Application of the Ranque-Hilsh Vortex Effect for Creation of the Evaporation Plant for Water Demineralization

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Abstract

In this paper, application of the Ranque-Hilsch vortex effect for creation of the evaporation plant for water demineralization is considered. The Ranque-Hilsch effect in a vortex flow is researched. The device used for application of this effect – the evaporation plant - is presented. Problems of the eddy currents modelling in the evaporation plant for water demineralization with a phase transfer implementing the Ranque-Hilsch effect are described.

Keywords: Ranque-Hilsch effect; vortex flow; evaporation plant; phase transfer; mathematical modeling

1. Introduction

At present, an actual problem in the energy sector is the use of high technology, advanced technologies aimed at enhancing the efficiency of production, with special attention being paid to energy efficiency, reducing the cost of electricity and heat, as well as reducing the harmful effects of the energy industries on the environment.

Offered to the study design will provide similar competitors desalinated water indicators are not due to multiple adiabatic boiling water in the evaporator stages, but by intensified heat and mass transfer processes in the field of centrifugal forces using mechanical activation effect in a complex non-uniform movement of the working medium.

Using a vortex effect in the circulating water contour will lower the coolant temperature to 30-40\(^\circ\) C degrees. This significantly affect the weight and size dimensions of the condenser section, which will set the time constraints for the introduction of evaporation plant for water demineralization at least one year and to reduce at least twice the

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cost of construction and installation works. The introduction of similar systems in the evaporators of instant boiling, because of their enormous weight and size takes two to three years.

Using intensify the processes of heat and mass transfer in a phase transfer in the field of centrifugal forces also have a significant affect on increasing the efficiency of evaporation plant for water demineralization by reducing the input power.

The evaporation plant for water demineralization designed to generate steam and to create the coolant flow can be used effects arising from vortex flows, including phase transfer representing processes of evaporation of water and water vapor condensation.

Vortex flows of various types with the realization of different physical processes are realize through a series of technological solutions. For the purposes of realization of carrying out applied research, consider the following technological solution based on the use of the vortex effect in evaporation plant for water demineralization [1].

2. Main part

The water treatment plant for the generation of steam and creating a flow of coolant can be used effects arising from eddy currents, including phase transitions representing the evaporation and condensation of water vapor.

Devices that are implemented vortex motion are called differently: centrifugal cyclone, the cyclone vortex chamber and the vortex, the vortex pipe (Ranque-Hilsch effect) and hydro cyclones, vortex separators, vortex combustor and combustion chambers, etc. [2,3]. Their common feature is the presence of the working area (typically cylindrical or conical shape) and the vortex flow (generally tangential or axial).

The term «vortex chamber» was introduced in the simulation of atmospheric vortices in the lab. According to the accepted terminology, the vortex chamber – is a device which implements a uniform distribution around the periphery of the medium input chamber and in which a working medium performs a rotary-translational movement.

In the study of vortex motion and application swirling flows were discovered their unusual features – counter and «recirculation zone» energy separation (Ranque-Hilsch effect). The presence in the flow field considerable centrifugal forces and significantly affects the properties of the eddy currents, causing those flow characteristics, which can be successfully used in the design of the vortex chambers for various purposes.

In the gas dynamics of vortex flows is nontrivial phenomenon known as the Ranque effect (effect Ranque-Hilsch or vortex effect), which consists in the fact that in vortex tubes fairly simple geometry (Fig. 1) is a division of the gas flow into two, one of which – peripheral – has a temperature above the temperature of the source gas and the second – center – correspondingly lower. This effect is all the more strange when you consider that, as in the case of vortex stabilization of gaseous discharges [4], the buoyancy forces would have to lead to a "surfacing" in the center of the vortex hotter gas.

Fig. 1. Schematic diagram of the vortex tubes: (a) countercurrent type, (b) a ram type
1 – smooth cylindrical tube, 2 – swirl tangential or snail type for compressed gas, 3 – throttle valve (throttle valve), 4 – out of the hot gas through the annular gap 5 – aperture to quit cold gas
Vortex tubes realizing Ranque-Hilsch effect may be used in the composition of the evaporating section for the simultaneous production of hot water, followed by evaporation to produce steam using vacuum vessel with hot water or water vapor directly into the vortex tube and the cold water used in condensing section for cooling the steam.

