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Multiphase Flow Models Range of Applicability

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May 18, 1998

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Summary

Four multiphase flow models or correlations (Duns & Ros, Hagedorn & Brown, Orkiszewski, and Beggs & Brill) are currently available in Hydra for predicting the pressure profile in a well. The range of applicability of the multiphase flow models is dependent on several factors such as, tubing size or diameter, oil gravity, gas-liquid ratio, and, two-phase flow with or without water-cut. The effect of each of these factors on estimating the pressure profile in a well is discussed separately for all the multiphase models considered. A reasonably good performance of the multiphase flow models, within the context of this document, is considered to have a relative error (between the measured and predicted values of the pressure profile) less than or equal to 20%.

Duns & Ros Correlation

The Duns & Ros correlation is developed for vertical flow of gas and liquid mixtures in wells. This correlation is valid for a wide range of oil and gas mixtures and flow regimes. Although the correlation is intended for use with “dry” oil/gas mixtures, it can also be applicable to wet mixtures with a suitable correction. For water contents less than 10%, the Duns-Ros correlation (with a correction factor) has been reported to work well in the bubble, slug (plug), and froth regions. The pressure profile prediction performance of the Duns & Ros method is outlined below in relation to the several flow variables considered:

- **Tubing Size.** In general, the pressure drop is seen to be over predicted for a range of tubing diameters between 1 and 3 inches.
- **Oil Gravity.** Good predictions of the pressure profile are obtained for a broad range of oil gravities (13-56 °API).
- **Gas-Liquid Ratio (GLR).** The pressure drop is over predicted for a wide range of GLR. The errors become especially large (> 20%) for GLR greater than 5000.
- **Water-Cut.** The Duns-Ros model is not applicable for multiphase flow mixtures of oil, water, and gas. However, the correlation can be used with a suitable correction factor as mentioned above.

Hagedorn & Brown Correlation

This correlation was developed using data obtained from a 1500-ft vertical well. Tubing diameters ranging from 1-2 in. were considered in the experimental analysis along with 5 different fluid types, namely: water and four types of oil with viscosities ranging between 10 and 110 cp (@ 80°F) The correlation developed is independent of flow patterns and its performance is briefly outlined below.

- **Tubing Size.** The pressure losses are accurately predicted for tubing sizes between 1 and 1.5 in., the range in which the experimental investigation was conducted. A further increase in tubing size causes the pressure drop to be over predicted.
- **Oil Gravity.** The Hagedorn-Brown method is seen to over predict the pressure loss for heavier oils (13-25 °API) and under predict the pressure profile for lighter oils (40-56 °API)
- **Gas-Liquid Ratio (GLR).** The pressure drop is over predicted for GLR greater than 5000.
- **Water-Cut.** The accuracy of the pressure profile predictions is generally good for a wide range of water-cuts.

Orkiszewski Correlation

This correlation is limited to two-phase pressure drops in a vertical pipe and is an extension of Griffith & Wallis work. The correlation is valid for different flow regimes such as the bubble, slug, transition, and annular mist and is a composite of several methods as shown below:

Method	Flow Regime
Griffith	Bubble
Griffith & Wallis	Slug (density term)
Orkiszewski	Slug (friction term)
Duns & Ros	Transition
Duns & Ros	Annular Mist

It should be noted that the liquid distribution coefficient (hold-up) is evaluated using the data from the Hagedorn & Brown model. The performance of Orkiszewski correlation is briefly outlined below for the flow variables considered.

- **Tubing Size.** The correlation performs well between 1 and 2 in. tubing sizes. The pressure loss is over predicted for tubing sizes greater than 2 inches.
- **Oil Gravity.** At low oil gravities (13-30 °API), the correlation over predicts the pressure profile. However, predictions are seen to improve as oil °API increases.
- **Gas-Liquid Ratio (GLR).** The accuracy of Orkiszewski method is very good for GLR up to 5000. The errors become large (> 20%) for GLR above 5000.
- **Water-Cut.** The correlation predicts the pressure drop with good accuracy for a wide range of water-cuts.

