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STUDY OF THE INFLUENCE OF VARIOUS FACTORS ON THE AVERAGE RESIDENCE TIME OF LIQUID IN A ROTARY FILM APPARATUS (RFA)

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Abstract *- the article investigates the average residence time of a product in a rotary film apparatus with hinged blades in the mode of evaporation of various liquids, including thermolabile ones.*

Keywords *- rotary film apparatus, rotor, blades, evaporation, concentration, thermolabile substances, average residence time.*

Problem statement. Mass transfer processes are one of the main processes of chemical technology, among which a significant part is carried out in gas-liquid systems. They are mainly used for separation of liquid mixtures or isolation of individual components from gas or vapour media.

Analysis of recent research. The equipment used for such processes remains relatively metal-intensive and inefficient in most cases. At the same time, the requirements for the quality of final products are constantly increasing, due to both competition between different manufacturers and the increasingly important role of environmental control. Therefore, the task of designing the equipment for modern mass transfer passages is to find the most efficient devices that will improve the quality and quantity indicators.

Objectives. Insufficient data on the operation of rotary film apparatus in the evaporation mode of various liquids, including thermolabile ones, hinders their widespread introduction into various sectors of the national economy. There are no thorough studies of hydrodynamics and heat transfer in the methods of mechanical intensification of the process, which requires further research.

The main part. Rotary thin-film apparatus are widely used for concentrating solutions with high viscosity or evaporation to a high concentration of solids. There are two groups of RFAs. The first group includes devices in which the process takes place in a film created on the inner surface of a fixed housing by

a rotating rotor. These devices are widespread due to their versatility, which allows them to carry out various technological processes: concentration of solutions, distillation, deodorisation, etc. Apparatus of the second group have a rotating surface of phase contact in the form of a cone, cylinder, spiral, along which the solution moves under the influence of centrifugal force.

Fig. 1 shows the design of the first type of RFA.

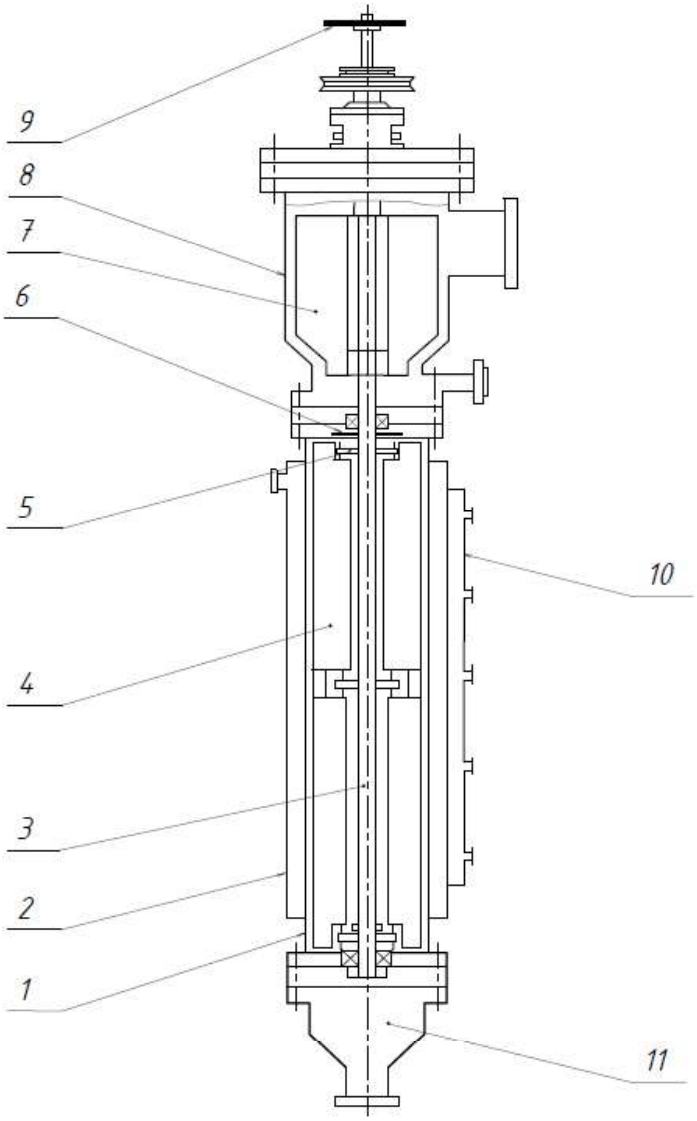

Fig.1 Construction of rotary thin-film apparatus with articulated blades

The main elements of these apparatuses are a body (1) with a heating jacket (2) for heating with dry saturated steam. Through an intermediate bearing the apparatus body was connected to a cage (8) of inertia type.

