Types of heat exchangers in industry, their advantages and disadvantages, and the study of their parameters

IOP Conf. Series: Materials Science and Engineering **963** (2020) 012027 doi:10.1088/1757-899X/963/1/012027

Types of heat exchangers in industry, their advantages and disadvantages, and the study of their parameters

Edreis Edreis[1] and A Petrov[1,2]

[1]Bauman Moscow State Technical University, 5 Second Baumanskaya Street, Moscow, 105005, Russian Federation

[2]E-mail: alexeypetrov@bmstu.ru

Annotation The heat exchanger as the main element in various types of energy complex is widely studied in technological and production processes. Heat exchangers are classified according to their application. Therefore, in this article we will consider the main types of heat exchange equipment, the choice of a specific type, depending on temperature, flow, pressure drop, and so on. The paper also provides a brief description of software for calculating, modeling and designing CFD, the advantages of each of the methods used to study heat transfer and its efficiency.

1. Introduction

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more environments using a working fluid and a working surface having different temperatures. Heat transfer can occur between a solid surface and a liquid, between solid particles and a liquid, etc.

The heat-exchange (or heat-utilizing) apparatus is one of the most common and important elements of power, utility and technological installations. Any conversion of energy from one type to another, as well as the transfer of energy from one device to another, is accompanied by the transition of a certain part of the energy to heat. Therefore, in almost all machines and apparatuses, heat transfer is important.

Heat exchangers play an important role in technological processes, energy, oil refining, manufacturing, transportation, air conditioning, cryogenic and recovery systems [1]. They also serve as key components of many industrial products available on the market. All heat exchangers can be classified according to various criteria.

2. Fields of applications of heat exchangers:

Heat exchangers are used in many different technological processes. The following roster lists some types of heat exchangers and their main purpose.

- Chiller: a heat exchanger that uses refrigerant to cool a liquid through a vapor compression or absorption refrigeration cycle.
- Condenser: condenses steam or a mixture of vapors with or in the presence of non-condensing gases.
- Cooler: cools a liquid or gas, usually using water.
- Heat exchanger: cools one liquid while heating another.
- Heater: transfers heat to a liquid or gas by contact with a heated surface.

- Reboiler: generates steam through fractional distillation. Heating occurs with the help of a heating element, as a result of which condensation of steam occurs.
- Thermosiphonreboiler: the natural circulation of boiling liquid is maintained by sufficient pressure.
- Forced circulation reboiler: A pump is used to circulate the fluid in the reboiler.
- Superheater: Heats the steam to a temperature above its boiling point.
- Evaporator: a heat exchanger that evaporates part or all of the liquid flow. [2]

3. Classification of Heat Exchangers:

3.1. «Pipe-in-pipe» heat exchangers

Equipment consisting of two pipes with different diameters inserted one into the other. With the help of clutch couplings, all parts of the pipes are assembled into a coil, which provides the necessary space for the heating and cooling medium. Sections are placed one above the other. The flows are directed counter-currently (towards each other). The cooling agent comes from below, and after heating rises up. The heated steam accumulates from above. After condensation, it goes to the bottom of the heat exchanger. This heat exchange equipment is used in the food industry. Heat exchangers of this design are characterized by a significant heat transfer coefficient and can operate at high pressure. The pipes are cleaned mechanically on level areas. The flow inside the two-pipe heat exchangers can be parallel or counter-current. [3]

Advantages and disadvantages of «pipe-in-pipe» heat exchangers.

1. The main advantages of the device of this design include:

• High flow rate of the coolant: this is achieved through careful selection of water pipes of the desired diameter, which allows the medium to flow freely inside the pipes.

• Ease of maintenance. This property makes it possible to carry out regular cleaning of equipment, which allows to increase the duration of its operation.

• Versatility. In systems, it is permissible to use a coolant both in the liquid and in the vapor phase.

2. The disadvantages of the equipment are:

• Dimensions: due to the large size, difficulties arise during transportation and use of the device. Most of all this refers to individual use, where space is very limited.

• High cost: the price of external pipes that are not involved in heat exchange, and which are connected to the heat exchanger, is quite impressive.

• Difficulties in the design: when choosing this equipment, you must contact the professionals, which is associated with the complexity of the calculation. At the same time, the overall cost of manufacturing and installation work increases.

