Science & Technology Development Journal – Engineering and Technology, 4(SI3):SI84-SI95

Open Access Full Text Article

Research Article

Numerical modeling of multiphase flow in the oil and gas gathering pipeline from wellhead platform of X field to central processing platform of Y field

Nguyen Hoai Tan[1,2], Mai Cao Lan[1,3,*]

Use your smartphone to scan this QR code and download this article

ABSTRACT

The main objective of this research is to investigate the characteristics of slug flow inside the riser which is a 68-meter vertical pipe segment reaching from the seabed to the central processing platform of the Y field. The oil and gas mixture flows into the riser from the wellhead platform of the X field through a 25-km horizontal subsea pipeline.

In this study, an integrated modeling approach is used to take into account major physical phenomena associated with the multiphase flow in the gathering system that might have strong influences on slug flow characteristics. The phase behavior model of oil and gas in the gathering pipeline were first built on the basis of Peng-Robinson equation of state to determine the multiphase equilibria and estimate fluid properties at various pressure and temperature conditions. The multiphase flow was then modeled by Beggs & Brill method for pressure drops and Hasan & Kabir for temperature distribution along the pipeline. In particular, the pressure drop calculation is based on empirical correlations from which the flow regimes can be identified and pressure drop is determined accordingly. The heat transfer calculation, on the other hand, is based on the mechanistic approach from which the temperature distribution along the pipeline system can be estimated. Finally, the slug-tracking model was developed to characterize the slug flow with essential properties such as slug frequency, length and surge volume. This helps identify slug flow existence inside the riser segment and predict potential consequences it may cause to surface facilities.

The results from this work show that the integrated modeling approach is suitable to the multi-physics nature of the flow assurance problem under consideration. The slug flow might exist in the 68-m riser where more than 20 slugs of 2-m length might occur after every 1.5 hours.

Key words: Fluid behavior model, multiphase flow modeling, slug flow characterization, flow assurance

[1]*Faculty of Geology and Petroleum, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2]*Fourth-year Student, Office for International Study Program (OISP), Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[3]*Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam*

Correspondence

Mai Cao Lan, Faculty of Geology and Petroleum, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam

Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam

Email: maicaolan@hcmut.edu.vn

History

- Received: 16/5/2021
- Accepted: 23/9/2021
- Published: 04/11/2021

DOI : 10.32508/stdjet.v4iSI3.841

Check for updates

VNU-HCM Press

INTRODUCTION

The main focus of this work is the oil and gas gathering pipeline from a well head platform of the X field (hereafer referred to as WHP-X) to the central processing platform of field Y (referred to as CPP-Y). The X field is a small oil field, remotely located in Cuu Long basin, offshore Vietnam. In order to develop such a marginal field, a tie-in solution has been implemented with a gathering system in which the mixture of oil and gas from WHP-X is transported to CPP-Y for processing by a 25-km subsea pipeline as described in Figure 1. Since the produced mixture from WHP-X is not processed yet, multiphase flow exists in the gathering pipeline and flow assurance issue is of primary concerns.

The main objective of this research is to characterize the slug flow in the 68-m riser at the end of the gathering system. The reason why slug flow is of great concern here is that once this special flow regime exists at the entry of CPP-Y, it can damage the surface equipment, especially the high-pressure separator on CPP-Y.

In this paper, three main tasks that have been done to meet the objective of our work are presented. They include (a) fluid behavior modeling, (b) multiphase flow modeling, and (c) slug characterization.

Several researches have been conducted on the topics related to our work and some primary work among them are briefly mentioned here for reference.

Regarding oil and gas phase behavior, among other researchers in the field, D.Y. Peng & D.B. Robinson (1976) developed an equation of state that reliably describes hydrocarbon properties and yields more precise estimate of fluid density[1]. The equation is used in this study and hereafter referred to as PR-EOS.

Regarding multiphase flow modeling, Beggs & Brill (1973) developed an empirical map for flow regime identification and the computational workflow based

Cite this article : Tan N H, Lan M C. **Numerical modeling of multiphase flow in the oil and gas gathering pipeline from wellhead platform of X field to central processing platform of Y field**. *Sci. Tech. Dev. J. – Engineering and Technology;* 4(SI3):SI84-SI95.

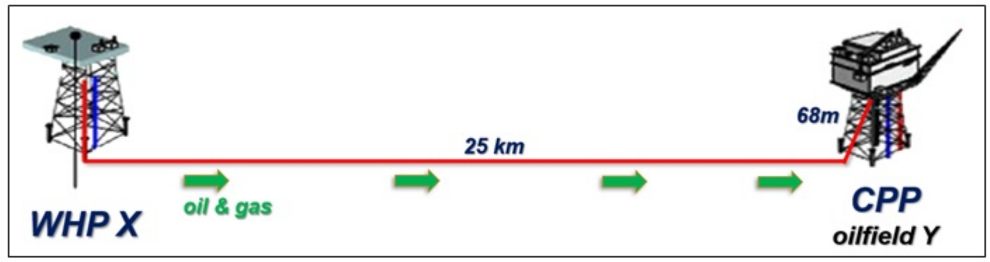

Figure 1: The gathering system has been built to transport oil and gas mixture from WHP-X to CPP-Y.

on which pressure loss can be estimated along the pipeline[2]. Alternatively, Petalas and Aziz mechanistic model combined with empirical correlations can be used for pressure loss calculation along the pipeline[3]. Among other researches on the field of slug characterization, C. Lawrence et al. (2013) studied the conditions that might form slug flows and developed a numerical method to define the slug density for each unit length based on the instability of flow[4]. Martin Cook & Masud Behnia (1999) carried out experiments to establish the empirical correlation of the slug length (L_s) in the slug flow in relation to the ratio between the bubble flow velocity and liquid droplet velocity (V_B/V_T)[5]. In addition, M. Miyoshi, D.R. Doty, Z. Schmidt (1988) developed the method to estimate the surge volume caused by slug flows using real-time recorded data on the CPP which is highly reliable[6].

