

Convective heat transfer in ship tank subjected to harmonic oscillations

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This thesis is devoted to the issue of impact of ship motion on a convective heat transfer in tanks with liquid cargoes. Simplified methods have been introduced for evaluation of a hull motion intensity and characteristics as a response to excitation in form of wave system. Analysis is focused on rolling motion, as having highest potential to induce liquid motion in a rectangular tank. A number of cases of marine liquid transport have been analysed in order to obtain a range of ship roll amplitude values and roll period values that occur in practice. The data obtained from the analysis were used to determine the parameters of the research stand for convective heat transfer in tank completely filled with liquid. The motion parameters were determined according to principles of the similarity theory. The stand was designed, built from scratch, launched and tested. A heat flux and an intensity of the convective heat transfer from the liquid to bottom, vertical and top walls of tank were recorded by measurement of temperature differences with use of thermocouple assemblies. Measurements were carried out with two model liquids: distilled water and spindle oil, both with the tank at rest and subjected to harmonic oscillations of varying intensity. An analysis of the dynamic cases was preceded by calculations of a liquid velocity field in the considered case of cuboidal tank filled with liquid. Differences in functions of velocity distribution were shown in relation to case of a tank with free liquid surface, which was the subject of research in the field in the doctoral dissertation carried out at the Institute of Fluid Flow Machinery of Polish Academy of Sciences exactly 40~years ago by Stefan S. Doerffer in year 1981. The results of the research were analyzed in several ways.

A general balance of taken measurements of heating power delivered to tank as well as a heat flux exchanged with the environment were made for all registered stationary heat transfer cases. The results were also analyzed in global perspective in order to determine the general coefficient of heat transfer intensification, between heat source and tank, due to tank excitations.

It has been hypothesized that the complex heat transfer process of mixed convection in a ship's tank can be described by an appropriate combination of elementary phenomena. In the investigated case, by combining the phenomenon of free convection, caused by the temperature difference between the walls and liquid, and forced convection, caused by forced flow oscillations in the tank. The possibility of application of the semi-empirical method for the processes of boiling and condensation, proposed by J.~Mikielewicz, was checked.

For each of the walls, the correlations of the characteristic numbers were determined, allowing the calculation of the values of the heat transfer coefficients, depending on the parameters of the transported liquid and the tank motion. Correlations were determined from both the data collected experimentally and calculated from semi-empirical method.

These results are of great importance for engineering applications, for calculation of thermal balances of marine tanks during design of heating installations. The previously unknown correlations for upper wall of tank was obtained and correlations for remaining walls were identified as different from the free-surface tank case.