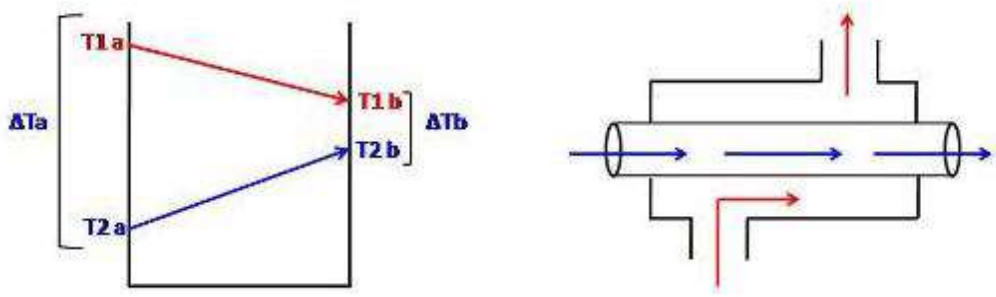

Fig.1: Parallelflow

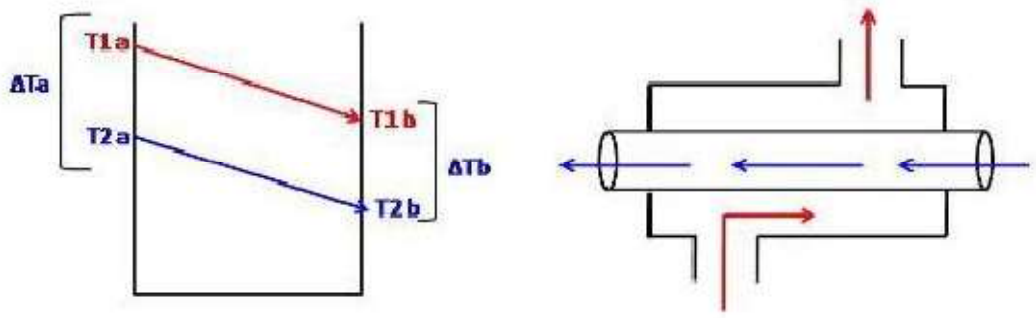

Fig.2: The counter-current flow.

3.2. Shell-and-tube heat exchangers:

The shell-and-tube heat exchanger includes a tubular tank and an integrated tubing section. The heat carriers in the heat exchanger are directed both parallel and towards each other. Shell-and-tube heat exchangers are used in the chemical, food, oil and gas and other fields. They are used as evaporators and condensers. Depending on the operating conditions of the equipment, it is installed in a vertical or horizontal position [4].

In multi-way devices, it is necessary to firmly fix the base and pipe sections. Such modules function even with a small difference in temperature of the working environment. When choosing the material of the heat exchanger, it is necessary to take into account the aggressiveness of the environment. Due to the inaccessibility of the heat exchanger tubes, the formation of corrosion is highly undesirable. Cleaning is carried out exclusively by a chemical method [5].

Advantages and disadvantages of shell-and-tube heat exchangers

1. The advantages of the devices are:

• Internal reliability. Shell-and-tube heat exchangers are more resistant to scale formation, which implies that cleaning should be done less frequently than with other heat exchangers.

• Possibility of power regulation. If necessary, increase or decrease the power, adjust the number of sections, the length and diameter of the pipes.

• Long service life. Shell-and-tube heat exchangers have a long service life.

2. Disadvantages:

• Large dimensions. A heat exchanger weighing 120–150 kilograms and a length of 4 meters can not always be fitted and installed at the facility.

• Vulnerability of the outer part of the case. Tube heat exchangers are made of electric welded pipe. After a short period of work, the outer coating begins to diverge along the seam, leaks appear, as a result of which oxygen begins to be released when the water is heated. This contributes to the development of metal corrosion [6].

• Efficiency. The coefficient is only 70%, which increases energy losses.

