Faik B. NAGIYEV, Hariri A. KAVEH

BUBBLES CHARACTERISTICS AND CONVECTIVE EFFECTS IN THE BINARY MIXTURES

Abstract

The anomaly effect in the boiling binary mixtures has been revealed. The parameters characterizing dynamics of bubbles in water mixture of ethyl spirit in the field of variable pressure lie between limiting values corresponding parameters for pure a component when pressure differences and accordingly a diffusion role are insignificant. At pressure difference increase along with thermal dissipation joins and diffusion dissipation. Thus speed collapse and bubble growth considerably above, than in corresponding pure components of a mixture under the same conditions. Absolutely other situation is observed at growth and collapse a steam bubble in water mixture ethylene glycol. In this case the effect diffusion the resistance leading to braking of speed of phase transformations is observed. Growth rate and collapse a bubble much less than corresponding values, but for pure components of a mixture.

1. Column separation — Water columns typically separate at abrupt changes in profile or local high points due to sub atmospheric pressure. The space between the water columns is filled either by the formation of vapor (e.g., steam at ambient temperature) or air, if it is admitted to the pipeline through a valve. With vaporous forces at pipe bends Transient forces—cavitations, a steam bubbles or vapor pocket forms and then collapses when the pipeline pressure increases as more flow enters the region than leaves it. Collapse of the vapor pocket can cause a dramatic high-pressure transient if the water column rejoins very rapidly, which can, in turn, cause the pipeline to rupture. Vaporous cavitations can also result in pipe flexure that damages pipe linings. High pressures can also result when air is expelled rapidly from a pipeline, which tends to repeat more times than when a vapor pocket collapses.

Water Column Separation and steam bubbles or Vapor Pockets - During a hydraulic transient event, the hydraulic-grade line (HGL), or head, at some locations may drop low enough to reach the pipe's elevation, resulting in sub-atmospheric pressures or even full-vacuum pressures. Some of the water may flash from liquid to vapor while vacuum pressures persist, resulting in a temporary water-column separation. When system pressures increase again, the vapor condenses to liquid as the water columns accelerate toward each other (with nothing to slow them down unless air entered the system at a vacuum breaker valve) until they collapse the vapor pocket; this is the most violent and damaging water hammer phenomenon possible.

Two-phase flow is a difficult subject principally because of the complexity of the form in which the two fluids exist inside the pipe, known as the flow regime (Fig. 1).

It is difficult to construct a model from first principles in all but the most elementary situations.

Fig. 1. Type of flow.

The usual question for the engineer is that of calculating the pressure drop required to achieve specified flow rates of the gas and the liquid through a pipe of a given diameter (Fig. 2).

Fig. 2. Liquid drops in the gas.

Vibrations—Rapid transient pressure fluctuations can result in vibrations or resonance that can cause even flanged pipes and fittings (bend and elbows) to dislodge, resulting in a leak or rupture. In fact, the cavitations that commonly occurs with water hammer can—as the phenomenon's name implies—release energy that sounds like someone pounding on the pipe with a hammer.

Fluid flow simulation through naturally fractured reservoirs has been investigated for nearly four decades. This study is important in applications involving oil and gas recovery from naturally fractured reservoirs, transport of hazardous waste and coal seams degasification. The numerical simulation of the flow response of multiphase, immiscible fluids is therefore highly significant.

2. Thermal and species fluxes occur during the exchange of energy and partial mass through the interface between the vapor and liquid phases and must be suitably modeled. In certain systems, it is also important to describe also the dynamics of the surface phase that can be non-trivial, due to the flows in the surrounding bulk phases perturbing the interface mechanical equilibrium.

The real behavior of liquid mixture in heat pipe needs the integration of continuity, momentum, energy and species equations obeying the appropriate entropy production laws in a context of irreversible processes thermodynamics in the space-time.

The thermodynamics of the vapor-liquid equilibrium in presence of multi-component systems requires the introduction of molar partial properties, fugacity, fugacity coefficients, activities and activity coefficients, involves Raoult‘s and/or Henry's laws, the determinations of the properties change of mixing for both the bulk phases, the expression of partial molar properties in terms of molar properties and the proper formulation of the local field equations in jump form at the interface between the bulk phases for the fields variables playing the (key) role of boundary conditions for the bulk balance equations.

