Reduction thermal resistance methods in the thermal stabilizer

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Abstract. The thermal resistance of the composite thermal stabilizer and methods for its reduction are investigated. The thermal resistance of thermal stabilizer decreases due to the heat exchange intensification in evaporator by a layer of aluminum oxide nanoparticles. A method of producing aluminum oxide nanoparticles has been developed. The liquid capillary rise height is measured in the layer of nanoparticles. Estimate of the properties stability is obtained in the coating from aluminum oxide nanoparticles. The thermal resistance dependences are obtained on the transferred heat flux for models of thermal stabilizers from steel and aluminum.

1. Introduction

Nowadays, thermostabilization of the soil is carried out with the help of composite thermal stabilizers in the construction of long objects in the region of permafrost. The thermal resistance of the composite heat stabilizer is influenced by the junction of heat pipes [1], structure of the evaporator [2,3], pipe material, coolant and orientation.

Kuzma-Kichta et al. [4,5] coated a thermal stabilizer evaporator to reduce thermal resistance by nanoparticles of aluminum oxide. It was proved that the coating from nanoparticles and wire improve heat transfer and reduce the thermal resistance of a weakly inclined thermal stabilizer.

Rahmatollah et all. [6] investigated the effect of coating from nano-and micro particles on the heat transfer coefficient in the evaporator of the vertical heat pipe filled with water. He found that the application of porous coatings on the evaporation site allows to increase the heat transfer coefficient up to 3 times.

Pismenni et all. [7] investigated the effect of the microstructure in the form of reservoir hollows on the heat transfer in the evaporator of the heat pipe for various liquids: acetone, pentane and ammonia. He found that reservoir cavities lead to an increase in boiling heat transfer to 2 times.

However, the available data on heat transfer are extremely limited.

The article considers the producing method of aluminum oxide nanoparticles, a study of the coating characteristics formed from aluminum oxide nanoparticles and data on the study of the thermal resistance for various models of thermal stabilizers.
2. Research of producing method for nanoparticle coating

For the formation of microporous coating [8] has been developed a method for producing aluminum oxide nanoparticles [9,10] based on the thermal decomposition of a dispersed solution of cellulose and aluminum sulfate. Nanoparticle coatings obtained at 950, 1000, and 1100 C were investigated. In Fig. 2, the characteristic size of aluminum oxide nanoparticles is shown as a function of production temperature. Established that with an increase in the temperature of thermal decomposition, the characteristic particle size decreases.

A layer of aluminum oxide nanoparticles (Fig. 1) was formed by boiling a colloidal solution of water and aluminum oxide nanoparticles on the surface of a nickel substrate. The liquid capillary rise height in the nanoparticles layer is 15 millimeters. The nanoparticles layer saves transport properties for a limited time.

![Figure 1. A layer of aluminium oxide nanoparticles on the nickel surface](image1)

![Figure 2. The dependence of the characteristic aluminum oxide particle size on the thermal decomposition producing temperature](image2)
The liquid capillary rise height was measured to assess the stability of the coating from aluminum oxide nanoparticles. The Fig. 3 shows the time change of the capillary rise height. The deterioration of the transport in the coating is explained by the adsorption of carbon molecules in the aluminum oxide nanoparticles layer.

3. Thermal resistance measuring
To study the thermal resistance of the vertical composite thermal stabilizer, an experimental setup was developed, the scheme of which is shown in (Fig. 4). The installation consists of a refrigerating machine (1-7) connected to a heat pipe using heat flux sensors (8). A thermal imager (9) records the temperature difference on the surface sensor, which allows determining the heat flux. The temperature difference between the evaporator and the condenser is measured by a differential thermocouple and a multimeter (10, 11). As working medium, freon R413a was used, the refrigerator provided 800 watts of power. In the condensation zone each thermocouple was fixed between the heat pipe and the heat sensor, and in the evaporation zone, the ends of the thermocouple were fixed with aluminum tape around the perimeter of the pipe. Since the surface temperature is determined using a thermal imager, the increase in hoarfrost and the appearance of condensate introduce an error in the measurements. This error was determined in special experiments and to reduce its effect, the surface was cleaned from frost and condensate before each measurement. To ensure that the Guide MOBIR M8 provides measurements correctly on dissimilar surfaces, all elements were covered with the same black paint. This paint was used when calibrating a thermal imager according to the degree of blackness. The models of thermal stabilizer were made of steel and aluminum.

The measuring thermal resistance method consists in determining the heat flux transferred from the refrigerating machine through heat flux sensors to the heat pipe condenser and measuring the temperature difference between the evaporator and condenser. The thermal resistance is calculated by the formula

\[
R = \frac{\Delta T}{Q}
\]
4. Thermal resistance of heat stabilizer

Experimental data were obtained for steel and aluminum heat pipes without a joint, with pipe-in-pipe joint and a flat shelf with the help of the developed universal installation for measuring the thermal resistance of a thermal stabilizer model. The measurement results are shown in (Fig. 5). At the junction, an increase in the surface temperature of the pipe was observed caused by an increase in thermal resistance. The smallest thermal resistance is established for a pipe made of aluminum without a joint (1) and when two pipes are joined using the “flat shelf” scheme (2). Steel models have a higher thermal resistance, both without a joint (3), and with a joint filled with air, water and thermal grease (4-6), respectively. We propose that when the nanoparticles of aluminum oxide applied to the evaporator, thermal resistance decreases (7), and when the orientation of the steel pipe changes from vertical to horizontal, it increases (8).
5. Conclusion
A method for producing aluminum oxide nanoparticles, consisting in the thermal decomposition of an aluminum salt and combining accessibility and reliability, was developed and patented [2].
A study of the liquid capillary rise height is used to assess the stability of the coating from aluminum oxide nanoparticles. The data on the thermal resistance of the investigated heat pipe models were obtained. The dependences of the thermal resistance were established for vertical heat pipe models on the transmitted heat flux for the following options: steel pipes with a joint made in the form of a pipe-in-pipe, dry and filled with water or LOCTITE SI 100 paste, pipes made of aluminum without a joint and a dry flat joint.
Steel models have a higher thermal resistance, both without a joint and with a joint filled with air, water and thermal grease, respectively. When applied to the evaporator coated by nanoparticles of aluminum
oxide, the thermal resistance decreases, and when the orientation of the steel pipe changes from vertical to horizontal, it increases.

The decrease in thermal resistance with increasing heat load for composite models of steel pipes suggests that, apparently, the contribution of condensation and evaporation zones to the total thermal resistance is comparable to the contribution of thermal conductivity at the point of contact of the joined surfaces.

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