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N. V. KALASHNIKOV and V. I. CHERNIKIN

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Abstract

Full Text

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STUDY OF HEAT EXCHANGE BETWEEN VIBRATING HEATERS AND VISCOUS LIQUIDS

(Presented by Academician P. A. Rebinder, July 2, 1957)

Heat transfer from stationary heaters to liquids in vessels is effected by free convection, which is very small for viscous liquids. One of the most effective methods for intensifying the heating of liquids is the use of vibrating heaters, whose heat output is determined mainly by forced convection.

The influence of heater vibration on heat transfer to viscous liquids was studied on an electromechanical vertical vibrator equipped with a horizontal cylindrical electric heater 1.98 cm in diameter and with a heat-releasing length of 28.2 cm. The amplitude of oscillation was varied within the range $2a = 1 \div 4$ cm, the frequency $n = 100$–1600 min^{-1}, and the root-mean-square vibration velocity

$$\bar{v} = \omega a/\sqrt{2} = 2\pi n a/\sqrt{2}$$

from 4 to 134 cm/sec. The following were heated: high-viscosity fuel oil 100 ($\nu_{20} = 66.2$ cm^2/sec), avtól 18 ($\nu_{20} = 13.0$ cm^2/sec), spindle oil ($\nu_{20} = 1.28$ cm^2/sec), and a mixture of spindle oil with kerosene, very close in viscosity to diesel fuel ($\nu_{20} = 0.17$ cm^2/sec).

Fig. 1. Dependence of the heat-transfer coefficient α on the vibration regime.
a —spindle oil with kerosene,
b —fuel oil 100.

It was found (Fig. 1):

1) The heat-transfer coefficient α from the heater to fuel oil without vibration ($n = 0$) lies within the range $40 \div 45$ kcal/m$^2 \cdot$ h $\cdot$ deg at $t_{av} = 42°$. Under

Fig. 2. Parameter Nu as a function of $\mathrm{Pe}^{0.67} \cdot \mathrm{Pr}^{-0.16}$ (experimental data and calculated dependence). *a*—mazut 100, *b*—avtol 18, *v*—spindle oil, *g*—spindle oil with kerosene

Figure 2: Fig. 2. Parameter Nu as a function of $\mathrm{Pe}^{0.67} \cdot \mathrm{Pr}^{-0.16}$ (experimental data and calculated dependence). *a*—mazut 100, *b*—avtol 18, *v*—spindle oil, *g*—spindle oil with kerosene

the vibration regime $2a \cdot n = 3 \cdot 1200$ ($\bar{v} = 134$ cm/sec), α increases to 900 kcal/m$^2 \cdot$h$\cdot$deg, i.e., by ~ 20 times. For the mixture of spindle oil with kerosene, under the same conditions, α increases from $80 \div 85$ kcal/m$^2 \cdot$ h $\cdot$ deg ⋯

up to 2080 kcal/m^2 • h • deg, i.e., by about 24 times. Thus, vibration of heaters is a powerful means of intensifying heat transfer.

2) Increasing $2a$ at $n =$ const and increasing n at $2a =$ const leads to a significant increase in α; consequently, α increases with increasing vibration velocity $\bar{v}$.

3) For low-viscosity liquids, the intensity of the increase of α at $\bar{v} =$ const depends to a greater extent on the amplitude than on the vibration frequency. With increasing viscosity of the liquid, the leading role of the amplitude decreases, practically disappearing when highly viscous liquids are heated.

Fig. 2. Parameter Nu as a function of $\mathrm{Pe}^{0.67} \cdot \mathrm{Pr}^{-0.16}$ (experimental data and calculated dependence).
a—mazut 100, *b*—avtol 18, *v*—spindle oil, *g*—spindle oil with kerosene.

4) At a vibration velocity of 20 cm/sec and higher, free convection practically does not affect the intensity of heat transfer to viscous liquids, and the heat-transfer process is determined entirely by forced convection.

Processing of the experimental data in the parameters of forced convection [1] led to the formula (Fig. 2):

$$\mathrm{Nu} = 0.146\,\mathrm{Pe}^{0.67} \cdot \mathrm{Pr}^{-0.16} \tag{1}$$

The determining temperature in (1) is $t_{\mathrm{av}} = 0.5\,(t_{\mathrm{p}} + t_{\mathrm{l}})_{\mathrm{av}}$; t_{p} is the temperature of the heater surface; t_{l} is the temperature of the liquid; the determining dimension is the diameter of the heater tube, d; the parameter Pe is calculated from the root-mean-square vibration velocity $\bar{v}$. Formula (1) is applicable to horizontal cylindrical heaters vibrating in the vertical direction with amplitude $2a = 1 \div 4$ cm and velocity $v = 20 \div 134$ cm/sec, for parameter values $\mathrm{Pe} = (1.6 \div 40) \cdot 10^4$ and $\mathrm{Pr} = 1.4 \cdot 10^2 \div 1.5 \cdot 10^4$.

The resistance force R of a heater vibrating in a liquid is determined by the following equations:

$$\begin{aligned} &\text{for } 0.5 < \mathrm{Re} < 2, && \mathrm{Eu} = 63\,\mathrm{Re}^{-2};\\ &\text{for } 2 < \mathrm{Re} < 7, && \mathrm{Eu} = 28\,\mathrm{Re}^{-0.82};\\ &\text{for } 7 < \mathrm{Re} < 100, && \mathrm{Eu} = 11.5\,\mathrm{Re}^{-0.36}, \end{aligned}$$

where

$$\mathrm{Eu} = \frac{R}{v^2 \rho F}, \qquad F = dl,$$

l is the length of the heater.

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named after I. M. Gubkin

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CITED LITERATURE

1. M. A. Mikheev, *Fundamentals of Heat Transfer*, 1956.

Note: Figure translations are in progress. See original paper for figures.