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HEAT-AND-MASS TRANSFER, PROPERTIES OF WORKING BODIES AND MATERIALS

Methods of Probing the Two-Phase Flows (Review)

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Abstract—The review of probing methods of two-phase flows is presented. Methods of electrical, optical, acoustical, and thermal probing are considered and their main errors are determined. It is shown that when determining the true local volume void fraction φ_L by the probing method of the flow, the errors that are small can be decreased via increasing the measurement duration and the frequency of the supplying voltage. The procedure is presented, based on which, the selection of the optimal (relatively minimal error) of the true volume void fraction is possible. The use of the suggested procedure makes it possible to increase the accuracy of determining φ_L and to improve the representativeness of the data. Advantages and disadvantages of the methods of optical probing and acoustic probing compared with electrical probing are considered. The method of thermal probing is described. When implementing it, the thermocouple junction is used, which is heated by passing the alternate current. Block diagrams of thermocouple probes and the procedure of determining the true volume void fraction using the thermal probing procedure are determined.

Keywords: electrical probing, optical probing, acoustic probing, thermal probing, local true volume void fraction, optimal discrimination level, electrical contact sensor

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To verify mathematical models in transient and emergency modes and to construct the physically substantiated computational procedures of heat-hydraulic characteristics of installations, experimental data on both the integral characteristics of the flow and the data on local characteristics and the structure of the flow are necessary. When using contactless methods of determining the characteristic of single-phase and two-phase flows such as the laser Doppler anemometry, phase Doppler anemometry by particle images, fluorescent methods, etc. [1], small light-scattering particles are introduced into an optically nonuniform flow. Currently, such methods are widely used in aerodynamic experiments. The structure of two-phase media through optical viewing windows is studied by high-speed photographing and filming. When investigating the water-steam flows, complications associated with turbidity of glasses because of their solubility appear. The use of contactless methods in conditions of the water-steam flow at high pressures and temperatures is complicated. In connection with this, when determining the local characteristics of single-phase and two-phase flows, probe methods are applied. As probing, we understand the indication of the phase state of a local volume of the medium via finding its electrical, optical, thermal, or acoustic conductivity. The necessary condition of using the probe is the smallness of the controlled volume of the medium compared with the volume of dispersed phases in the flow. The interaction of the sensitivity probe element with the phase leads to a jump-like variation in conductivity of the controlled volume fixed by a secondary circuit. Probing the flow, the true volume local void fraction (gas content), phase velocities, the sizes of steam and liquid inclusions, etc., are determined.

TRUE VOID FRACTION φ_L

Substantiation of the Method

As the steam (gas) content, we usually understand the average over time fraction, which is occupied by steam inclusions in the volume of the steam-liquid mixture under consideration:

$$\bar{\varphi} = \frac{\bar{V}_s}{V_\Sigma}, \qquad (1)$$

where $\bar{\varphi}$ is the volume void fraction and $V_\Sigma = V_s + V_L$ is the mixture volume.

When measuring $\bar{\varphi}$ by probe methods, volume V_Σ is rather small, i.e., $V_\Sigma \to 0$. In this case, taking into account formula (1), we formally obtain

$$\varphi_L = \lim_{V_\Sigma \to 0}\left(\frac{\bar{V}_s}{V_\Sigma}\right) \qquad (2)$$

and

$$\bar{\varphi} = \frac{1}{V_\Sigma}\int_{V_\Sigma} \varphi_L dV. \qquad (3)$$