COMPARATIVE ANALYSIS OF PIPES OF DIFFERENT GEOMETRY IN THE HEATING CHAMBER OF THE EVAPORATOR

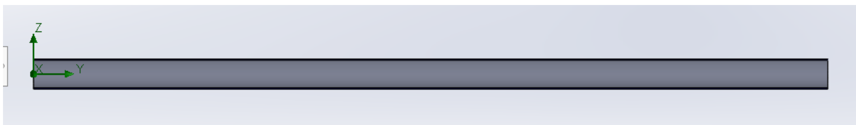
Heraskin N.R., Kosova V.P.
Igor Sikorsky Kyiv Polytechnic Institute, vera62@ukr.net

Abstract
The novelty of this development lies in the development of a more advanced design of the evaporator using a finned tube in the heating chamber. The work is aimed at using finned heating tubes. The proposed solution allows you to reduce the total number of tubes and, due to the intensification of heat exchange, allows you to reduce the time for the boiling process. Visual visualization of processes in the tubes of the evaporator.
Keywords. *Evaporator, smooth tube, finning*

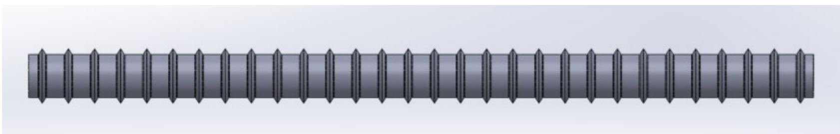
Introduction. Evaporation equipment has a significant metal content and energy consumption during operation. This is due to the peculiarity of the operation of the devices, namely the need to maintain high temperatures. Among the possible directions for improving the designs of evaporators, a change in the geometry of the pipes in the heating chamber is considered. This is implemented by creating spiral corrugations, annular knurling, single-way corrugations, recesses on the surface or finning [1]. A special coating is also used that prevents the formation of scale and excessive corrosion on the walls of the pipes and inside the body of the device. The use of the coating makes it possible not to lose the efficiency of heat transfer, which directly depends on the amount of sediment in the process of boiling the solution, as this causes a decrease in the cross-section of the pipes, as a result, an increase in the wall thickness and hydraulic resistance.

The aim of our work was to construct a 3D model of pipes in a heating chamber.

Materials and methods. In order to confirm the appropriateness of changing the pipe geometries, a comparative analysis was conducted in the SolidWorks program, where models of a smooth and finned pipe were built (Fig. 1).



a



b

Fig. 1. Pipe design: a – smooth; b – ribbed.

The main condition for modelling was to set the turbulent mode of motion of the hot coolant, which is a steam with a temperature of 127 °C and a speed of 15 m/s. The solution is fed into the pipes at a temperature of 80 °C and a speed of 2 m/s. Since the problem is external, the properties of the solution can be neglected. The pipe material is stainless steel 12X18N10T, the wall thickness is 3 mm, the thermal conductivity coefficient is 16 W/ m·°C [2]. The height of the ribs relative to the surface is 5 mm with a step of 25 mm. The test time is 10 s. During the study, phase transitions were not taken into account.

After obtaining the results, we will first analyze the smooth pipe (Fig. 2).

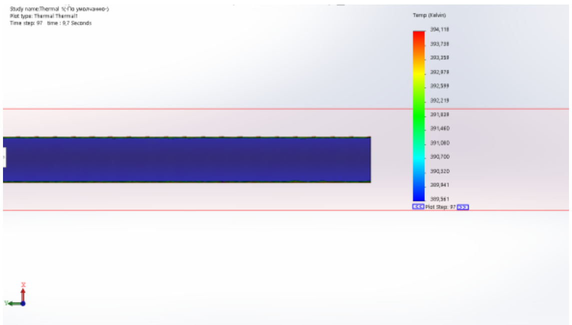


Fig. 2. Temperature gradient of a smooth pipe.

During visual analysis, we conclude that the heating of the outer surface is uneven, which, in turn, slows down heat transfer to the solution.

On the enlarged image of the pipe cross-section, we record the maximum surface temperature of 121 °C and the minimum surface temperature of 116 °C. We also establish the temperature difference between the outside and inside of the profile, which will be 4 °C (Fig. 3).