Let's consider two-temperature model of interphase heat exchange of a bubble with a liquid. Such model assumes uniformity of temperature in phases. The binary mix with the density, ρ_l consisting of components 1 and 2, the resulted density accordingly was considered ρ_1 and ρ_2. And, $\rho_1 + \rho_2 = \rho_l$, $\rho_1/\rho_l = k$, $\rho_2/\rho_l = 1 - k$, where k - mass concentration of a component of 1 mix [2,6-12]:

$$R\dot{w}_l + \frac{3}{2}w_l^2 = \frac{p_1 + p_2 - p_\infty - 2\sigma/R}{\rho_l} - 4\nu_1 \frac{w_l}{R}, \tag{1.1}$$

$$j_i = \rho_i \left(\dot{R} - w_l - w_i \right), \quad (i = 1, 2), \tag{1.2}$$

$$\rho_1 w_1 = -\rho_2 w_2 = -\rho_l D \left. \frac{\partial k}{\partial r} \right|_R \tag{1.3}$$

$$\dot{R} = w_l + \frac{j_1 + j_2}{\rho_l} \tag{1.4}$$

$$\frac{R}{3}\dot{\rho}'_i + \dot{R}\rho'_i = j_i, \quad (i = 1, 2) \tag{1.5}$$

$$p_i = BT_v \rho'_i/\mu_i, \ \ (i = 1, 2), \tag{1.6}$$

$$\begin{gathered} k_0 = \frac{1 - \chi_2^0}{1 - \chi_2^0 + \mu\left(\chi_1^0 - 1\right)}, \quad \mu = \mu_2/\mu_1, \\ c_0 = \frac{\rho'_{10}}{\rho'_{10} + \rho'_{20}} = \frac{k_0 \chi_1^0}{k_0 \chi_1^0 + (1 - k_0)\,\chi_2^0}, \end{gathered} \tag{1.7}$$

$$\chi_i^0 = \exp\left[\frac{l_i \mu_i}{B} \left(\frac{1}{T_{ki}} - \frac{1}{T_0} \right) \right], \qquad i = 1, 2 \tag{1.8}$$

where w_l - velocity of a liquid on a bubble surface, $R(t)$ - radius of a bubble, p_1 and p_2 - pressure steam component in a bubble, p_∞ - pressure of a liquid far from a bubble, σ and ν_1 - factor of a superficial tension of kinematics viscosity of a liquid, B - gas constant, T_v - temperature of a mixture, $\rho_i^{'}$ - density a component of a mix of steam in a bubble, μ_i - molecular weight, j_i - the weight stream i - oh - components from an $(i=1,2)$ interphase surface in $r=R(t)$, w_i - diffusion speeds a component on a bubble surface, l_i - specific warmth of steam formation, k_R - concentration 1-th components on an interface of phases, T_0, T_{ki} - temperatures of boiling of liquid components of a binary mixture at initial pressure p_0, D - diffusion factor.

Boundary conditions at $r=\infty$ and on mobile border register in a kind

$$k|_{r=\infty}=k_0,\ k|_{r=R}=k_R,\ T_l|_{r=\infty}=T_0,\ T_l|_{r=R}=T_v \tag{1.9}$$

$$j_1 l_1 + j_2 l_2 = \lambda_l D \left.\frac{\partial T_l}{\partial r}\right|_{r=R}, \tag{1.10}$$

$$\left(\lambda_l \frac{\partial T_l}{\partial r}\right)_{r=R} = Nu_l \cdot \frac{\lambda_l (T_0 - T_v)}{2R}, \tag{1.11}$$

where λ_l, - heat conductivity factor.

In work [16] analytical expression for parameter of Nusselt Nu_l is received:

$$Nu_l = 2\sqrt{\frac{\omega R_0^2}{a_l}} = 2\sqrt{\frac{R_0}{a_l}\sqrt{\frac{3\gamma p_0}{\rho_l}}} = 2\sqrt{\sqrt{3\gamma}\cdot Pe_l}, \tag{1.12}$$

where $a_l = \dfrac{\lambda_l}{\rho_l c_l}$- thermal conductivity of liquids, c_l - factor of a specific thermal capacity. $Pe_l = \dfrac{R_0}{a_l}\sqrt{\dfrac{p_0}{\rho_l}}$- Number of Pekle.

Intensity mass transfer a bubble with a stream of a bearing phase we will set further by means of dimensionless parameter of Shervud Sh:

$$\left(D\frac{\partial k}{\partial r}\right)_{r=R} = Sh \cdot \frac{D(k_0 - k_R)}{2R}$$

Let's set parameter of Shervud in a kind:

$$Sh = 2\sqrt{\frac{\omega R_0^2}{D}} = 2\sqrt{\frac{R_0}{D}\sqrt{\frac{3\gamma p_0}{\rho_l}}} = 2\sqrt{\sqrt{3\gamma}\cdot Pe_D}, \tag{1.13}$$

where $Pe_D = \dfrac{R_0}{D}\sqrt{\dfrac{p_0}{\rho_l}}$- diffusion number the Pekle.

