World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:16, No:04, 2022

Multiphase Equilibrium Characterization Model For Hydrate-Containing Systems Based On Trust-Region Method Non-Iterative Solving Approach

Authors : Zhuoran Li, Guan Qin

Abstract : A robust and efficient compositional equilibrium characterization model for hydrate-containing systems is required, especially for time-critical simulations such as subsea pipeline flow assurance analysis, compositional simulation in hydrate reservoirs etc. A multiphase flash calculation framework, which combines Gibbs energy minimization function and cubic plus association (CPA) EoS, is developed to describe the highly non-ideal phase behavior of hydrate-containing systems. A non-iterative eigenvalue problem-solving approach for the trust-region sub-problem is selected to guarantee efficiency. The developed flash model is based on the state-of-the-art objective function proposed by Michelsen to minimize the Gibbs energy of the multiphase system. It is conceivable that a hydrate-containing system always contains polar components (such as water and hydrate inhibitors), introducing hydrogen bonds to influence phase behavior. Thus, the cubic plus associating (CPA) EoS is utilized to compute the thermodynamic parameters. The solid solution theory proposed by van der Waals and Platteeuw is applied to represent hydrate phase parameters. The trust-region method combined with the trust-region sub-problem non-iterative eigenvalue problem-solving approach is utilized to ensure fast convergence. The developed multiphase flash model's accuracy performance is validated by three available models (one published and two commercial models). Hundreds of published hydrate-containing system equilibrium experimental data are collected to act as the standard group for the accuracy test. The accuracy comparing results show that our model has superior performances over two models and comparable calculation accuracy to CSMGem. Efficiency performance test also has been carried out. Because the trust-region method can determine the optimization step's direction and size simultaneously, fast solution progress can be obtained. The comparison results show that less iteration number is needed to optimize the objective function by utilizing trust-region methods than applying line search methods. The non-iterative eigenvalue problem approach also performs faster computation speed than the conventional iterative solving algorithm for the trust-region sub-problem, further improving the calculation efficiency. A new thermodynamic framework of the multiphase flash model for the hydrate-containing system has been constructed in this work. Sensitive analysis and numerical experiments have been carried out to prove the accuracy and efficiency of this model. Furthermore, based on the current thermodynamic model in the oil and gas industry, implementing this model is simple.

Keywords : equation of state, hydrates, multiphase equilibrium, trust-region method
Conference Title : ICAE 2022 : International Conference on Applied Energy
Conference Location : Tokyo, Japan
Conference Dates : April 25-26, 2022