Beggs & Brill Correlation

The Beggs & Brill correlation is developed for tubing strings in inclined wells and pipelines for hilly terrain. This correlation resulted from experiments using air and water as test fluids over a wide range of parameters. The performance of the correlation is given below.

- **Tubing Size.** For the range in which the experimental investigation was conducted (i.e., tubing sizes between 1 and 1.5 in.), the pressure losses are accurately estimated. Any further increase in tubing size tends to result in an over prediction in the pressure loss.
- **Oil Gravity.** A reasonably good performance is obtained over a broad spectrum of oil gravities.
- **Gas-Liquid Ratio (GLR).** In general, an over predicted pressure drop is obtained with increasing GLR. The errors become especially large for GLR above 5000.
- **Water-Cut.** The accuracy of the pressure profile predictions is generally good up to about 10% water-cut.

General Recommendations

In general, the Orkiszewski and Hagedorn & Brown model are found to perform satisfactorily for vertical wells with or without water-cut, and should therefore be considered equally as the first choice in such wells. As mentioned earlier, the Duns & Ros correlation is not applicable for wells with water-cut and should be avoided for such cases. The Beggs & Brill method is applicable for inclined wells with or without water-cut and is currently the best choice available for deviated wells. However, the method can also be utilized for vertical wells as the last choice. Finally, it should be noted that the performance of the multiphase flow models may not always be affected entirely by the particular flow variable against which the performance trend is indicated. In most cases, the performance of these models may be dependent on a combination of several of these flow variables considered. Therefore, keeping these limitations in mind, the above discussion could be used as a guide to eliminate or select a particular correlation in the absence of other relevant information.

References

1. Beggs, H. D. and Brill, J. P.: "A Study of Two-Phase Flow in Inclined Pipes," *J. Pet. Tech.* (May 1973) 607-617.

2. Duns, H., Jr. and Ros, N. C. J.: "Vertical Flow of Gas and Liquid Mixtures in Wells," *Proc. Sixth World Pet. Congress,* Frankfurt (Jun. 19-26, 1963) Section II, Paper 22-PD6.

3. Espanol, J. H., Holmes, C. S., and Brown, K. E.: "A Comparison of Existing Multiphase Flow Methods for the Calculation of Pressure Drop in Vertical Wells," SPE 2553 presented at the 44th Annual Fall Meeting of the Society of Petroleum Engineers of AIME, Denver, CO (Sept. 28-Oct. 1, 1969).

4. Griffith, P.: "Two-Phase Flow in Pipes," Special Summer Program, Massachusetts Institute of Technology, Cambridge, Massachusetts (1962).

5. Griffith, P. and Wallis, G.B.: "Two-Phase Slug Flow," *J. Heat Transfer; Trans. ASME* (Aug. 1961) 307-320.

6. Hagedorn, A. R. and Brown, K. E.: "Experimental Study of Pressure Gradients Occurring During Continuous Two-Phase Flow in Small Diameter Vertical Conduits," *J. Pet. Tech.* (Apr. 1965) 475-484.

7. Lawson, J.D. and Brill, J.P.: "A Statistical Evaluation of Methods Used to Predict Pressure Losses for Multiphase flow in Vertical Oilwell Tubing," *J. Pet. Tech.* (Aug. 1974) 903-914.

8. Orkiszewski, J.: "Predicting Two-Phase Pressure Drops in Vertical Pipe," *J. Pet. Tech.* (Jun. 1967) 829-838.

9. Vohra, I.R., Robinson, J.R., Brill, J.P.: "Evaluation of Three New Methods for Predicting Pressure Losses in Vertical Oilwell Tubing," *J. Pet. Tech.* (Aug. 1974) 829-832.

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