MODELLING THE EVOLUTION OF NEGATIVE PRESSURE MEASURED DURING FLASHING OF WATER

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First results of experimental investigations confirming the possibility of obtaining negative pressures measured during flashing of water were published by Briggs[1] in 1950, then by Borkar et al.[2] in 1977. The results provide a testimony that the bulk viscosity of a two-phase system in the first stage of flashing can assume considerable values. The present paper is devoted to modeling of evolution of kinetic, or hydraulic pressure $P^h = \frac{1}{3} trP_{ij}$, where P_{ij} is a pressure tensor. The kinetic pressure undergoes relaxation to the thermodynamic pressure P which is always positive.

It is shown that the equation to describe the evolution of P^h can be obtained based on Classical Irreversible Thermodynamics (CIT) in the form

$$P^h - P = L_{21}\left(\mu_l - \mu_g\right) + L_{22}\frac{\partial w_i}{\partial z_i} \tag{1}$$

where L_{ij} are the phenomenological coefficients, and L_{22} corresponds to the bulk viscosity $L_{22} = -\varsigma$, μ_l and μ_g are chemical potentials of the liquid and vapor respectively and $\frac{\partial w_i}{\partial z_i}$ denotes divergence of velocity. The equation (1) says that the generalized thermodynamic flux $P^v = P^h - P$ is effected by two thermodynamic forces, namely the difference of the chemical potentials $\mu_l - \mu_g$ and the relative rate of change of flow volume $v(t)$ which is expressed by $\frac{\partial w_i}{\partial z_i}$ At the same time, another thermodynamic flux of the zero tensorial rank $\frac{dx}{dt}$, where x stands for the dryness fraction, is also a function of the same forces and is expressed in the following form

$$\dot{x} \equiv \frac{dx}{dt} = L_{11}\left(\mu_l - \mu_g\right) + L_{12}\frac{\partial w_i}{\partial z_i} \tag{2}$$

A different form of the evolution equation for P^v can be derived from Extended Irreversible Thermodynamics (EIT), namely

$$\theta_P \frac{d\left(P^h - P\right)}{dt} + P^h - P = L_{21}\left(\mu_l - \mu_g\right) + L_{22}\frac{\partial w_i}{\partial z_i} \tag{3}$$

where θ_P means the relaxation time and $\frac{d}{dt}$ denotes the substantial derivative. Equation (3) can be conjugated with an appropriate equation describing the evolution of $\dot{x}$ namely

$$\theta_x \frac{d\dot{x}}{dt} + \dot{x} = L_{11}\left(\mu_l - \mu_g\right) + L_{12}\frac{\partial w_i}{\partial z_i} \tag{4}$$

where θ_x means the relaxation time prescribed to rate of evaporation $\dot{x}$.

The third equation applied to describe the evolution of P^h is taken from a simple expansion of the equilibrium - thermodynamic pressure P

$$\frac{dP^h}{dt} = -\frac{P^h - P}{\theta_P} \tag{5}$$

However the paper also exhibits differences in evolution of P^h during flashing of water as found from these three approaches.

REFERENCES

1. Briggs, L.J., Limiting Negative Pressure of Water, *J. Appl. Phys.*, Vol. 21, pp. 721-722, 1950.
2. Borkar, G.S., Lienhard, J.H. & Trela, A Rapid Hot-Water Depressurization Experiment, *Report EPRI NP-527* Project RP687-1, 1977.