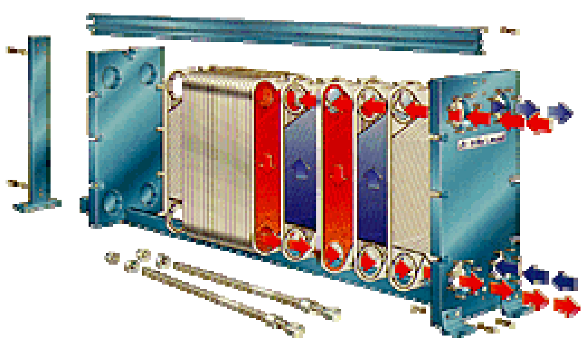

Figure 4

Plates made of materials that agents depend on the nature of work, and most commonly used are:

- Stainless steel;
- Aluminium alloys;
- Titanium alloys;
- Copper-nickel alloys.

Plate thickness can vary between 0.6 ... 1.1 mm or more.

Gasket can also use different materials depending on temperature range:

- Nitrile (t_{max} = 110 °C);
- butyl (t_{max} = 135 °C);
- ethylene-propylene (t_{max} = 155 °C);
- Viton (t_{max} = 190 °C).

3. Capability Indices of Heat Exchangers

Calculating the process capability requires knowledge of the process mean and standard deviation μ and σ. These values are usually estimated from data collected from the process. C_p assumes that the normal distribution is the correct model for the process. C_p can be highly inaccurate and lead to misleading conclusions about the process when the process data does not follow the normal distribution.

The major weakness in C_p was the fact that few, if any processes remain centred on the process mean. Thus, to get a better measure of the current performance of a process, one must consider where the process mean is located relative to the specification limits. The index C_{pk} was created to do exactly this. With C_{pk}, the location of the process centre compared to the USL and LSL is included in the computations and a worst case scenario is computed in which C_p is computed for the closest specification limit to the process mean.

$$C_{pk} = \min\left\{\frac{USL - \overline{\overline{X}}}{3\hat{\sigma}}, \frac{\overline{\overline{X}} - LSL}{3\hat{\sigma}}\right\}. \quad (1)$$

where $\overline{\overline{X}}$, the overall average, is used to estimate the process mean μ, and $\hat{\sigma}$ is process standard deviation estimated/

The process capability index C_{pm} is intended to account for deviation from the target T in addition to variability from the mean. This index is often defined as:

$$C_{pm} = \frac{USL - LSL}{6\sqrt{\sigma^2 + (\mu - T)^2}} = \frac{\dfrac{T_s - T_i}{6\sigma}}{\sqrt{1 + \dfrac{(\mu - T)^2}{\sigma^2}}}, \quad (2)$$

$$C_{pm} = \frac{C_p}{\sqrt{1 - V^2}}, \quad (3)$$

where $V = \dfrac{T - \overline{X}}{s}$ and : $T = (T_i + T_s)/2$.

4. Case Studies

The case study consists of estimation of process capability indices for normal distribution using Monte-Carlo simulation for a heat exchanger studied.

The histogram is presented in figure 5.

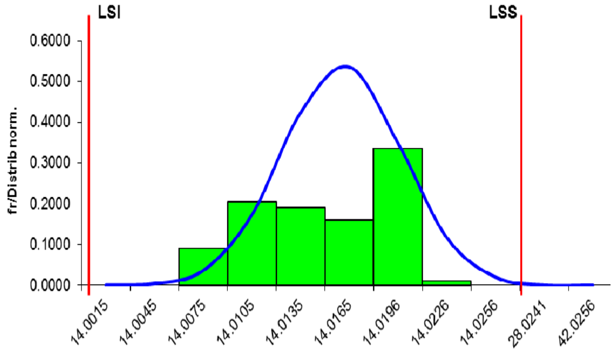

Figure 5

The estimated defective fraction is: p_{inf} = 0.00%, p_{sup} = 1.63%, p_{tot} = 1.63%

5 Conclusions

- Capability indices can be used to compare the product/process matches and identify the poorest match (lowest capability). The poorest matches then can be targeted on a priority basis for improvement.
- In many industrial instances, product quality depends on a multitude of dependent characteristics and, therefore, there is an urgent need for appropriate multivariate models and methods.
- One problem is to define suitable tolerance regions taking into account the correlation structure among the variables. The problem of tolerance regions is closely connected to the problem of deriving process capability indices. Assuming the normal model might lead to inferior methods and wrong decisions.
- Multivariate techniques are necessary taking into account the correlations between quality characteristics for calculating quality charts, tolerances and capability indices.

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