International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Research Article

Heat Exchange of Marine Tankers' Tubular Heater

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Accepted 25 November 2013, Available online 01 December 2013, **Vol.3, No.5 (December 2013)**

Abstract

The investigation of the heat exchange of the marine tankers' tubular heater made it possible to receive criterion equations for calculating average and local heat emission in free convection for a wide range of Ra and Pr numbers taking into account the variable viscosity. The oscillations intensify the heat exchange process. The heat exchange process of tubular heater while tankers are tossing belongs to a stationary mixed convection. Three zones of oscillation influence on the heat exchange of the horizontal cylinder are formed, and the boundaries of these zones are determined. The criterion equation, which generalizes the heat exchange at vibration, oscillations, rotation and horizontal cylinder flow, is received.

Keywords*: heat exchange, variable viscosity, oscillations, horizontal cylinder, tossing, marine tankers.*

Introduction

For heating viscous liquids during transportation on tankers, steam coiled or sectional tubular heaters are mainly used. Parameters of a heater (heat transfer surface, effective length of a heater, hydraulic resistance, etc.) significantly depend on the intensity of the heat exchange between the heat fluid and the outer surface of the pipes of a heater. On marine tankers rolling influences significantly on the heat transfer of a heater [Sherbakov A.Z., Selivanov N.V., Belonogov V.A.1983]. Inaccurate determination of heat transfer coefficient between the fluid and the surface of a heater will increase capital and operating costs for the heating system for liquid cargo and will ultimately increase the cost of viscous oil transportation. That is why the study of the influence of capacity fluctuations on the heat transfer around a horizontal tubular heater is one of the most urgent tasks for transportation of high-viscosity liquids by sea.

The influence of the vibration in a horizontal cylinder on the heat transfer during the free convection process is considered in [Galiceiskiy B.M., Rigov U.A., Yakush E.V. 1977 - Richardson P. D., Tinactin K.1974], the most work is focused on low-amplitude high-frequency oscillations (vibrations). In the area of low relative amplitudes the movement of the fluid around the cylinder is aperiodical. There is a critical level of the vibration intensity below which the heat transfer is not very different from the free convection process. By increasing the relative amplitude of $A/d > 0.25$, according to [Carr W., Black W. Z 1974.], the critical level is not observed, and the heat transfer gradually increases with increasing of the amplitude and the frequency of vibration. For the area of relatively large amplitudes the heat transfer process can be considered as quasi-stationary [[Galiceiskiy B.M., Rigov U.A., Yakush E.V. 1977, Carr W., Black W. Z.1974, Diver F.K., Penney V.R., Jefferson T.V.1962]. The heat transfer during the vibration with large-amplitudes is approaching, in a sense, the heat transfer during the cross flow of the cylinder. With increase of the oscillation frequency of the cylinder mainly small-scale and turbulent disturbances occur. Since high-frequency pulsations in the fluid decay rapidly without extending to the volume, this leads to the slowdown of the growth rate of the heat transfer [Kremnev O.A., Satanovskiy A.V., Lopatin V.V.1968].

To assess the impact of the fluctuations on the heat transfer of the horizontal cylinder it is necessary to know the intensity of the heat transfer during the free convection process. Analysis of the results obtained in [Akagi S. 1965, Kuehn T. H., Goldstein R. J. 1980] has shown that at $Ra \le 10^5$ the approximations of the boundary layer are invalid. For this case, the dependence for calculation of local heat transfer coefficient, which approximates the results of the numerical solutions [Akagi S. 1965 – Selivanov N.V.2002] at $Ra \ge 10^2$ with an accuracy of 2% in the range of variation $Pr_l = 0.01 - \infty$ has been obtained:

$$Nu_{d,l} = Ra_{d,l}^{0.25}\left[\left(\frac{Pr_l}{1+2\left(Pr_l^{0.5}+Pr_l\right)}\right)^{0.25} g(\varphi)(\bar{\mu})^k + \frac{1{,}2Pr_g{}^{0.0147}}{Ra_{d,l}^{0.25}}\right] \quad (1)$$

where $Nu_{d,l} = \alpha d/\lambda$ – the Nusselt number; $Pr_l = \nu/a$ – the Prandtl number; $Ra_{d,l} = g\beta\Delta td^3/(\nu a)$ – the Rayleigh number; $\mu = \mu_l/\mu_w$ – relative viscosity (μ_l and μ_w – dynamic viscosity at the liquid temperature and the wall temperature respectively, Pa·s); α – heat transfer coefficient W/(m^2·K ·); λ – thermal conduction coefficient, W/(m·K); ν – kinematic viscosity of the liquid, m^2/sec; β – temperature coefficient of the thermal expansion of the

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