On fig. 3 and 4 theoretical calculations on an example of water mixture of ethyl spirit and ethylene glycol (the antifreeze used in radiators of cars) are illustrated. It is visible that the first mixture is not suitable for the task in view decision whereas the water mixture ethylene glycol with the concentration defined theoretically boils in comparison with pure water and ethylene glycol essentially more slowly. It confirms reliability of the developed method. Calculations show that such solution practically does not freeze.

By the same technique it is possible to offer concrete cooling mixtures for heating up details and knots of various machine tools and mechanisms.

Fig.3. Dependence from time of vapor bubble radius.
1 - water, 2 – ethyl spirit, 3 – water mixtures of ethyl spirit.

Fig.4. Dependence from time of vapor bubble radius.
1 - water, 2 – ethylene glycol, 3 – water mixtures of ethylene glycol.

References

[1]. Nigmatulin R.I. *Multiphase media dynamics*, M., "Naka", 1987, Vol. 1,2 (Russian).

[2]. Nagiyev F.B., Khabeev N.S. *Dynamics of binary solutions bubbles. Thermal physics of high temperatures.* 1988, Vol. 27, No 3, pp. 528-533.

[3]. Gerasimov Yu.I. and others. *Course of physical chemistry.* 1963, Vol. 1. Goschimizdat. M.

[4]. Nigmatulin R.I., Khabeev N.S., Nagiyev F.B. *Dynamics, heat and mass transfer of vapor-gas bubbles in a liquid.* Int. J. heat Mass transfer.

[5].Tikhonov A.N., Samarskii A.A. *Equations of mathematical physics.* M., "Nauka", 1977, 736 p. (Russian).

[6]. Nagiyev F.B., Kadirov B.A. *Tleat exchange and dynamics of steam bubbles in binary solution of liquids.* DAN Az. SSR, 1986, No 4, pp. 10-13.

[7]. Nagiyev F.B. *Damping of oscillations of bubbles of boiling benary solutions.* Materials of the VIII Republican conf. on mathematics and mechanics. Baku, 26-29 October, 1988, pp. 177-178 (Russian).

[8]. Nagiyev F.B. *Terkibinde buxar gabarciglari olan ikikomponentli mayenin dinamicasi ve istilik kutle mubadilesi. Turkiye-azerbaijan petrol semin.* Konusmaler. Ankara. 1933.

[9]. Nagiyev F.B. *The method of creation effective collness liquids.* Third Baku international Congress. Baku, Azerbaijan Republic. September 1995, pp. 19-22.

[10]. Nagiyev F.B., Kadirov B.A. *Small vibrations of bubbles in binary mixture in acoustic field.* Izv. AN Az. SSR, ser. fiz.-techn. i mat. Nauk, 1986, No 1 (Russian).

[11]. Nagiyev F.B. *Linear theory ofdistribution of perturbations in bunary bubble solutions of liquids.* Dep. in VINITI, 17.01.86, No 405, B 86, 1986 (Russian).

[12]. Nagiyev F.B. *Structure of stationary shock waves in boiling binary solutions.* Izv. AN SSSR, Makh. Zidkosti i Gaza (MZG) 1989, No 1, pp. 81-87.

[13]. Rayleigh. *On the pressure developed in a liquid during the collapse of a spherical cavity.* Philos. Mag. Ser. 6, 1917, v. 34, N 200, pp. 94-98.

[14]. Nigmatulin R.I., Nagiyev F.B., Khabeev N.S. *Destruction and collapse of steam bubbles and amplification of shock waves in liquid with vapor bubbles.* In: "Gas and wave dynamics", issue 3, MGU, 1979, pp. 124-129.

[15]. Minnaert M. *On musical air bubbles and the sounds of running water.* Phil. Mag., 1933, v. 16, No7.

[16]. Nigmatulin R.I., Nagiyev F.B., Khabeev N.S. *Effective coefficients of bubbles heatexchanse, radially pulsating in liquid.* Materials of the VI All Union conference on heat-mass exchange. Vol.5. a Heat-moxss exchange in two phases. minsk, 1980, pp. 111-115.

[17]. Vargaftik N.B. *Reference book on thermophysical properties of gas and liquids.* M.: "Nauka", 1972 (Russian).

Faik B. Nagiyev
Scientific-Research Institute, Azerbaijan
"Geotechnological Problems of Oil,
Gas and Chemistry".

Hariri A. Kaveh
Department od Energy, Iran.
the Water Management Company (Gilan)
Tel.: (99412) 439 47 20 (off.).

Received October 02, 2008; Revised December 25, 2008.