In the field of flow assurance studies in Vietnam, Đỗ-Xuân, Hoà (2008) studied the paraffin deposition of the oil and gas mixture and suggested using chemicals to deal with such an issue in the same pipeline under consideration[7]. In addition, Phạm-Sơn, Tùng & Mai-Cao, Lân (2014) concentrated their work on the multiphase flow modeling with special focuses on flow regime identification, pressure drop estimation, and heat transfer calculation along the same 25-km pipeline[8].

As can be seen in Figure 2, the main contribution of this work comparaed to the previous studies mentioned above focuses particularly on slug characterization in the 68-m riser with the purpose to assess the potential damage it may cause to the surface equipment.

METHODOLOGY

In order to characterize slug flow in the 68-m riser segment of the gathering pipeline under consideration, an integrated modeling approach has been proposed in this work that consists of the three main components: (a) fluid behavior modeling for equilibrium calculations; (b) multiphase flow modeling for flow regime identification, and pressure drop as well as heat transfer calculations; (c) slug characterization for the estimation of slug density, slug length and surge volume.

Fluid Behavior Modeling

Equation of state (EoS) by Peng & Robinson (1976) is used to define fluid properties such as liquid fraction (x_i), vapor fraction (y_i), gas deviation factor (z_i) of the fluid components as well as phase equilibrium at certain conditions[1]. In this work, the computational workflow shown in Figure 3 is applied with PR-EoS to model the phase behavior of the fluid in the pipeline of interest:

In particular, the workflow shown in Figure 3 is consists of 6 main steps:

- **Step 1**: Assume a guess value of K_i for i-th component using Wilson's correlation (1986):

$$K_i^s = K_i^A = \frac{p_{ci}}{p} e^{\left[5.37(1+\omega_i)\left(1-\frac{T_{ci}}{T}\right)\right]} \quad (1)$$

- **Step 2:** Calculate the values of x_i, y_i and n_V:

$$A = \sum_i \left[z_i\left(K_i^s - 1\right)\right] \quad (2)$$

$$B = \sum_i \left[\frac{z_i\left(K_i^s - 1\right)}{K_i^s}\right] \quad (3)$$

$$n_V = \frac{A}{A-B} \quad (4)$$

$$n_L = 1 - n_V \quad (5)$$

$$x_i = \frac{z_i}{n_L + n_V K_i^s} \quad (6)$$

$$y_i = x_i K_i^s \quad (7)$$

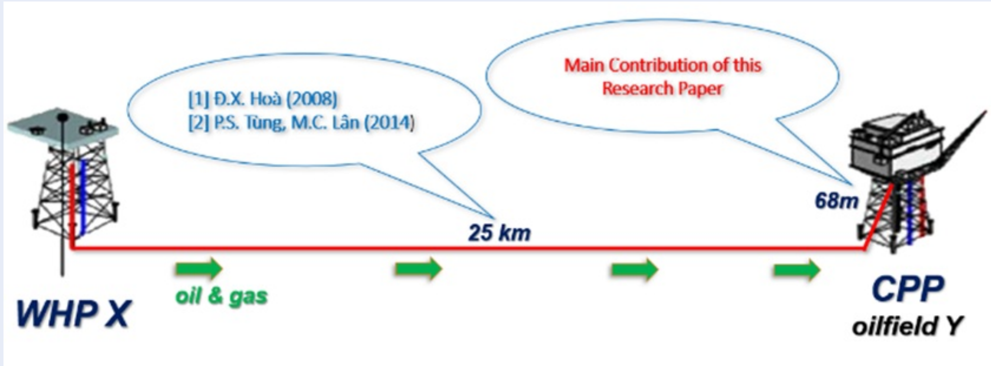

Figure 2: The main contribution of this work focuses on slug characterization in the 68-m riser segment.