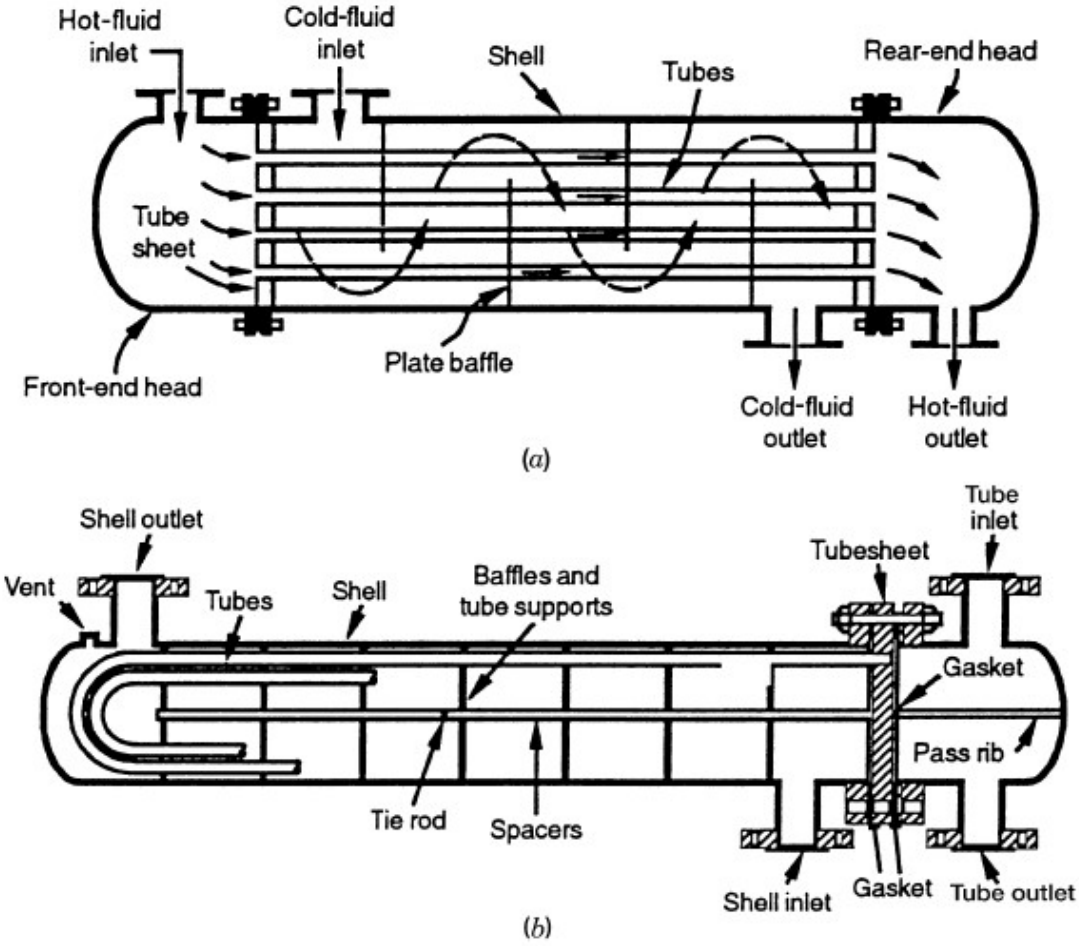

Fig.3: a) shell-and-tube heat exchanger with one outer shell and one pipe passage; b) shell-and-tube heat exchanger with one outer shell and two pipe passages.[7]

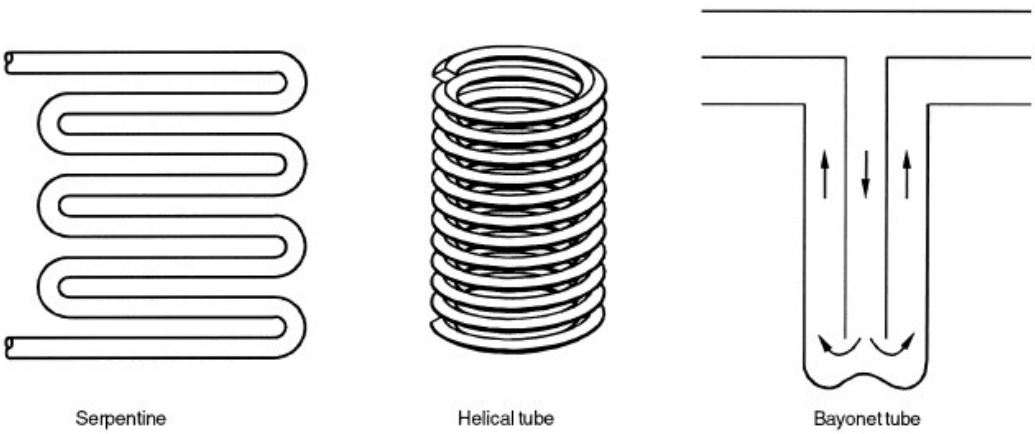

Fig.4: Various configurations of pipes used in shell and tube heat exchangers. [7]

