THERMOGRAPHY ANALYSIS OF TURBULENT MIXING PROCESS IN T-JUNCTION CROSS-FLOW

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ABSTRACT: The flow field in the T-junction mixing two fluids with different temperatures was studied experimentally. This study was conducted to clarify the turbulent pulsations frequency and amplitude. When the fluid temperature fluctuation is transferred to the wall and further converted to the stress, frequency of the fluctuation has a significant influence. In recent years, a lot of researches on non-isothermal mixing of liquids devoted to investigation of flows in a T-shaped configuration of pipes (T-junction). These non-isothermal flows are, in general, 3D, unsteady, and unstable; fluctuations occur near the surface and in volume flow. Flows visualization is a difficult problem. The main practical interest in this case is formation of experimental data for validation of CFD-calculations. The usual way of researches is in combining of velocity distributions measurements with a PIV and LDV systems and temperature measurements with thermocouples [1].

Introduction.

The aim of the paper is to clarify the possibilities of effective use of thermography for the study of the processes of turbulent mixing of the liquid, accompanied by unsteady turbulent fluctuations of temperature. The model was rectangular tubes connection (hereinafter - the "T-junction").

Turbulent mixing of fluids of different temperatures takes place in a large number of elements of the heat-exchange equipment of reactor facilities. Their specificity is the fact that they almost always are accompanied by intensive fluctuations of temperatures. When the fluid temperature fluctuations are transferred to the wall, they are further converted to the stress. Thus temperature fluctuations cause additional thermal cycling loads, in some cases, determining the resource items of equipment of power plants.

The motion of fluid in the T-shaped and M-shaped junction in a three-dimensional and two-dimensional case was visualized [2]. The turbulent isothermal and thermal mixing phenomena have been investigated in a T-junction [3]; CFD results have been compared to wire-mesh sensor, LDV and thermocouple measurements. Fluid temperature and velocity distributions in the T-pipe were measured by using a movable thermocouple and high speed PIV, respectively [4]. Experiments to study the flow regimes and heat transfer for an air–water flow in inclined tubes by using thermography were carried out by Hetsroni et al. [5]. The thermal patterns on the heated wall and local heat transfer coefficients were obtained by infrared thermography. The temperature
distribution along the pipe perimeter shows a maximum at the top and a minimum at the bottom of the pipe.

**Infrared technique.**

The IR technique is a non-contact, non-destructive test method for convective heat transfer measurements [6]. This powerful optical tool can be used in complex fluid flows to either evaluate wall convective heat fluxes, or investigate the surface flow field behavior.

In this paper the analyses of the capability of IR thermography to perform heat transfer measurements in the high frequency pulsations in non-isothermal convective water flow is presented. It was suggested to use thermography for qualitative analysis of the pulsations of the water temperature near the wall (window), transparent for infrared radiation [7].

We used a model of the T-junction with rectangular cross-section 50x10 mm. The front tested surface (Fig.1a) was made from 1) copper and 2) stainless steel. The rear wall of the model was made of optically transparent plexiglas, which allowed visualization of the pattern of dyed mixing flows. Special round windows with a diameter of 30 mm, made of zinc selenide were mounted on the rear wall of the tube downstream mixing zone (Fig.1 b). Method of specular reflection was carried out; it allowed to observe directly water flows from both sides of the model. To obtain the temperature fields in mixing area of T-junction, a calibrated, midwave (3.7-4.8 μm) infrared camera (FLIR Systems) was used.

Temperature measured by IR camera through SeZn window versus temperature in quite water is presented on fig.2.

The complex studies on the pattern of mixing non-isothermal water flow using the thermal imager were conducted. The T-junction model was tested: the mixing of different hot ~ 50°C and 20°C cold water, changing locations of hot and cold water in the junction, when the tees angles of ± 150°.

**Results and discussion.**

Typical instant thermograph image of cold and hot water mixing zone is on fig. 3.
Fig. 3. IR image of T-junction mixing zone.

Figure 4 shows the typical thermogram of heat transfer difference through metal surface (bottom) and through zinc selenide windows (4 round small images on top). The image was taken using specular reflection method. Temperature curves in the chosen points 1 and 2 are on fig. 5 (right). Turbulent pulsations frequency and amplitude were measured, depending on water temperature.
The power spectrum of the turbulent fluctuations recorded with IR camera on T-junction mixing zone is presented on Fig. 6.

Fig 4.

The results obtained in the experiments revealed quantitative features of mixing non-isothermal flow and allowed to verify the CFD calculations. 2D and 3D CFD simulations of the non-stationary turbulent viscous flow were conducted. Instant temperature fields are presented on Fig. 6. The hydrodynamic Navier-Stokes equations were solved.

Fig 5. Power spectrum.
Conclusions.

The flow visualization and the temperature field dynamics measurements were conducted using IR camera with high time and space resolution in T-junction. The temperature field dynamics measured by thermography revealed the turbulent pulsations of high frequency. They are due to the temperature difference in the mixing layer. It was shown that the frequency of the nearwall temperature pulsations can be visualized and measured using thermography.

References