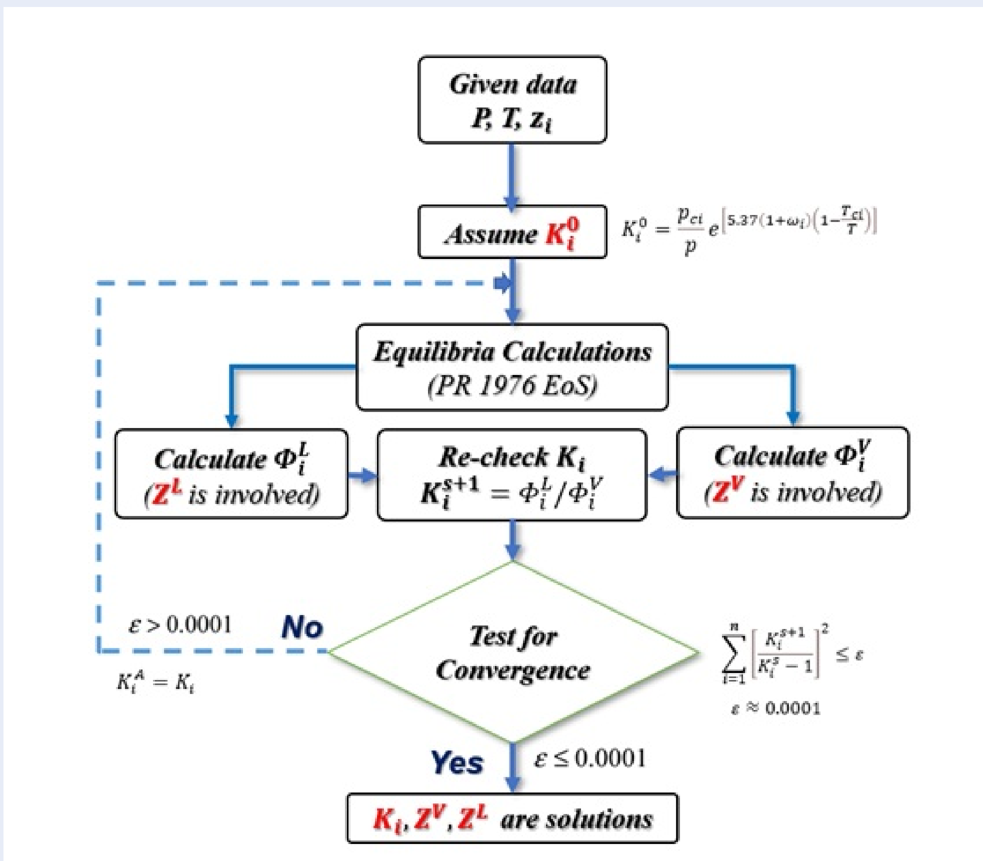

Figure 3: Workflow for fluid behavior modeling using Peng & Robinson's EoS.

where z_i is the mole fraction of component i, n_V is the vapor mole, n_L is the liquid mole, x_i is the liquid fraction of the mixture (%), y_i is the vapor fraction of the mixture (%). A and B are representative parameters for the equilibrium factor K_i.

- Step 3: Determine the fugacity coefficient ϕ_i^V for the vapor phase [1]:

$$\ln\left(\phi_i^V\right) = \frac{b_i\left(Z^V-1\right)}{b_m} - \ln\left(Z^V-B\right) - \frac{A}{2\sqrt{2}B}\left[\frac{2\psi_i}{(a\alpha)_m} - \frac{b_i}{b_m}\right]\ln\left[\frac{Z^V+\left(1+\sqrt{2}\right)B}{Z^V-\left(1-\sqrt{2}\right)B}\right] \quad (8)$$

where ϕ_i^V is the fugacity coefficient, ψ_i is the representative parameter for the BIC k_{ij} [1]:

$$\psi_i = \sum_j \left[x_j\sqrt{a_i a_j a_i a_j}\left(1-k_{ij}\right)\right] \quad (9)$$

whereas $(aa)_m$ is the representative coefficient for $a(T)$ as mentioned earlier to calibrate the temperature dependency [1]:

$$(aa)_m = \sum_i\sum_j \left[x_i y_i\sqrt{a_i a_j a_i a_j}\left(1-k_{ij}\right)\right] \quad (10)$$

- **Step 4:** Determine the fugacity coefficient ϕ_i^L of the liquid phase [1]:

$$\ln\left(\phi_i^L\right) = \frac{b_i\left(Z_L-1\right)}{b_m} - \ln\left(Z^L-B\right) - \frac{A}{2\sqrt{2}B}\times\left[\frac{2\psi_i}{(a\alpha)_m} - \frac{b_i}{b_m}\right]\ln\left[\frac{Z^L+\left(1+\sqrt{2}\right)B}{Z^L-\left(1-\sqrt{2}\right)B}\right] \quad (11)$$

similar to step 3, there is the participation of ψ_i and $(aa)_m$ whose equation is exactly the same

- **Step 5:** Calculate the value of K_i^{s+1}

$$K_i^{s+1} = \frac{\phi_i^V}{\phi_i^L} \quad (12)$$

ϕ_i^L and ϕ_i^V are fugacity coefficients calculated in previous steps.

- **Step 6:** Check for convergence. If the error is not satisfied, then assign new value for K_i

$$\sum_{i=1}^n\left[\frac{K_i^{s+1}}{K_i^s-1}\right] \le \varepsilon;\ \varepsilon \approx 0.0001 \quad (13)$$

if the error is greater than (ε) then returning to Step 1, assigning new value for K_i. The iteration loop ends when (ε) is smaller than error tolerance $(10^{-4} \div 10^{-6})$.

Once the fluid phase behavior has been defined, the study continues with the multiphase flow calculation.

Multiphase Flow Modeling

This section presents the fundamental background for flow regime identification and pressure drop calculation in multiphase flow modeling.

Beggs & Brill (1973) developed a flow regime map to classify different types of flow regime based on the Froude number (N_{FR}) and the no-slip liquid fraction λ_{ns} [2]:

- No-slip factor, λ_{ns}:

$$\lambda_{ns} = \frac{v_{sl}}{v_{sl}+v_{sg}} \quad (14)$$

where: v_{sl} superficial velocity of the liquid phase (ft/s) và v_{sg} superficial velocity of the vapor phase (ft/s)

- **Froude number, N_{FR}:** is defined as the boundaries for different flow regimes which is calculated as:

$$N_{FR(1)} = Fr_1 = 316\lambda_{ns}^{0.302} \quad (15)$$

$$N_{FR(2)} = Fr_2 = 0.0009252\lambda_{ns}^{-2.4684} \quad (16)$$

$$N_{FR(3)} = Fr_3 = 0.1\lambda_{ns}^{-1.4516} \quad (17)$$

$$N_{FR(4)} = Fr_4 = 0.5\lambda_{ns}^{-6.738} \quad (18)$$

Besides, the Froude coefficient of the mixture is defined by the following formula:

$$Fr_M = \frac{v_M^2}{gD} \quad (19)$$

where: g is the gravitational acceleration (ft/s^2), D is the inner diameter of the pipeline (in).

