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NUMERICAL ANALYSIS OF BOILING AND CONDENSING PHENOMENA USING GAS-LIQUID UNIFIED ALGORITHM

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ABSTRACT

CFD is expected to have a major role to play in optimizing the design of steam injector (SI)[1][2]. The steam injectors are simple, compact, passive steam jet pumps for a steam-injector-driven passive core injection system or steam-injector-driven primary loop recirculation system. However, it is very difficult to simulate hydraulic phenomena in the stream injector because it contains various kinds of problems such as complicated geometries, multiphase flow, free surface, phase change and turbulence. Therefore, for the purpose of numerically simulating thermal hydraulic phenomena in steam injector system, we have developed a new code, CRIMSON[3][4], introducing advanced CFD techniques such as CIVA[5] and CUP[6]. The governing equations are given by

$$\partial_t \rho + u \cdot \nabla \rho = -\rho \nabla \cdot u + \Omega \quad (1)$$

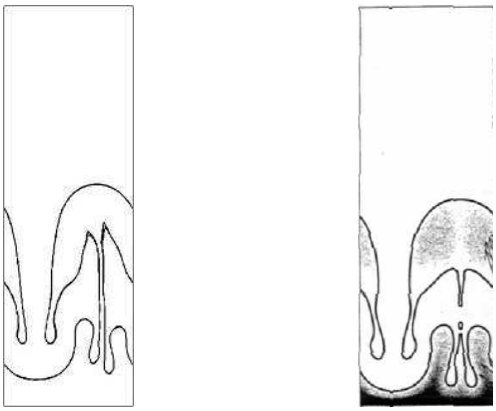
$$\rho \partial_t u + u \cdot \nabla u = \nabla \cdot \Pi + F \quad (2)$$

$$\rho \partial_t e + u \cdot \nabla u = \{\nabla \cdot \Pi\} \cdot u - \nabla \cdot q + Q_S \quad (3)$$

$$\partial_t \alpha + u \cdot \nabla \alpha = \Gamma \quad (4)$$

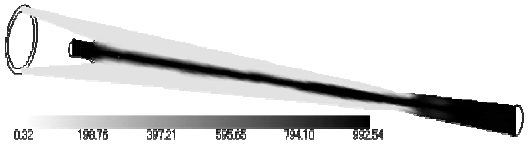
where ρ is the density, u the velocity vector, Π the viscous stress tensor, e the internal energy, q the heat flux, a the void fraction, Γ and Ω the rate of change in the void fraction and density, respectively, caused by the phase change, Qs the latent heat effect caused by the phase change, and F the external force such as the gravity and surface tension. As for phase change model, we adopted the temperature recovering method.

For verifying the code, we simulated 2D film boiling of hydrogen (see Fig.1). Then, we numerically analyzed 3D thermal hydraulic phenomena in steam injectors (see Fig.2) and compared the results with the experimental data.

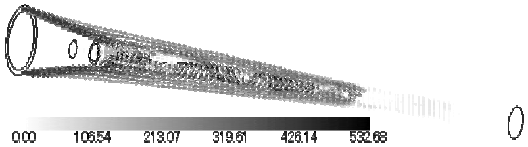


(a) Present numerical results (b) Reference solution[1]

Fig. 1 Comparison of density contours at t=30 [ms] in 2D hydrogen film boiling problem



(a) Density profiles



(b) Velocity profiles

Fig.2 Numerical analysis of thermal-hydraulic behaviors in 3D steam injector system

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