3.3. Plate Heat Exchangers

They consist of a large number of corrugated plates made of stainless steel. They are separated by seals that are installed without the use of adhesive mixtures, but allow tight fit to each other. Gaskets provide absolute tightness and do not allow mixing of media. The direction of flow is counter-current. The power of the heat exchanger is determined by the number of plates installed inside. Service, cleaning and repair of the device is done by disassembling it. Areas of use: housing and public utilities, shipbuilding, metallurgy, oil and gas, pharmaceutical industries and so on. The choice of material of the heat exchanger must be carried out depending on the technological process, the type of coolants in the system, temperature load and pressure. The most universal in application: plate heat exchangers made of stainless steel with copper pipes [8].

Advantages and disadvantages of a plate heat exchanger

1. Theadvantagesare:

• High efficiency. Due to the large area of the heat exchange surface, the efficiency reaches 95%, which is much higher than that of tubular apparatuses.

• Compactness. The device is selected in accordance with the required heat consumption. With a small number of plates, the differences will be less, respectively, with a larger number of plates, the differences will increase.

• Multifunctionality. Plate heat exchangers are used in many areas of life, have a wide range of capacities.

• The cost of the device depends on the number of plates installed in it. There is the possibility of selecting the right number of plates. Repair costs replacing a worn (damaged) plate, and not the entire system.

2. Disadvantages:

• Short service life. Plate heat exchangers are quickly clogged. The maximum service life without cleaning is 3 years.

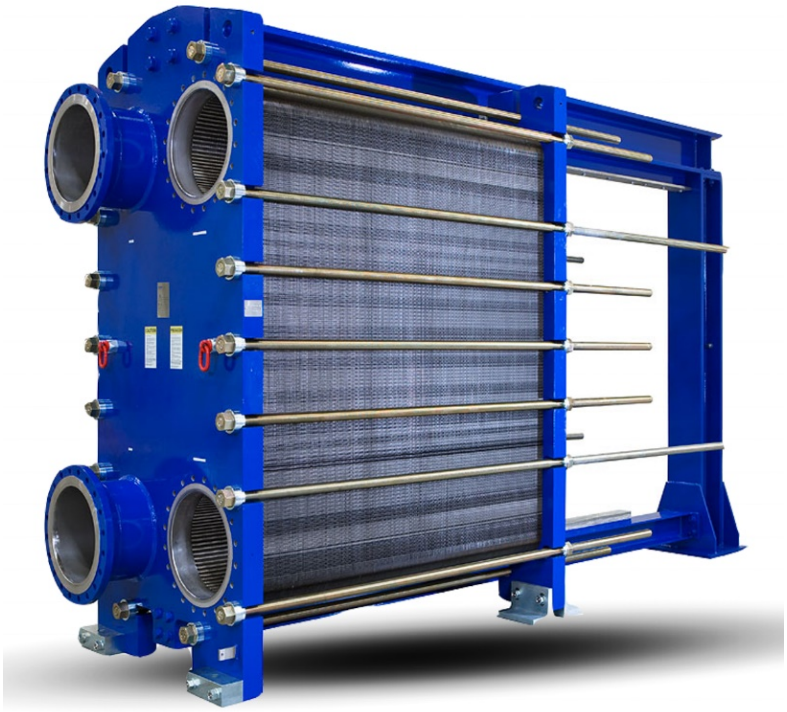

Fig.5: Plate heat exchanger

3.4. Spiral plate heat exchangers:

Spiral plate heat exchangers are made of two metal plates that are wound on each other. One stream of process fluid enters the heat exchanger through the center and flows from the outside, while the second stream enters from the outside and flows inward. This creates a close to natural backflow [9].

Advantages and disadvantages of a spiral plate heat exchanger:

1. The advantages are:
   - Single flow paths reduce the rate of scale build-up associated with liquids containing solids.
   - Ability to work with two highly polluting liquids.
   - Lack of dead zones for accumulation of solid particles inside the heat exchanger
   - Counterflow.
   - Madeofmanyalloys.
   - Very low pressure drop.
2. Disadvantages:
   - Designs are the intellectual property of companies, a limited number of manufacturers.
   - As a rule, the design is more expensive than other types of heat exchangers.

