CHAPTER VII

CONCLUSION

This study is intended to investigate the applicability of Guo's four-phase flow model to two-phase and three-phase flow wells under different conditions and improve its accuracy. Two hundred and eight data sets were collected from five published SPE papers. All 208 data sets were used to calculate the bottomhole flowing pressures using Guo's four-phase flow model and six other multiphase flow correlations (Duns and Ros (modified), Hagedorn and Brown, Fancher and Brown, Beggs and Brill, Orkiszewski, Duns and Ros (original)). A program called PROSPER was used to compute the results for these six multiphase flow correlations.

The calculated bottomhole flowing pressures calculated by Guo's four-phase flow model and six other multiphase flow correlations were compared with the measured bottomhole flowing pressures. Statistical parameters such as the average absolute error (AAE) and standard deviation (SD) were then computed. The average absolute error (AAE) was used as an indicator of the accuracy in this study. AAE and SD of the original Guo's four-phase flow model were significantly higher than those of the other six multiphase flow correlations; therefore, it was necessary to improve its accuracy.

To improve the original Guo's four-phase flow model, the following five modifications were considered:

1) modification of Guo's four-phase flow model with tuning factor
2) modification of Guo's four-phase flow model with the Z factor (with and without the tuning factor)
3) modification of Guo's four-phase flow model with R_s and B_o (with and without the tuning factor)
4) modification of Guo's four-phase flow model with Z, R_s, and B_o (with and without the tuning factor)
5) modification of Guo's four-phase flow model using incremental calculation (with and without the tuning factor)

For modification of Guo's four-phase flow model with tuning factor and modification of Guo's four-phase flow model with the Z factor, tuning factor for liquid holdup (F_{LHU}) was determined by the procedure described in Section 4.1. In the determination of F_{LHU}, 25 data sets were discarded due to negative values of F_{LHU}. Therefore, 183 data sets were used to determine F_{LHU}.

However, in the case that solution gas-oil ratio (R_s) calculated from the correlation at the bottomhole is higher than the actual total gas-oil ratio (R), F_{LHU} cannot be back calculated from Guo's model. In this study, 85 data sets have solution gas-oil ratio (R_s) calculated from the correlation at the bottomhole higher than the actual total gas-oil ratio (R). Therefore, only 98 data sets were used to determine F_{LHU}, X, and the relationships of X with well parameters.

In the case of Guo's model modified with gas compressibility factor (Z), solution or dissolved gas-oil ratio (R_s), and formation volume factor of oil (B_o), 85 data sets cannot be used due to solution gas-oil ratio (R_s) calculated from the correlation at the bottomhole are higher than the actual total gas-oil ratio (R) and 8 data sets that give negative F_{LHU} cannot be used, either. Therefore, a total of 90 data sets were used to determine F_{LHU}, X, and the relationships of X with well parameters.

The modified Guo's models tuning for gas flow rate (Q_g) give the best result over the other modified Guo's models. Among the modified Guo's models, the modification by the Z factor with tuning for gas flow rate is the best. Therefore, this model was chosen for incremental calculation. X value obtained from Guo's model modified by the Z factor with tuning for gas flow rate was used to calculate F_{LHU} for each data set.

For each modification, X value for each data set was plotted with natural logarithms of liquid flow rate (Q_L), gas flow rate (Q_g), and Reynolds number (N_{Re}). Each plot was trended with linear, logarithm, and polynomial. Each trend line has its relationship and coefficient of determination (R^2). It can be seen that R^2 value of polynomial trend line was maximum for every plot in all modifications. Therefore, the relationship of X value with well parameters that obtained from polynomial trend line was selected to determine X value and F_{LHU} for all modifications.

The friction factor was corrected with the calculated F_{LHU} for each data set and used in the modified Guo's models to calculate BHFP. This calculated BHFP was then compared with the measured BHFP.

In order to illustrate that the method works, we determined the tuning factor from 90 sets of data instead of using the whole set of data available for Guo's model modified with the Z factor tuning for gas flow rate. Thus, the tuning factor was used to compute the pressure. Same procedures were used to determine F_{LHU}, X, and the relationships of X for Guo's model modified with the Z factor tuning for gas flow rate. The relationships determined from 90 data sets were used to calculate the bottomhole flowing pressures by Guo's model modified with the Z factor tuning for gas flow rate. These calculated bottomhole pressures were compared with the measured bottomhole flowing pressures. Statistical parameters such as the average absolute error (AAE) and standard deviation (SD) were determined.

Then, the average absolute errors (AAE) for the case in which the tuning factor was determined from 183 data sets are compared with the average absolute errors (AAE) for the case in which the tuning factor was determined from 90 data sets.

In addition, the comparisons of modified Guo's four-phase flow models against six other multiphase flow correlations (Duns and Ros (modified), Hagedorn and Brown, Fancher and Brown, Beggs and Brill, Orkiszewski, Duns and Ros (original)) were expressed in this study. As mentioned before, the modified Guo's model tuning for gas flow rate (Q_g) gives the best result over the other modified Guo's models for each modification. Therefore, the modified Guo's model tuning from gas flow rate (Q_g) was chosen to compare with six other multiphase flow correlations.

In the comparisons, statistical parameters such as the average relative error, the average absolute error, and standard deviation are analyzed in different groupings based on gas-liquid ratio (GLR), tubing ID, API gravity, liquid flow rate, and gas flow rate. However, the average absolute error is used as an indicator of the accuracy in this study.

Then, the modified models and correlations were ranked according to the percentage of the results to be sure that the average absolute error (AAE) was within certain limits.

In this study, the following conclusions are made:

1) The average absolute error (AAE) and standard deviation (SD) of Guo's four-phase flow model are significantly higher than six other multiphase flow correlations for 208 data sets.

2) For each modified Guo's model, it was found that the modified model tuning for gas flow rate gives the best result over the other modified Guo's models. Among these models, Guo's model modified with the Z factor tuning for gas flow rate gives the best accuracy of 17.2% of AAE. Guo's original model modified with tuning for gas flow rate gives the fair accuracy of 24.0%. Guo's model modified with Z, R_s, and B_o tuning for gas flow rate and Guo's model modified with R_s and B_o tuning for gas flow rate gives the accuracy of 29.1% and 29.8 %, respectively.
3) In order to illustrate that the tuning factor determined in this study was not particularly tuned for the 183 data sets used in the study, only 90 sets of data were used in the determination of the tuning factor. The new tuning factor was then used to calculate pressure loss in 183 wells. The average absolute errors of the results computed from the tuning factor determined from 90 data sets are not significantly differed from those computed from the tuning factor determined from 183 data sets for the case of modification with the Z factor tuning for gas flow rate.
4) In the comparison of the modified Guo's four-phase flow models against six other multiphase flow correlations, statistical parameters were analyzed in different groupings based on gas-liquid ratio (GLR), tubing ID, API gravity, liquid flow rate, and gas flow rate. From the comparison, it can be seen that Guo's model modified with the Z factor tuning for gas flow rate can compare its accuracy with other multiphase flow correlations for various well conditions except for 1.995" tubing ID, API gravity less than 20°, liquid flow rate less than 350 stb/d, or gas flow rate less than 1,000 Mscf/d since these cases have AAE more than 20%.