Experimental and Numerical Study of Flow and Heat Transfer due to Intermittent Impinging Mist Jets

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Abstract

Impinging jet is employed in many industrial applications (for example drying of sheets of various materials, cooling of electronic devices and GT blades, printing processes, etc) due to heat and mass transfer enhancement around of stagnation point. In many technical applications intermittent (pulsed) flow occurs due to moving parts, by vibrations or flow oscillations. Studies performed show a complex physical situation that in some cases leads to significant heat transfer enhancement, however, also decrease of heat transfer can occur. Spray impingement on hot surfaces has capability of removing large amounts of heat due to use of the latent heat of evaporation. The impingement of pulsed mist flow on hot surfaces also occurs in practical situations, which require a comprehensive knowledge of the flow patterns and the interaction of the spray with the impinging surface.

The aim of the present work is experimental and numerical simulation of the effect of droplets evaporation on the flow and heat transfer in turbulent impinging pulsed mist jets.

The experimental set-up consists of the heat exchanger with the original digital calorimeter and pulse spray source. The heat exchanger is made of high heat-conducting copper with the plane dimensions of 140 × 140 mm and thickness of 25 mm. The air-droplets flow is formed by the pulse spray source from 16 sprayers (matrix of 4 × 4) and 25 air nozzles (matrix of 5 × 5). The source generates pulses of droplets (duration t_{on} from 2 ms to 10 ms, frequency f_i from 1 Hz to 50 Hz and with a velocity – from 0 ms^{-1} to 20 ms^{-1}) that move to the surface of the heat exchanger in a constant cocurrent gas flow (speed U_{L1} – from 0 to 25 ms^{-1}). The main studies have been carried out, when the distance between the heat exchanger and source was L = 230 mm. At this position on a cross-section of heat exchanger surface the source of pulse gas-droplet flow forms a two-phase flow with the area of 300 × 300 mm^2. Near the plate surface (L ~ 200 mm) the jets are split into separate droplets of two main sizes: large (0.12 ÷ 0.15) mm and small ones (0.045 ÷ 0.05) mm.

The numerical model based on the axisymmetrical Euler/Euler approach. For the gas phase were used the set of non-steady-state RANS equations. In the study is considered for the gas phase the second moment closure by Craft and Launder (1992). For the dispersed phase velocity fluctuations were used kinetic stresses equations, turbulent heat flux and temperature fluctuations equations by Zaichik (1999). The two-way coupling model was used along with the particulate feedback onto the mean distribution of the gas phase.

The comparison between our predictions and experiments for pulsed mist jet measurements was provided. These results are presented in the Fig. Agreement between our computation results and numerical and measurements data was rather good especially for the small value of the time of the pulse t_{on} (line *1*) when the wall surface in the experiments is dry. The increase of t_{on} leads to the formation of liquid film and spots on target plate (observed in the measurements) and the residual between our simulations and experiments is rise (line *2*). We did not take into account the film formation on the wall from deposited droplets. We assumed droplets deposited onto the impinging surface momentarily evaporate (solid curves). The predictions without taking into account the heat spend the droplets heat up and evaporation q_{WL} (dashed curve) agreed better with measurements.

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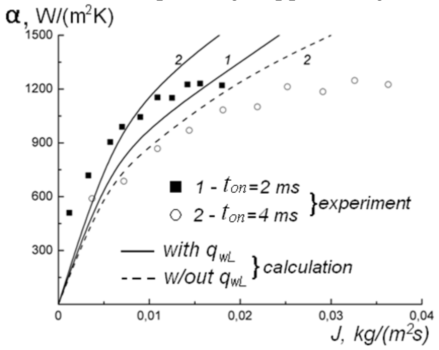

Fig. Heat transfer coefficient in intermittent mist impinging jet. Symbols are experimental results, curves are computations. H = 230 mm, time of the pulse t_{on} = 2 and 4 ms, f_i = 1 – 50 Hz, $T = T_\infty$ = 295 K, T_W = 373 K, U_{L1} = 14.8 m/s. *1* – t_{on} = 2 ms, *2* – t_{on} = 4 ms; solid curves – instant evaporation of droplets on the surface of the heat exchanger (with q_{wL}); dashed curve – w/out q_{wL}.

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