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LETTER TO THE EDITOR

EFFECT OF GAS EXPANSION ON SLUG LENGTH

Please allow us to make a few comments regarding the article by Y. Taitel on the effect of gas expansion on slug length in long pipelines (Taitel 1987).

Taitel considers a train of two slugs separated by a slug bubble, propagating down a pipe [see figure 3, Taitel (1987)].

The downstream slug travels at a larger velocity than the upstream one, due to the gas expansion caused by the pressure drop along the line. As the liquid shedding rate at the end of the slugs is proportional to the slug velocity, the shedding rate at the end of the downstream slug exceeds that of the upstream slug.

Taitel, however, makes the mistake of equaling this difference in shedding rates to the net rate of liquid added to the upstream slug. In reality, part of the liquid shed by the downstream slug goes to increase the liquid film volume under the expanding slug bubble.

Defining a translational velocity (V_t) for the tail of the liquid slug, as suggested by Taitel (1987),

$$V_t = (1 + C)V_s \qquad [1]$$

where V_s is the average velocity in the liquid slug, the shedding rate of the upstream slug may be expressed as

$$X_1 = (V_{t1} - V_{s1})R_{s1}\rho_L A = V_{s1} C R_{s1} \rho_L A \qquad [2]$$

and that of the downstream slug by

$$X_2 = (V_{t2} - V_{s2})R_{s2}\rho_L A = V_{s2} C R_{s2} \rho_L A, \qquad [3]$$

where R_s is the liquid holdup in the slug.

Assuming constant density for the liquid, a total liquid mass balance across the entire slug unit (liquid slug and bubble) yields

$$X_2 - X_1 = (V_{s2}R_{s2} - V_{s1}R_{s1})C\,\rho_L A = \rho_L A \frac{d}{dt}[L_s R_{s1} + L_f R_f] \qquad [4]$$

which should be compared to Taitel's equation [11] (Taitel 1987, p. 633):

$$X_2 - X_1 = (V_{s2} - V_{s1})R_s C\,\rho_L A = A R_s \rho_L \frac{dL_s}{dt}, \qquad [5]$$

where

L_s = the liquid slug length,
L_f = the liquid film (or slug bubble) length,
R_f = average liquid holdup of the liquid film

and

ρ_L = the liquid density.

Comparing [4] and [5], it is observed that Taitel has neglected the increase in the amount of liquid under the slug bubble, as well as the effects of holdup changes along the pipe. A quantitative estimate of the consequences of including these effects may be obtained as follows.

The change in total length of the slug unit is given by

$$(V_{t2} - V_{t1}) = (1 + C)(V_{s2} - V_{s1}) = \frac{d}{dt}[L_s + L_f]. \qquad [6]$$

Continuity of liquid across the slug bubble nose yields an expression for R_f:

$$(V_f - V_t)\, R_f = (V_s - V_t)\, R_s; \qquad [7]$$

or, applying [1],

$$R_f = \frac{C\, R_s}{1 + C - \dfrac{V_f}{V_s}}, \qquad [8]$$

where V_f is the average liquid film velocity.

For horizontal flow, Taitel assumes that $V_f = 0$, which yields

$$R_f \approx \frac{C\, R_s}{1 + C}. \qquad [9]$$

For mixture velocities above 5.0 m/s, Taitel further assumes that

$$R_s = \text{const} = 0.48. \qquad [10]$$

Inserting [9] and [10] into [4] then gives

$$R_s C(V_{s2} - V_{s1}) = R_s \frac{dL_s}{dt} + \frac{C}{1 + C} R_s \frac{dL_f}{dt}. \qquad [11]$$

Inserting dL_f/dt from [6] into [11] finally results in

$$C\,(V_{s2} - V_{s1}) = \frac{dL_s}{dt} + C(V_{s2} - V_{s1}) - \frac{C}{1 + C} \frac{dL_s}{dt}, \qquad [12]$$

which gives

$$\frac{dL_s}{dt} = 0. \qquad [13]$$

In the general case, however, R_s and R_f are not constant and V_f is different from zero.

It may, however, be concluded, that gas expansion does not significantly contribute to the slug growth mechanism.

REFERENCE

TAITEL, Y. 1987 Effect of gas expansion on slug length in long pipelines. *Int. J. Muliphase Flow* **13,** 629–637.

K. BENDIKSEN
N. HOYER
D. MALNES
Institute for Energy Technology
P.O. Box 40, 2007 Kjeller
Norway

Professor Taitel, who was consulted on this letter, agrees that there is an error in his paper and thanks the authors for pointing it out.

G. HETSRONI
Editor