Base on the 4 value of Froude $(FR_{1\to4})$, there are conditions which defines different flow regime:

- **Segregrated Flow**

$$\begin{aligned}&\lambda_{ns} < 0.01\ \&\ Fr_M < Fr_1\\ &or\ \lambda_{ns} \ge 0.01\ \&\ Fr_M < Fr_2\end{aligned} \quad (20)$$

- **Transient Flow:**

$$\lambda_{ns} \ge 0.01\ \&\ Fr_2 < Fr_M < Fr_3 \quad (21)$$

- **Intermittent Flow:**

$$\begin{aligned}&0.01 < \lambda_{ns} < 0.4\ \&\ Fr_3 < Fr_M < Fr_1\\ &or\ \lambda_{ns} \ge 0.4\ \&\ Fr_3 < Fr_M < Fr_4\end{aligned} \quad (22)$$

- **Distributed Flow:**

$$\begin{aligned}&0.4\lambda_{ns} < 0.4\ \&\ Fr_M > Fr_1\\ &or\ \lambda_{ns} \ge 0.4\ \&\ Fr_M > Fr_4\end{aligned} \quad (23)$$

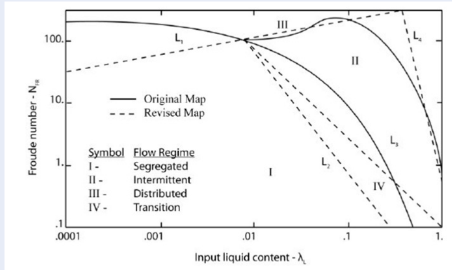

Figure 4: Flow Regime Map developed by Beggs & Brill (1973)[2].

Beggs & Brill (1973)[2] developed a flow regime map which has been discussed earlier which represents the relationship between Froude coefficient (N_{FR}) and No-slip liquid fraction, N_{FR} as shown in Figure 4.

Besides, Beggs and Brill also constructed the formula to define the pressure loss along the pipeline which consists of 3 main components: elevation, acceleration and friction loss[2]:

$$\frac{dP}{dL} = \frac{\rho_m g \sin\theta}{g_c} - \frac{f_m \rho_m v_m^2}{g_c} - \frac{\rho_m v_m d v_m}{g_c dL} \tag{24}$$

where: ρ_m is the fluid density (lb/ft^3), f_m friction factor (dimensionless), v_m is mixture velocity (ft/s), g_c gravitational constant 32.17 (lbm.ft/lbf.s^2), g gravitational acceleration (ft/s^2), θ is inclination.

For the thermal issues, the formula is studied by A.R. Hasan & C.S. Kabir, (1998)[9]:

$$Q = w_{C_p} L_R \left(T_{ei} - T_f\right) \tag{21}$$

where: Q heat (lost or gained) by the fluid in the pipeline, w_{C_p} mass flow based on the thermal conductivity C_p (lbm/s), T_{ei} = initial temperature of the fluid (^{o}F), T_f = formation temperature (^{o}F). L_R is Ramey coefficient:

$$L_R = \frac{2\pi}{wC_p}\left(\frac{rU_{k_e}}{k_e + rUT_D}\right) \tag{22}$$

where: k_e thermal conduction of the Earth (lbm.ft/s^3.^{o}F, =Earth), U_{k_e} = heat transfer coefficient of the Earth (lbm.ft/s^4.^{o}F), r = Earth radius, T_D dimensionless time coefficient:

$$T_D = \ln\left[e^{(-0.2t_D)} + (1.5 - 0.3719e^{t_D})\sqrt{t_D}\right] \tag{23}$$

where: t_D dimensionless time.

Flow assurance: Slug Characterization

In this research, the flow assurance study will highlight the slug characterization in the 68-m riser because this is the location where the slugging flow has the highest possibility of occurrence (due to the dramatic change of pipeline inclination)

Slug characterization concerns:

- Slug density
- Slug length
- Surge volume

Slug Density

By definition, the slug density is the value present the number of slugs appears in a specific unit length of the pipeline.

C. Lawrence et al (2013)[4] worked for SPT Group at Norway who studied the experimental recording to develop the equation to define the slug density basing on the instability of the flow current.

$$\frac{\partial N}{\partial t} + \frac{\partial}{\partial x}(NU_A) = B - D \tag{25}$$

where: N is number of slug appears in one specific unit length of the pipeline (1/m), U_A is the velocity of the slug liquid, B is slug birthrate, (1/m/s), D is slug death rate (1/m/s).

To define the slug birthrate (B) as mentioned above. The authors[4] defined the B basing on the difference between the velocity of the slug front and slug tail, as described followingly:

$$B = k_B (N_P - N) \frac{V^F - V^T}{10D} \tag{26}$$

where k_B is a constant, most of the time, it has the value of 1.0, N_P is the density of slug appearance on a unit length which is measured earlier (1/m), D is the inner diameter of the pipeline (m).

Other parameter presents the development as well as the appearance of the slug V^F: is front velocity of the candidate slug, similarly, V^T is a tail velocity of the candidate slug

V^F and V^T is classified:

if $V^F - V^T < 0$ means the slugs quickly die.

if $V^F - V^T > 0$ means the slugs are formed.

Slug Length

As for the length of the slugs, the author Cook & Masud Behnia (1999)[5] carried out the experiment to measure the length of the slug basing the number of the slugs in the pipeline, presents the relationship between the velocity of the bubble flow and the slug tail velocity, as described followingly:

$$\frac{V_B}{V_T} = 1 + 0.56exp\left(-0.46\frac{L_S}{D}\right) \quad (27)$$

where: D is the inner diameter (mm) L_S slug length (the same unit as the inner diameter), V_B is the bubble phase velocity of the flow (m/s), V_T is the velocity of the slug tail (m/s).

Surge Volume

With many years of experience in their researches, M. Miyoshi, D.R. Doty, Z. Schmidt (1988) [6] observed the changes in the volume of the separator with respect to time as shown in Figure 5.

