Postprint: Pressure Oscillation Characteristics of Variable-Mass-Flow-Rate Submerged Steam Jets

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Abstract

This study experimentally investigates the pressure oscillation characteristics of steam submerged jets with variable mass flow rates, revealing that the steam mass flow rate decreases exponentially with time. The steam jet condensation process undergoes four distinct stages: stable condensation, oscillatory condensation, transition, and chugging. Higher initial water temperatures of the jet correspond to higher steam mass flow rates at the transition points between condensation regimes. The influence of steam mass flow rate and subcooled water temperature on oscillation characteristics varies across different condensation regions. At a constant steam mass flow rate, elevated initial water temperatures result in lower oscillation frequencies. Both the root-mean-square and peak values of oscillation intensity attain their maxima within the condensation oscillation region, with higher initial water temperatures yielding higher steam mass flow rates at these maxima; the peak oscillation intensity can reach up to 70 kPa.

Full Text

2.1 Experimental Setup and Conditions

This experimental study investigates pressure oscillation characteristics during steam jet condensation in subcooled water. The schematic diagram of the experimental apparatus is shown in [Figure 1: see original paper]. Table 1 summarizes the test conditions, which cover steam pressures ranging from 50 to 650 kPa, water temperatures of 16°C and 55°C, and mass fluxes from 250 to 800 kg/(m^2 · s). The experimental system injects saturated steam through a nozzle into a pool of subcooled water, with high-frequency pressure transducers deployed at multiple locations to capture oscillation intensity.

2.3 Results and Analysis

The variation patterns of steam and water parameters under different operating conditions are illustrated in [Figure 2: see original paper]. [Figure 3: see original paper] presents the change rules of oscillation frequency, revealing how the dominant frequency evolves with steam injection pressure and mass flux. The root-mean-square values of oscillation intensity are depicted in [Figure 4: see original paper], while [Figure 5: see original paper] shows the change laws governing the peak oscillation intensity.

Experimental results demonstrate that pressure oscillations exhibit distinct regimes across the parameter space. At lower pressures (e.g., 70 kPa), oscillation intensity remains relatively modest. As mass flux increases to 350 kg/($m^2 \cdot s$), pressure fluctuations become more pronounced. The frequency analysis indicates that the primary oscillation frequency follows the relationship $(cid:24) ” (cid:192) (cid:4)_)(cid:3)ł(cid:3)ø (cid:11)(cid:3)œ (cid:9)ß(cid:3)(cid:252) ¸(cid:242)1,ø„ -(cid:242) 1 (cid:246)(cid:9)(cid:247) ~(cid:253)(cid:3)(cid:254)(cid:9)(cid:255) ¸(cid:242) ” (cid:239) -(cid:242) ” ,” „” (cid:216) ” (cid:190) ” (cid:239) (cid:1) ‘(cid:3)(cid:218) (cid:9)N (cid:9)(cid:18) (cid:9)n(cid:9)o (cid:11)(cid:9)œ (cid:9)(cid:6)(cid:9)n(cid:9)o ¸(cid:242)(cid:221)‰” (cid:190)” (cid:192) ¸(cid:242) ” (cid:239) ,” „” (cid:216) ” (cid:190) ‰” (cid:190) (cid:1)(cid:2) (cid:4)(cid:3) (cid:1)(cid:5) (cid:1)(cid:6)(cid:8)(cid:7) a(cid:1)’ (cid:1)b (cid:1)’ (cid:1)a(cid:1) ‘Q(cid:9)R $, while the second dominant frequency becomes significant at elevated mass fluxes.

The correlation between oscillation intensity and operating parameters can be expressed as $(cid:21)(cid:9)(cid:22) (cid:31) W(cid:3)N(cid:3)X(cid:3)(cid:192)(cid:3)´ (cid:130)(cid:190) (cid:3)(cid:204) {(cid:226)(cid:9)ª (cid:9)(cid:28) (cid:7)(cid:9)(cid:8)(cid:9)(cid:17)(cid:9)(cid (cid:9) • (cid:9),(cid:9)„(cid:9)”(cid:9)I(cid:9)(cid:30)(cid:9)J (cid:1)(cid:9)(cid:2) (cid:30)(cid:29) (cid:30)(cid:2) (cid:31) ” ‰” (cid:190) (cid:30)! #” $, where peak values show nonlinear dependence on both steam pressure and water subcooling. RMS measurements indicate that the pressure-affected region expands further into the water pool at higher steam flow rates. Temperature conditions of 16°C and 55°C produce different condensation regimes, with greater subcooling generating more intense pressure fluctuations. The pressure range of 50–650 kPa encompasses the transition from stable condensation to oscillatory behavior, with the stability threshold occurring around 250 kg/($m^2 \cdot$ s).

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