For a better understanding of the processes and structure of the flow in the vortex tubes should be, except for the considered planar vortices present features swirling three-dimensional flows in cylindrical channels. Consider a long tube (Fig. 2) near the closed end which is located swirler – a gas distribution device that provides spin when entering the gas pipe.

![Diagram of gas flow in a counterflow vortex tube](image)

Fig. 2. The scheme of gas flow in a counterflow vortex tube (a) and typical radial profiles: b – tangential (v), c – axial (u) and d – radial (j) speeds in the relevant sections 1 – smooth-walled pipe; 2 – tangential or snail swirl; 3 – throttle (gate); 4 – output of the hot gas through the circular aperture; 5 – output of the cold gas through a circular aperture; 6 – peripheral vortex flow; 7 – a return vortex flow; 8 – radial flow in boundary layer of aperture
Characteristics of the vortex tube is a temperature difference of incoming and hot flows and heating of the vortex tube, which characterizes the capacity of the tube as a heater. Figure 3 presented of typical characteristics of the vortex tube [3].

![Fig. 3. Typical experimental characteristics of the vortex tube – solid curve, dotted curve – calculation for the gas under the assumption that within the boundary layer on the aperture flows 9% of the total gas flow rate](image)

An important feature of the vortex flow is the presence of phase transitions, in detail these processes are considered in paper [5]. For water treatment systems that use as a working medium water characterized by the processes of evaporation and condensation of water vapor occurring during the movement of the medium in the vortex tube.

In operation of all types of vortex power converters, there is a common characteristic of all the vortex devices property consisting in that, when creating a vortex flow of gas or liquid therein is intensive heat and mass transfer processes that change the physical characteristics of the fluid and its status. At the same time the energy impact on the working environment at the expense of the various methods of organization and management of the vortex flow.

Various physical effects accompany the vortex gas or liquid flow and two-phase heterogeneous environments, among which are the most important: the heating and cooling of the working medium, the formation of two-phase liquid-gas environments, accompanied by cavitation, dispersion, and spray fluid. Understanding the nature of the processes occurring in the vortex flow of gaseous, liquid and two-phase liquid-gas vortex flow allows purposefully lead the development of the vortex energy converters and processing equipment using them, which opens up opportunities for improving the quality of devices using eddy currents.

Hot water at a pressure of 2-5 atmospheres and a temperature of 90-100 °C in the vortex tube leads to the fact that the flow of hot water begins intensive evaporation (boiling) to form a large amount of steam, which will flow out of the «hot» end of the vortex tube. Because of the «cold» end of the vortex tube will expire chilled water. A feature of work processes in the vortex tube in this case is the presence of a multiphase fluid, greatly complicates the dynamic processes in the vortex tube, whose behavior requires a fairly complex and lengthy investigations.
The use of steam as a source of the working environment, on the contrary, causes condensation of steam in the «cold» end of the vortex tube (in some cases, the formation of the solid phase – ice, greatly complicates the work of the vortex tube because of infringement of the design mode).

In addition, in order vortex tube can be supplied and vapor-liquid mixture. Thus, depending on the parameters of the vapor-liquid mixture, and the geometric characteristics of the vortex tubes may be implemented by various modes of energy separation streams. For the simulation of such flows is necessary to use models and methods of mechanics of heterogeneous media [6,7].

3. Conclusion

Currently vortex tubes which realizing the effect of Ranque-Hilsch used for different purposes. Vortex flows, including implemented in vortex tubes using Ranque-Hilsch effect, applied in a number of industrial devices and assemblies [8]. The book discussed a study of energy separation in intensive swirling flow when the flow channels on the axially symmetric vortex tubes. Analyzed existing models Ranque-Hilsch effect and given the improved method for calculating the characteristics of vortex tubes. Techniques of analysis and design of vortex devices. Described based on vortex tube vortex burner igniters, plasma torches, their design and method of calculation.

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