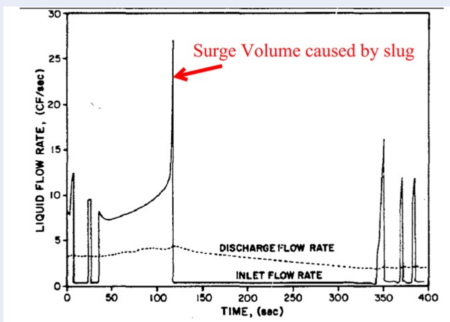

Figure 5: The unexpected increase in the volume is recorded during a short period of time on the CPP [6]

Based on the observed data in Figure 5, the authors developed a formula for surge volume as follow:

$$V_{surge} = \left[\left(u_L + u_g\right)\lambda_{ns} - u_L\right] A_p t_L \quad (28)$$

where: V_{surge} is the surge volume caused by the slugging flow (m^3), u_L is the liquid phase velocity (m/s), u_g gas phase velocity (m/s), λ_{ns} no-slip liquid fraction, A_p is cross-section area of the pipeline (m^2), t_L is the time of interest (s).

RESULTS & DISCUSSIONS

In this section, the method described in the Methodology section is applied to the problem defined in the Introduction section. The results from phase behavior fluid and multiphase flow modeling are the basics for characterization of slugs in the riser.
The input data for this work is summarized in Table 1. In this work, OLGA software is used to model the gathering pipeline system from WHP-X to CPP-Y. As can be seen in Figure 6, the four production wells 1P, 2P, 3P, 4P are connected to the WHP-X from which the multiphase produced mixture is transported to the CPP-Y via the 25-km subsea pipeline and the 68-m riser.

Table 1: Compositional data of fluid in WHP X

Component	Mol (%)	Mol Weight	Liquid density (g/cm^3)
N_2	0.111	28.014	
CO_2	0.03	44.010	
C_1	60.15	16.043	
C_2	9.820	30.070	
C_3	5.750	44.097	
iC_4	1.240	58.124	
nC_4	2.200	58.124	
iC_5	0.830	72.151	
nC_5	0.980	72.151	
C_6	1.130	86.178	0.6640
C_7	1.870	96.000	0.7380
C_8	2.460	107.00	0.7650
C_9	2.120	121.00	0.7810
C_{10}	1.330	134.00	0.7920

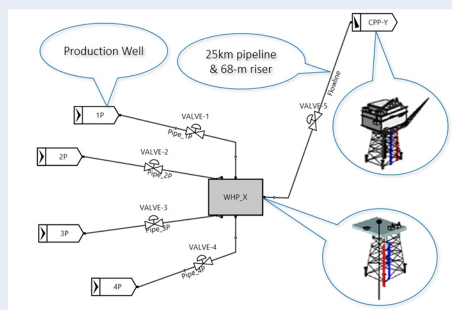

Figure 6: OLGA computational model for the gathering pipeline system from WHP-X to CPP-Y via the 25-km subsea pipeline and 68-m riser

Results of Phase Behavior Fluid Modeling

By applying the equation of state of Peng & Robinson, the basic properties are simulated of the fluid in the pipelines:

- Oil density (p_o)
- Gas fraction of the mixture (y_i)

According to the results of Figure 7 and Figure 8, out studied fluid is most likely to light oil with $\rho \approx 720$ to

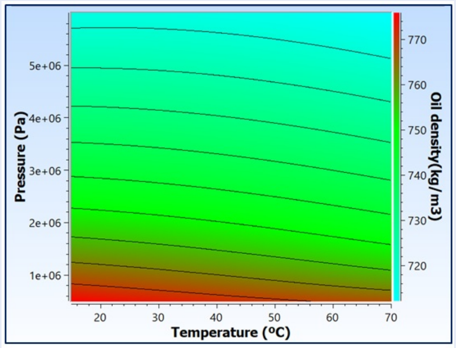

Figure 7: Oil density values generated by Peng & Robinson (1976) EoS

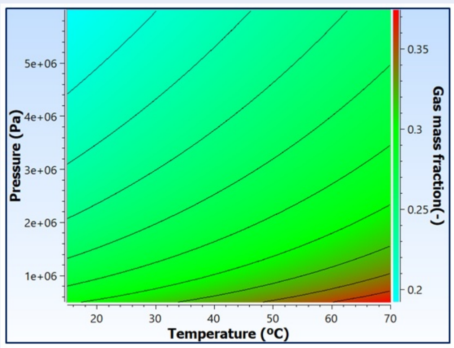

Figure 8: Gas fraction (of the mixture) values generated by Peng & Robinson (1976) EoS

760 (kg/m^3) and the gas content (y_i) takes over significantly the mixture with the value around $\approx 30\%$.

Results of Multiphase Flow Modeling

By applying the Beggs & Brill method[2], the flow regime inside the riser can be identified as shown in Figure 9:

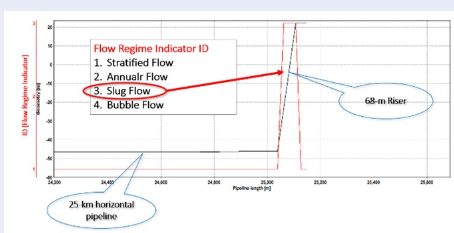

Figure 9: Results of the simulation for the flow regime in the pipeline of the studied subject.

As can be seen in Figure 9, the flow is stable (stratified) in the 25-km horizontal pipeline. However, in the 68-m riser there is serious issue which is the slugging flow due to the rapid change in inclination.

Besides, the simulation results also give the pressure profile of the pressure:

The result in Figure 10 shows that the average pressure at the CPP is about 560 (psi) and the average temperature is 46 (degC). This result agrees very well with that from the research of[8]. This means the model reflects quite accurately the studied subject in real life and the generated outcomes are reliable.