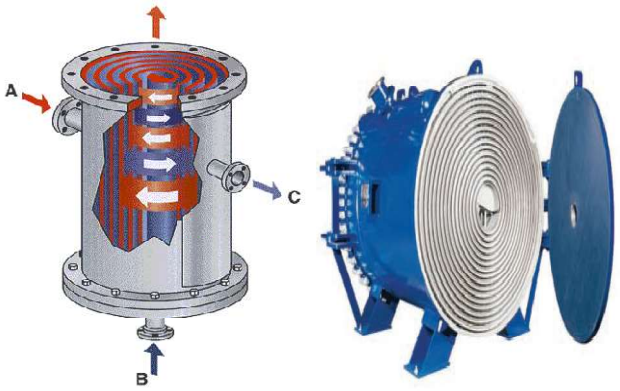

Fig.6: Spiral plate heat exchanger

3.5. Spiral tube heat exchangers:

Spiral tubular heat exchangers are made of spiral pipes. In some cases, the tube is installed inside the bundle to ensure the compactness of the heat exchanger. These heat exchangers are mainly used for small capacities [10].

Advantages and disadvantages of a spiral tube heat exchanger:

1. The advantages are:
   - Compact and inexpensive heat exchanger requiring low power.
   - Canwithstandhighpressures.
2. Disadvantages:
   - Designs are the intellectual property of companies - a limited number of manufacturers.

Fig.7: Spiral tube heat exchanger

3.6. Air-cooled heat exchangers:

Air-cooled heat exchangers use ambient air to cool and condense the working medium. They are usually used in places where there is a shortage of cold water. Air-cooled heat exchangers are commonly used when the temperature at the outlet of the heat exchanger is at least 20° C higher than the ambient temperature. They can be designed for closer temperatures, but often become expensive compared to a combination of a cooling tower and a water-cooled heat exchanger. Air-cooled heat exchangers use electric fans to move air through a series of pipes [11]. Therearetwomainmechanisms:

- Induced draft fans draw air through the tube blocks.
- Fans blow air through a series of pipes.

Air-cooled heat exchangers are expensive compared to water-cooled heat exchangers due to their large size, low air heat transfer coefficient, and structural and electrical requirements. In addition, air-cooler heat exchangers require large surface areas of pipes and must be designed in such a way as to withstand daily and seasonal changes in air temperature [11].

The low heat transfer coefficient associated with the flow around the air of the outer sides of the pipes is partially overcome due to the wide use of finned pipes to increase the outer surface area. Changes in ambient temperature are often controlled by fans with a variable speed or airflow adjustment step. In cold climates, it may be necessary to develop a design with the ability to recirculate air to prevent freezing during operation. Smaller heat exchangers (similar to radiators) are used for small areas of responsibility [12].

Advantages and Disadvantages of Air-cooled Heat Exchangers

1. Theadvantagesare:

- Do not use water for cooling.

2. Disadvantages:

- Requires a large area of the site.
- Highmanufacturingcosts.
- Ribs may become clogged in dirty environments.
- Fansmaymakenoise.