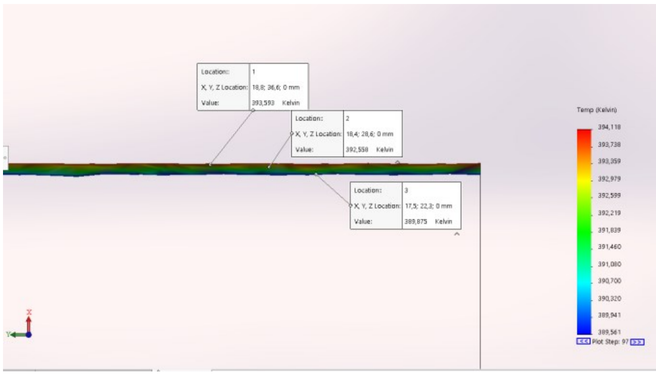


Fig. 3. Temperature gradient of a smooth pipe.

In Fig. 4 we note the features of the trajectory of the hot coolant flows. The nature of the movement is observed without obvious eddies. Accordingly, in such conditions, more time will be spent on heating the surface, which cannot be an economically viable option.

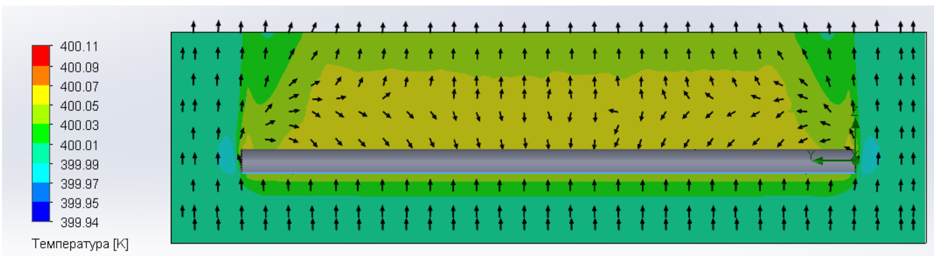


Fig. 4. Vectors of motion of the hot coolant from the outside of the smooth pipe surface.

Next, we will consider the proposed ribbed pipe surface in the heating chamber (Fig.5).

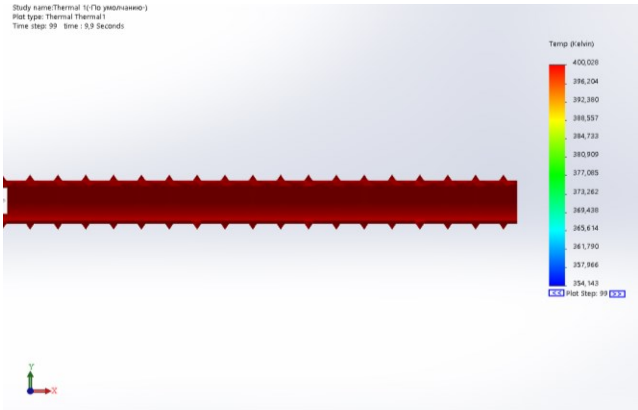


Fig. 5. Temperature gradient of a finned tube.

Visually analysing the results obtained, it can be stated that over the entire cross-sectional surface a relatively constant indicator is equal to 127 °C (Fig. 6

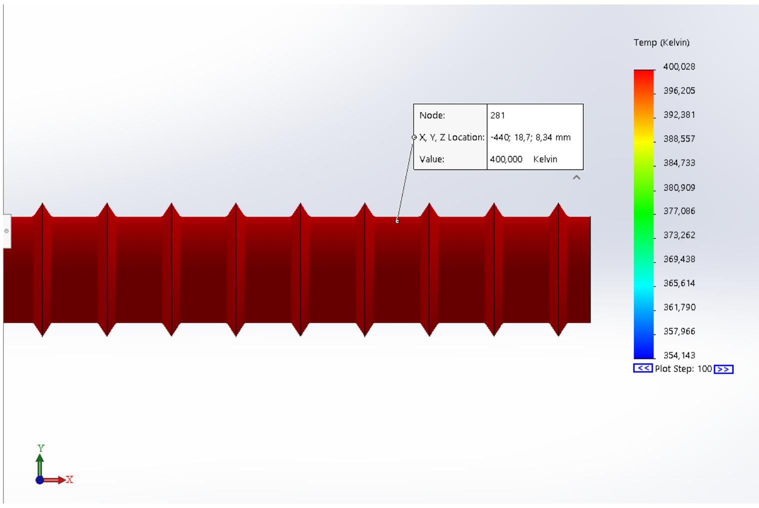


Fig. 6. Temperature gradient of a finned tube.