Results of Slug Characterization

From the multiphase flow modeling result in the previous section, it is obvious that there is a serious issue of slugging flow in the 68-m riser. The slug characterization has been performed in this work to estimate the slug properties as shown in Figure 11:

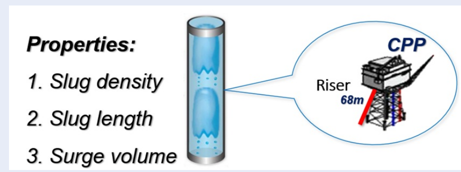

Figure 11: Slug characterization for the 68-m riser is to estimate the main properties of slugs such as slug density, slug length and surge volume.

Slug Frequency

Applying the method discussed in the Methodology - Slug Density subsection to define the slug density for the slugging flow at the 68-m riser, the simulation result is shown below:

According to the Figure 12, the average number of the slug is about 22 (slugs) per every 1.5 (h) interval. The highest number slug recorded can climb up to 30 (slugs) in just half an hour.

Slug Length

Applying the method of Cook & Masud[5], the simulation result is presented below:

According to the Figure 13, the slug length has the average length of about 22 (dm), about 10 times greater than the pipe inner diameter $D = 0.2371$ (m). This result agrees quite well with the experimental recorded measurement of Cook & Masud, 1999[5].

Surge Volume

The final studied property is the surge volume caused by the liquid slug. This is an important for the engineer to design the separator (sizing) which can with-

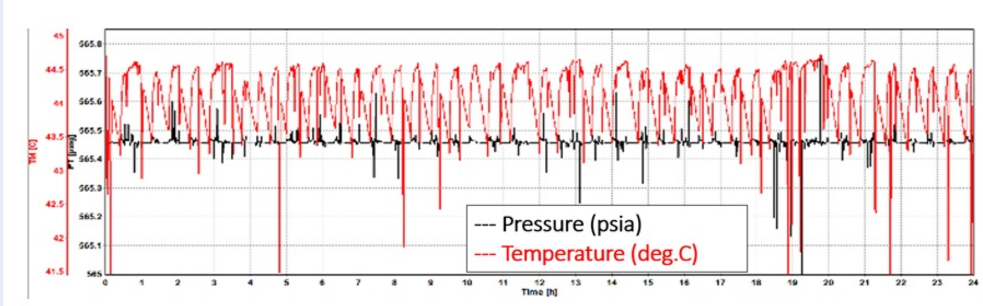

Figure 10: Simulation result for the pressure and temperature with respect to time (24h) at the entry of the separator on the CPP in oil field Y

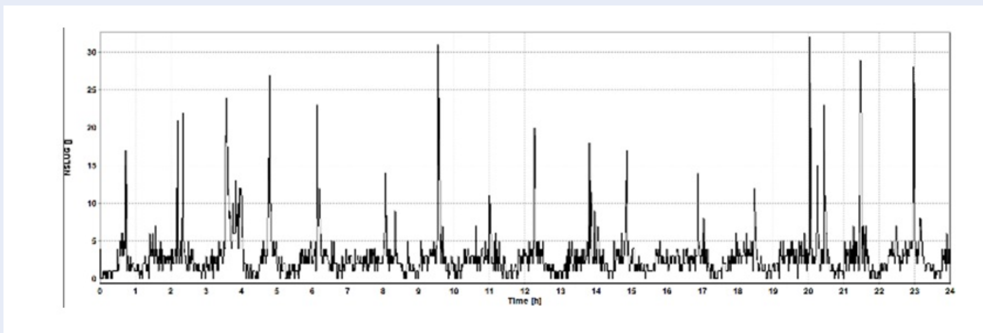

Figure 12: Simulation results of the number of the slugs in 24(h).

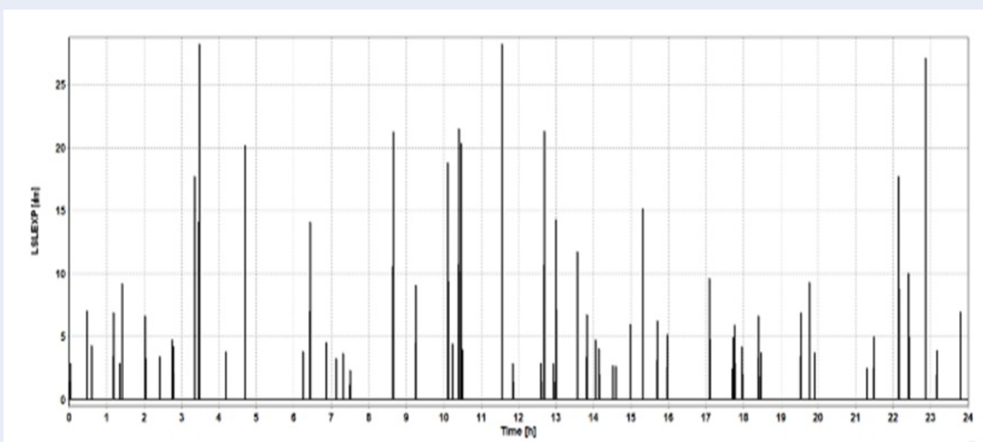

Figure 13: Result of slug length simulation with respect to time (24h)

