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DETERMINATION OF PROPAGATION VELOCITY OF WAVE IN THREECOMPONENT RISING FLOW WITH BUBBLE REGIME CONDITION

Abstract

In the work determination of propagating of wave is done in threecomponent rising flow with bubbly regime condition. A hypothesis is applied according to which threecomponent mixture (liquid+gas+solid particles) is introduced as twocomponent one; carrying quasycontinuum (liquid+solid fractions) +gas. The obtained results for propagation velocity of wave are testified by the experimental data.

Let's discuss threecomponent rising flow consisting of the components among which there are no phase transmissions (such as water, air, sand or coal). Flows like that are often found with hydraulic handling by means of airlifts. Let's assume that there is bubbly flow regime. For such regime in a case of twophase mixture (liquid+gas) the dependency is yielded for determination of propagation velocity of wave in (1)

$$C_{fg} = \frac{1+\delta}{\delta}\left(\gamma_g RT\right)^{1/2}, \tag{1}$$

where δ - gas and liquid consumption relation by volume $\left(\delta = \frac{Q_g}{Q_f}\right)$;

β - gas and liquid mass consumption relation $\left(\beta = W_g / W_f\right)$;

$R = \frac{\beta}{1+\beta} R_g$;

R_g - gas constant;

γ_g - isoenthrope characteristic (response);

T - absolute temperature.

Let's transform expression (1) taking into account that true gascontent α volume is determined as follows:

$$\alpha = \frac{Q_g}{Q_g + Q_f} = \frac{\delta}{1+\delta}. \tag{2}$$

So

$$C_{fg} = \frac{1}{\alpha}\left(\gamma_g R_g T\right)^{1/2}\left(\frac{\beta}{1+\beta}\right)^{1/2}. \tag{3}$$

As propagation flow in gas C_g equals

$$C_g^2 = \gamma_g R_g T, \tag{4}$$

we get

$$C_{fg} = \frac{1}{\alpha} C_g \left(\frac{\beta}{1+\beta}\right)^{1/2}. \tag{5}$$

The relation of mass consumption of components could be expressed through gascontent α:

$$\beta = \frac{\alpha\rho_g}{(1-\alpha)\rho_f}, \tag{6}$$

where ρ_g and ρ_f - correspond gas and liquid density.

From (6) it is easy to yield

$$\frac{\beta}{1+\beta} = \frac{\alpha\,\rho_g}{(1-\alpha)\rho_f + \alpha\,\rho_g}. \tag{7}$$

So in the end

$$C_{fg} = \frac{1}{\alpha} C_g \left[\frac{\alpha\,\rho_g}{(1-\alpha)\rho_f + \alpha\rho_g}\right]^{1/2}. \tag{8}$$

Let's try to generalize the obtained dependency on the threecomponent mixture. The principal hypothesis is that threecomponent mixture (liquid+gas+solid particles) reduces to twocomponent one; carrying quasicontinuum (liquid+solid fractions)+gas. It should be mentioned that the final results testify that the hypothesis is quite rightful (to an accuracy). Let æ denote the consuption concentration of solid component then we yield (2) for carrying quasicontinuum density:

$$\rho_{fs} = \left(1 - \frac{\text{æ}}{1-\alpha}\right)\rho_f + \frac{\text{æ}}{1-\alpha}\rho_s, \tag{9}$$

where ρ_s - density of solid component.

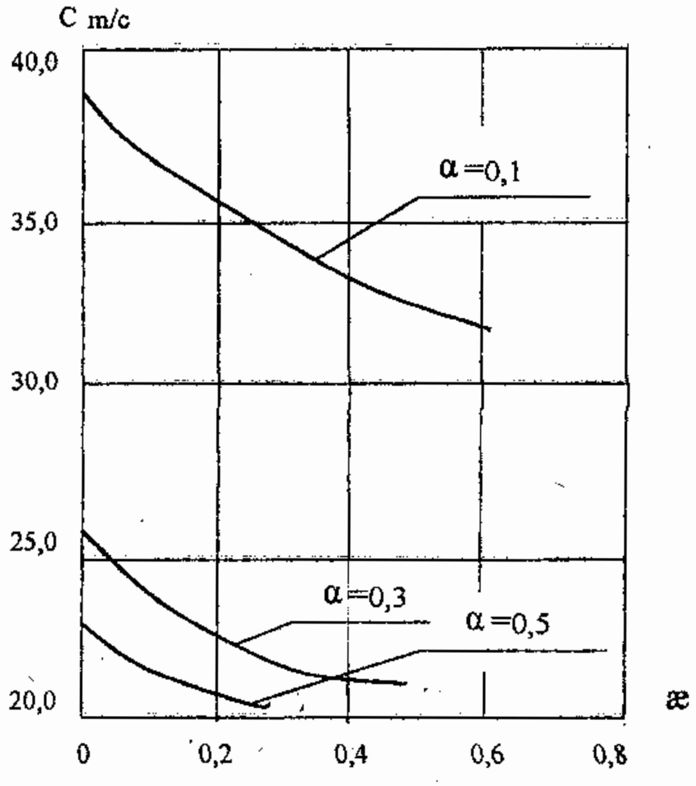

Fig. 1. Propagation velocity of wave in threecomponent mixture

Therefore finally for propagation flow velocity in three component mixture will be equal to

$$C_{gfs}=\frac{1}{\alpha}C_g\left[\frac{\alpha\rho_g}{(1-\alpha)\left[\left(1-\frac{æ}{1-\alpha}\right)\rho_f+\frac{æ}{1-\alpha}\rho_s\right]+\alpha\rho_g}\right], \tag{10}$$

or

$$C_{gfs}=\frac{1}{\alpha}C_g\left[\frac{\alpha\rho_g}{(1-\alpha-æ)\rho_f+æ\rho_s+\alpha\rho_g}\right]. \tag{11}$$

Fig. 1 represents a plot of dependency of propagation flow velocity in threecomponent mixture (water+air+coal): $\rho_g=1{,}2$ kg/m^3; $\rho_f=1000$ kg/m^3; $C_g=336$ m/c.

It should be noted that the obtained theoretical results are verified by exprerimental data.

According to the obtained results the following conclusions could be made: the propagation flow velocity gets reduced in threecomponent mixture both with the gascontent and solid component concentration increase.

References

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