Therefore, we note a uniform temperature distribution due to the presence of vortices (Fig. 7), accordingly, we will have a smaller indicator of the time spent on heat transfer of the solution [3]. The temperature difference between the outer and inner surfaces is less than 4 °C.

In order to determine the relationships between input and output parameters, establish optimal operating modes and design data of the evaporator, mathematical models are used in practice. Their use helps to save costs on the selection and reasoning of design and operating parameters of the system.

Internal local disturbances are characterized by a violation of thermal resistance due to the formed scale, a change in solution parameters and the accumulation of non-condensable gases.

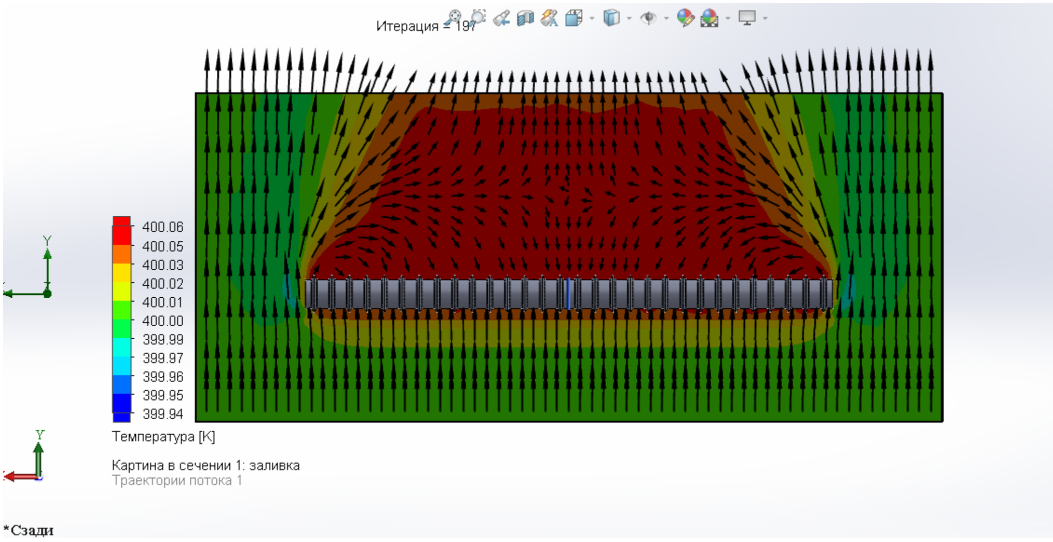


Fig. 7. Vectors of movement of hot coolant from outside the surface of the finned tube.

Results and discussion. Depending on the specified technological processes and properties of the evaporated solution, a specific installation design is selected. The operating mode of the equipment, its static and dynamic properties, in particular, pressure, are also determined. The device can operate under excessive, excess, atmospheric pressures in accordance with the properties of the liquid and the ability to reuse the exhaust steam. The evaporation process is characterized by the presence of a phase transition during the concentration or separation of solutions. This process is mainly used for aqueous solutions. In addition, for the isolation of the target product in solid form with the use of subsequent cooling, for example, for the isolation of citric or itaconic acids or in order to obtain a solvent in pure form. The described processes are implemented using evaporators of various purposes and types of constructive design.

Conclusions. The results obtained demonstrate the feasibility of using a finned tube in the heating chamber of the evaporator. Comparing the presented models, in particular, the temperature inside the tubes, it was recorded in a smooth tube 116 °C and in a finned one – 127 °C. Accordingly, the difference is 11 °C. Uniform temperature distribution, as a result, allows you to reduce the time for the process of heat transfer of the solution inside the tube, which solves the issue of overall energy consumption. Thus, the effectiveness of the ribs is confirmed.

References:

1. Zaid S. Heat transfer enhancement in two-start spirally corrugated tube / S. Zaid et al. *Олександрійський інженерний журнал*. 2015. Vol. 54. P. 415–422.

2. Сидоров Ю. І., Влязло Р. Й., Новіков В. П. Процеси і апарати мікробіологічної та фармацевтичної промисловості. Технологічні розрахунки. Приклади і задачі. Основи проектування: навчальний посібник. Львів : Інтелект-Захід, 2008.

3. Коваленко І. В., Малиновський В. В. Основні процеси, машини та апарати хімічних виробництв: підручник. Київ : Інрес: Воля, 2005.