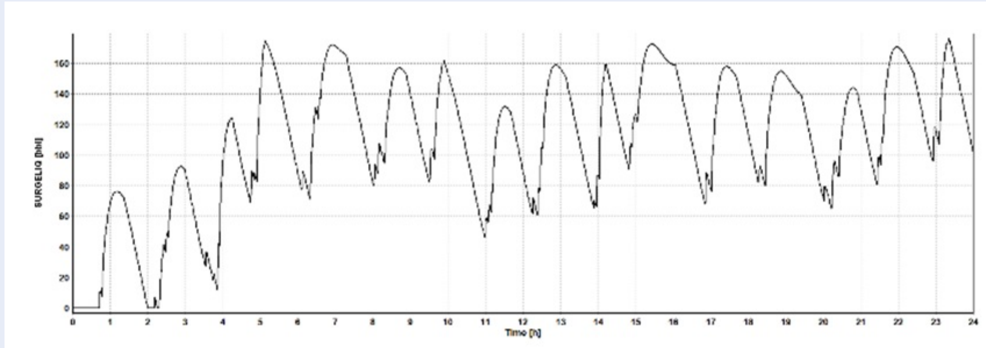

Figure 14: Simulation results for the slug surge volume with respect to time (24h)

stand the unexpected amount of slug liquid. The result is shown in Figure 14 below:

The result of Figure 14 implies the surge volume of at the entry of the CPP of the oilfield Y increases with respect to time which is alarming, moreover, the average value is about 25 (m^3) or 158 (bbl). This result is essential for the engineers concerning the slug-catcher designing or separator sizing as every 1.5 (h), the entry of the CPP loses 158 (bbl) of oil. As for the designing aspect, the volume of slug catcher must be greater than the value of V_{surge} to combat with the unexpected increase volume of liquid caused by the slugging flow at the CPP.

CONCLUSION

This paper reports our recent flow assurance study for the pipeline system from the wellhead platform X to the central processing platform (CPP) of the oilfield Y. The main focus in this work is to characterise slug flow that may exist inside the riser pipe segment at the entrance of the CPP. A multphase flow model and slug-tracking model have been constructed for the prediction of slug flow characteristics such as slug frequency and surge volume.

The results from this work show that the slugg flow issues inside the riser would be serious as it can cause lots of damage on the surface facility especially the separator in the central processing platform. This is also the concern for separator sizing the capacity to withstand the value of the surge volume, about 158 (bbl) with approximately 22 slug of 2-m length coming at the separator inlet after every 1.5 hours.

ACKNOWLEDGEMENT

The authors highly appreciate all supports from Ho Chi Minh City University of Technology – Vietnam National University HCM. Special thanks also go to Schlumberger company for their support on OLGA software usage for Nguyen Hoai Tan during his internship at Schlumberger Information Solutions (SIS) Vietnam.

ABBREVIATIONS

CPP: Central Processing Platform

BIC: Binary Interaction Coefficient

EoS: Equation of State

OLGA: a dynamic multiphase flow simulation software developed by Schlumberger.

WHP: Wellhead Platform

NOMENCLATURE

K_i = phase equilibrium ratio between vapor and liquid phase (dimensionless)

k_{ij} = binary interaction coefficient of the component i and j, (dimensionless)

p_c = critical pressure, psia

T_c = critical temperature, ^{o}F

x_i = mole fraction of component i of the mixture, (%)

y_i = mole fraction of component i of the mixture, (%)

V_{surge} = surge volume, (m^3 or bbl)

ϕ_i^L = fugacity coefficient of component i in liquid phase, (dimensionless)

ϕ_i^V = fugacity coefficient of component i in vapor phase, (dimensionless)

Z_i^L compressibility of component i in liquid phase, (dimensionless)

Z_i^V = compressibility of component i in vapor phase, (dimensionless)

BENEFIT CONFLICTS

The authors claim that there is no conflict in this publication of the research paper.

AUTHOR CONTRIBUTION

Dr. Mai Cao Lân: Academic advisor, reviewing the results and revising the paper.
Nguyen Hoai Tan: Performing the scientific research and writing the paper.

APPENDIX A

Results from Fluid Behavior Modeling

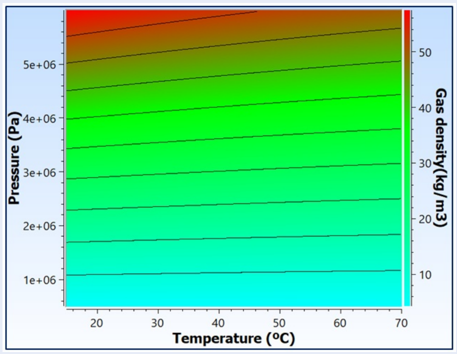

Figure 15: Gas density of the mixture with respect to pressure and temperature calculated using Peng & Robinson (1976) [1] equation of state

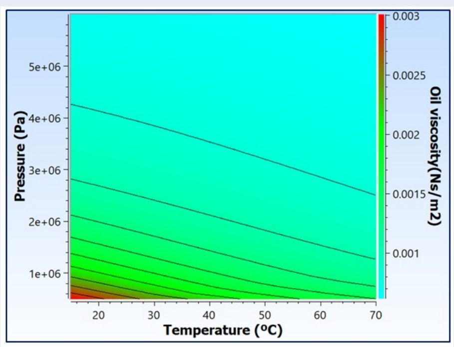

Figure 16: Oil viscosity of the mixture with respect to pressure and temperature calculated using Peng & Robinson (1976) [1] equation of state