Four-bladed impeller (7) of the separator was mounted on one shaft (3) with the rotor. The hinged rotor of the apparatus is collapsible. It consists of a shaft, blades (4) and three hubs (5). At the ends of the blades are welded pins to install them in the hub sockets. After assembly, the blades were free to rotate both sides by forty-

five degrees. On the rotor shaft above the upper hub was attached to the distributor ring (6), designed for uniform irrigation of the working fluid of the inner surface of the housing apparatus. The lower part of the housing ended with a conical bottom (11). The angle at the top of the cone was chosen one hundred and twenty degrees, which favoured quick removal of the product from the apparatus. On the upper end of the shaft there was placed the sensor (9) of the tachometer.

One of the objectives of the research was to study the dependence of the heat transfer coefficient on a number of factors: fluid flow rate, rotor speed and a number of other factors. Since the local and average heat transfer coefficient depend on the heat flow and temperature head, it was necessary to study the temperature distribution in the liquid film at the height of the apparatus. For this purpose, 5 thermoelements were installed in the apparatus wall at a distance of 80 mm from each other (10).

This allowed us to study the local variation of the heat transfer coefficient along the length of the apparatus.

An important feature of rotary film evaporators is the intensification of the process by conducting it in a thin intensively stirring film. Film formation on the vertical surface of the apparatus body is provided by a distributing ring and a rotary mixers with blades fixed on it. Types of rotary mixers are shown in Fig. 2.

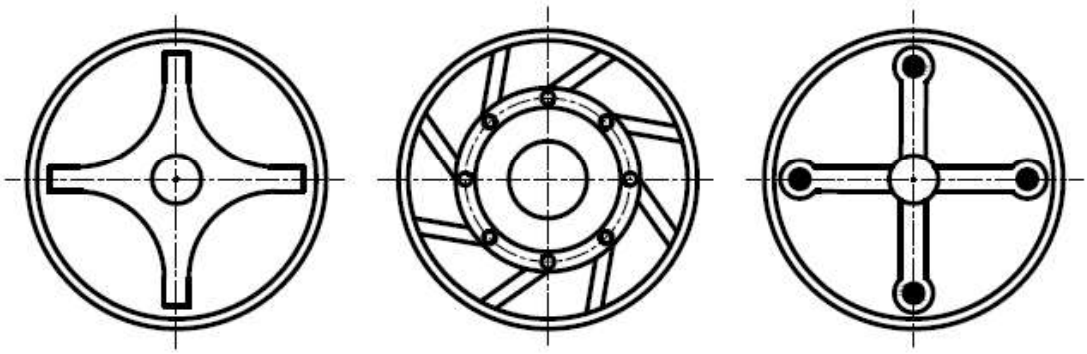

Fig. 2 Rotary mixers: a – rigid fastening, b – with joint fixing, c - with movable blades

In apparatuses with rigid fastening of rotor mixers a strictly fixed gap is created between the body and rotor, and in apparatuses with joint or movable blades the film thickness is determined by the centrifugal force and physical and chemical properties of the solution. The liquid flowing down the film is smeared by the rotating rotor along the perimeter of the heating surface. This contributes to the intensification of the heat transfer process and, consequently, the evaporation of the solvent.

However, the wider implementation of thin-film rotary evaporators in various sectors of the economy is hindered by insufficient information on the operation of these apparatuses in the evaporation of various liquids, especially thermolabile.

For thermolabile products the time of contact with the heating surface of the apparatus is strictly regulated. This was the reason for our research.

Distilled water, glycerine, its aqueous solutions (50; 85% wt.), additive C-150 and its solutions in petrol (40-95% wt.) were used as working liquids in experiments on determination of average residence time. The joint influence of rotor rotation speed, liquid flow rate, number of rotor blades and its type on the average stay time of liquid residence in RFA was studied.

It was found that with the increase in the number of revolutions there is an increase in the average residence time. This is due to the fact that the reduction of the gap between the edge of the blade and the body of the apparatus due to an increase in the centrifugal forces acting on the blade leads to an increase in the mass of liquid in the 'bow wave' in front of the rotor blades.

Increase of irrigation density at constant rotor speeds leads to increase of liquid volume in rollers, which gives possibility to more liquid mass to move in axial direction.

The data characterising the influence of the number of blades and its type on the average residence time show that the increase in the number of blades leads to an increase in the average thickness of the liquid film (which is similar to the increase in the rotor speed), while the tangential component of the liquid velocity increases and, consequently, the average residence time of the liquid in the RFA increases.

Conclusions. A considerable number of factors influencing hydrodynamics and heat exchange in RFAs indicates that the analytical solution of the problem presents serious difficulties and is not yet available. RFAs can be calculated on the basis of experimental data, empirical formulae and criterion equations. Due to the complexity of the processes occurring in RFAs, it is desirable to use the data obtained by us under conditions approaching the experimental ones. The joint influence of liquid flow rate, rotor speed, number of blades and their type, and thermophysical properties of liquid on the average stay time of liquid residence in RFA has been investigated.

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