MEAN HEAT TRANSFER IN TRANSVERSE AIR FLOW AROUND A CYLINDER

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A modified method of analyzing experimental data is outlined, allowing the degree of linearity of the relation between the Reynolds and Nusselt numbers to be determined.

In designing thermoanemometers, it is desirable to have information on bodies with a linear dependence of the heat-transfer coefficient of the sensitive element on the flow rate of the medium being monitored in the range of measurable rates. It was shown in [1] that this requirement is satisfied by a cylindrical sensor, the mean heat extraction from the lateral surface of which is described in the range Re = $7 \cdot 10^3 - 10^6$ by a broken line consisting of three segments with a linear dependence of Nu on Re. It was also shown in [1] that the method of analyzing the experimental data may significantly influence the interpretation of the character of the dependence of the Nusselt number on the Reynolds number. The method proposed in [1] allows the experimental data to be analyzed on a computer in the form of a binomial power dependence law

$$\mathrm{Nu} = \mathrm{Nu}_0 + C\mathrm{Re}^n. \tag{1}$$

However, the deficiency of the method of [1] is the possible loss of accuracy of the approximation in differentiating the discrete function, which leads to indeterminacy in finding the degree of linearity of the dependence of Nu on Re. To increase the accuracy of analysis of the experimental data, the following method has been developed. The experimental data are divided into zones with a monotonic (without breaks) dependence of Nu on Re. Specifying n = 0.1, a straight line is constructed through the points (Re_i^n, Nu_i) by the least-squares method. Varying n from 0.1 to 1.5 in steps of 0.05, analogous straight lines are plotted. For each straight line, the mean square deviation is calculated. The optimal straight line is that for which the mean square deviation is minimal. If the step 0.05 is not appropriate, then, after finding the straight line with the least mean square deviation for the given step, the two values of n corresponding to the two neighboring optimal straight lines are taken, and the above computational process is conducted between these values of n with a smaller quantization step. In the computer realization of this method, it is simple to organize the iterative process, which ceases on reaching the specified error of the approximation.

The method is tested for Hilpert's experimental data on the mean heat extraction of a cylinder in [2], which are regarded as the most reliable in the given region of investigation, and also those of [3]. Analysis of the data by the above method reveals the following linear dependences: according to the Hilpert data

$$\mathrm{Nu} = \begin{cases} 20 + 0{,}0032\,\mathrm{Re}, & 7\cdot 10^3 \leqslant \mathrm{Re} \leqslant 2\cdot 10^4, \\ 42 + 0{,}0021\,\mathrm{Re}, & 2\cdot 10^4 < \mathrm{Re} \leqslant 2\cdot 10^5, \end{cases} \tag{2}$$

according to the data of [3]

$$\mathrm{Nu} = \begin{cases} 20 + 0{,}0035\,\mathrm{Re}, & 7\cdot 10^3 \leqslant \mathrm{Re} \leqslant 2\cdot 10^4, \\ 46 + 0{,}0022\,\mathrm{Re}, & 2\cdot 10^4 < \mathrm{Re} \leqslant 2\cdot 10^5. \end{cases} \tag{3}$$

The difference in slope of the straight-line segments in Eqs. (2) and (3) may be explained by the different degree of turbulence of the fluxes, leading to multiplicative shift of the lines but not changing the character of the Nu–Re relation. At lower values of Re, n is less than unity.

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Thus, the dependence of Nu on Re in transverse flow around the lateral surface of a cylinder is a broken line with straight-line segments when $Re \geq 7 \cdot 10^3$; this must be taken into account in designing thermoanemometric sensors.

NOTATION

Re, Nu, Reynolds and Nusselt numbers; Nu_0, C, n, constants defined in the text.

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EXCITATION OF THERMOACOUSTIC OSCILLATIONS IN A HEATED CHANNEL

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It is shown that one of the main causes of thermoacoustic oscillations in heated channels is associated with positive work done by bubbles in a sound wave. The sign of the work depends on the characteristics of the bubbles: their size, velocity, and heat and mass transfer with the surrounding liquid.

Thermoacoustic oscillations [1-4] can arise in a heated channel in which the relatively cool surface boiling region occupies a significant fraction of the heated length of the channel. The amplitudes of these oscillations can reach values of the order of the average pressure in the channel in the case when the heated region is relatively short and the underheated, relatively cool region is significant. Thermoacoustic oscillations appear in the form of several different modes (usually three).

Thermoacoustic oscillations can lead to undesirable phenomena: a disturbance of the operating conditions of the device, a lowering of the critical heat loads, and a premature collapse of the channel as a result of fatigue heat loads. The excitation of thermoacoustic oscillations in heated vapor-generating channels at subcritical pressures has been studied mainly experimentally [1-4], and not very extensively. A number of suggestions have been put forth on the mechanism of the excitation of thermoacoustic oscillations, however all of them are mainly qualitative in nature. There is currently no rigorous quantitative treatment available describing the conditions for excitation of thermoacoustic oscillations in surface boiling.

In the present paper we extend the approach developed in [2, 5]. In this approach the excitation of thermoacoustic oscillations depends on the work done by the bubbles in a sound wave over a period of oscillation. The work A done by the bubble over a period of oscillation T in the acoustic pressure field is the intrinsic contribution of the bubble to the excitation of thermoacoustic oscillations. If $A > 0$, then over a period of oscillation the bubble does positive work on the surrounding liquid and this leads to a "build-up" of the oscillation. If $A < 0$ the bubble stabilizes the process. The perturbations of the pressure and volume of the bubble can be written in the form

$$\delta P = a_P \sin \omega t, \tag{1}$$

$$\delta V = a_V \sin (\omega t + \beta). \tag{2}$$

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