Fig.8: Finnedpipes

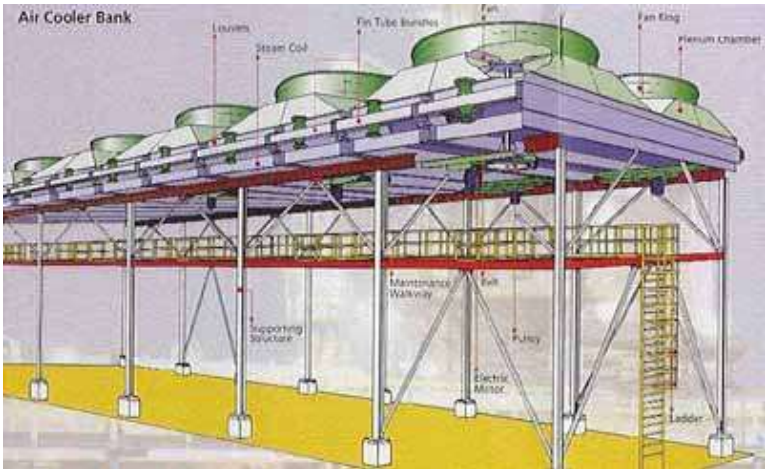

Fig.9: Air-cooled heat exchanger

4. Heat exchanger using the CFD simulation method:

There are two classes of CFD methods: this is the Euler approach and the Lagrange approach. In the Lagrangian approach, a liquid is represented as a set containing a large number of particles with properties such as mass, velocity, and temperature. Then all particles are tracked along the flow, and based on the interactions between the particles, temporary changes in various properties are calculated. In the Euler approach, a liquid is represented using selected volumes in the form of mesh elements whose coordinates are fixed. Observe the flow through these control volumes and calculate the flows to measure the rate of change of properties such as speed and temperature. Methods developed on the basis of the Euler approach are called mesh methods, and methods developed on the basis of the Lagrangian approach are called methods without a particle grid. Both classes of methods have their pros and cons. The meshless feature has one of the biggest advantages for R&D engineers, as mesh is the most time-consuming and complex preprocessing phase for CFD Euler solvers. In recent decades, researchers have developed methods that combine the Lagrange and Euler approaches to make up for the weaknesses of both methods [13–14].

A wider study of heat exchangers can be carried out using specialized software, such as CFD packages, in which variables such as temperature, volumetric or mass flow rate, differential pressure, characteristic of heat transfer in fluid mechanics can be determined. These CFD packages provide ease of displaying areas of influence of pressure drop or temperature using a convenient graphical interface [15].

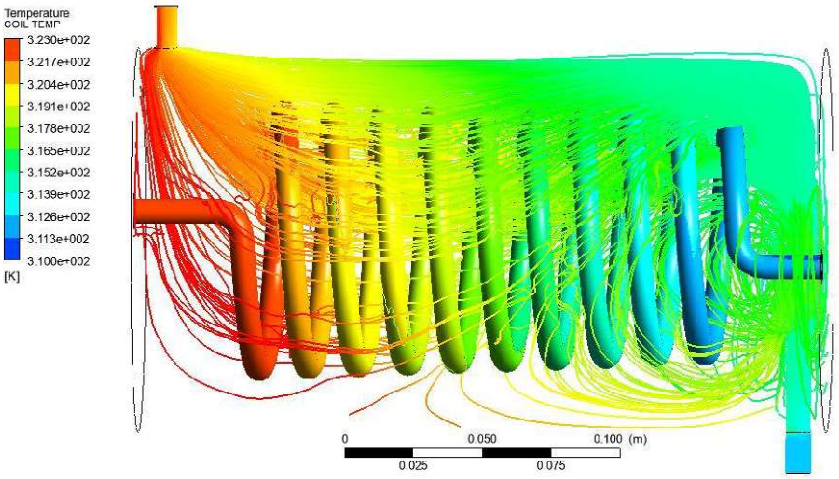

Fig.10: Temperature distribution in the heat exchanger

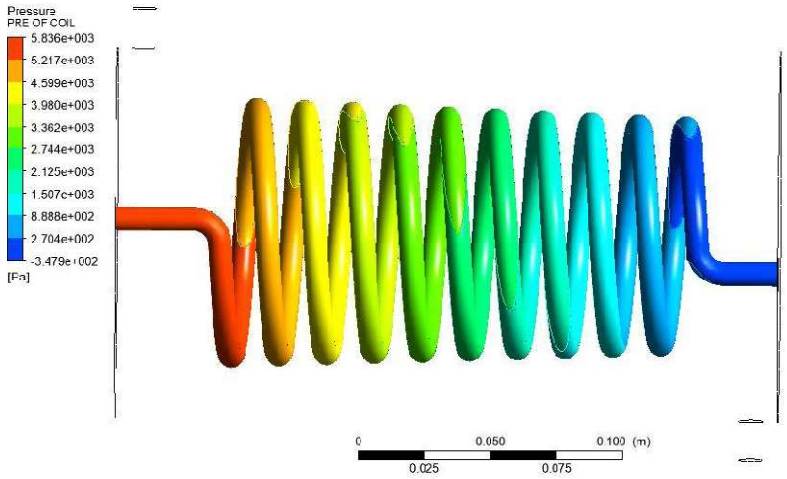

Fig.11: Pressure distribution in the heat exchanger.

5. Conclusion:

In this paper, various types of heat exchangers used in industry, the criteria for the selection of devices depending on power and purpose are considered. Basically, they are made as condensers, evaporators, heaters, depending on the process conditions.

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