APPENDIX B

Results from Multiphase Flow Modeling

REFERENCES

1. Peng DY, Robinson DB. A new two-constant equation of state. Canada. 1976;Available from: https://doi.org/10.1021/i160057a011.
2. Brill B. Multiphase Flow Production Model. Texas, USA. 1973;.
3. Markit IH. Pressure Loss Calculation. 2016;.
4. Lawrence C. Mechanistic models for three-phase stratified and slug flows with dispersions. SPT Group, Norway. 2013;.
5. Cook MB. Slug Length Prediction in the gas-liquid Intermittent Flow. Sydney, Australia. , . 1999;Available from: https://doi.org/10.1016/S0009-2509(99)00485-6.
6. Miyoshi M, et al. Slug-catcher Design for Dynamic Slugging in an Offshore Prodcution Facility. University of Tulsa, USA. 1988;Available from: https://doi.org/10.2118/14124-PA.
7. Đỗ Xuân H. Tối Ưu Hoá Quá Trình Vận Chuyển Dầu Khí Từ Mỏ Cá Ngừ Vàng Đến Giàn Công Nghệ Trung Tâm số 3 Mỏ Bạch Hổ. 2008;.
8. Phạm-Sơn T, Lân MC. Multiphase Flow Assurance in Subsea Pipeline from Ca Ngu Vang oilfield to Central Processing Platform 3 of Bach Ho oilfiled. 2014;Available from: https://doi.org/10.32508/stdj.v17i3.1487.
9. Hasan AR, Kabir CS. Wellbore Two-phase Flow and Heat Transfer During Transient Testing. SPE (Society of Petroleum Engineers). 1998;Available from: https://doi.org/10.2118/38946-PA.

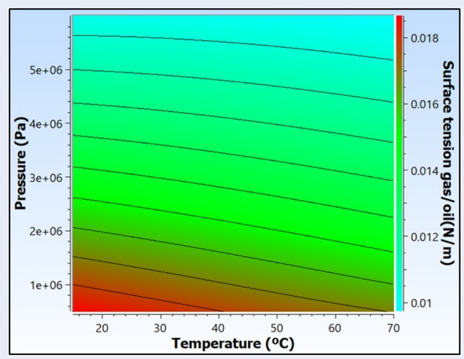

Figure 17: Surface tension gas/oil of the mixture with respect to pressure and temperature calculated using Peng & Robinson (1976) [1] equation of state

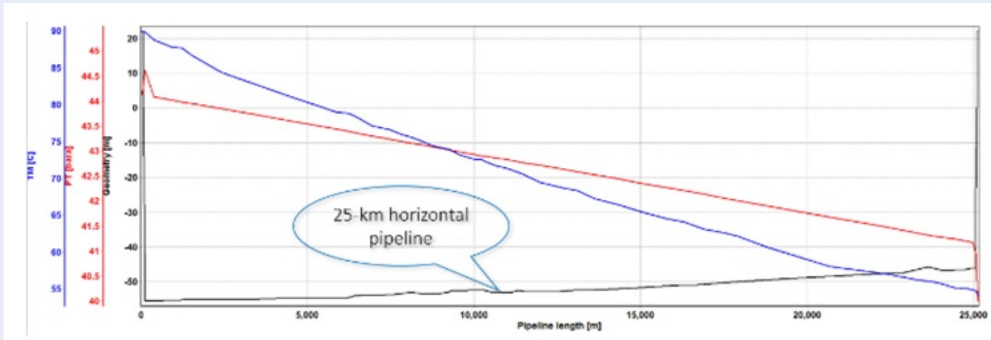

Figure 18: Pressure and temperature profile of the 25-km horizontal pipeline

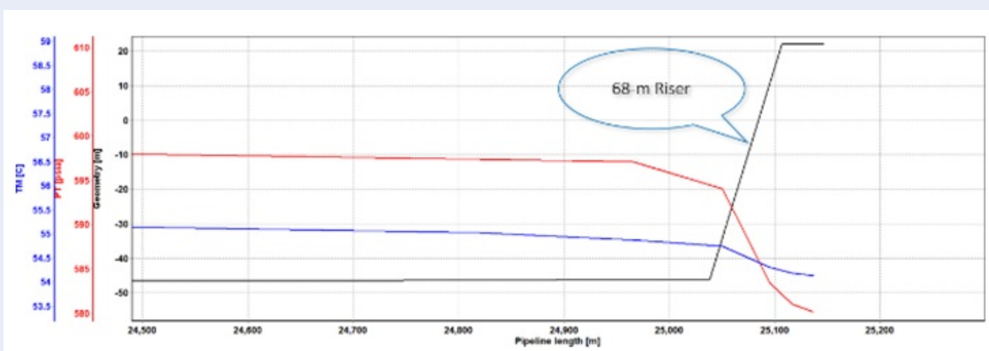

Figure 19: Pressure and temperature profile of the 68-m riser

Tạp chí Phát triển Khoa học và Công nghệ – Engineering and Technology, 4(SI3):SI84-SI95

Open Access Full Text Article

Bài nghiên cứu

Mô hình hóa dòng chảy đa pha trong đường ống thu gom dầu khí từ giàn đầu giếng thuộc mỏ X đến giàn xử lý trung tâm mỏ Y

Nguyễn Hoài Tân[1,2], Mai Cao Lân[1,3,*]

TÓM TẮT

Mục tiêu chính của nghiên cứu này là khảo sát đặc trưng của dòng chảy nút lỏng trong đoạn ống nâng thẳng đứng 68 m từ đáy biển lên giàn xử lý trung tâm (CPP) của mỏ Y. Dòng hỗn hợp dầu khí chảy vào đoạn ống riser này đến từ giàn đầu giếng (WHP) của mỏ X thông qua đường ống ngang dài 25-km dưới đáy biển.

Trong nghiên cứu này, hướng tiếp cận mô hình hóa tích hợp được sử dụng để xem xét các hiện tượng vật lý chính yếu gắn liền với dòng chảy đa pha trong hệ thống thu gom có thể gây ảnh hưởng lớn đến các đặc trưng của dòng chảy nút lỏng. Mô hình ứng xử pha của dầu khí trong đường ống thu gom được xây dựng trước tiên trên cơ sở của phương trình trạng thái Peng-Robinson nhằm xác định trạng thái cân bằng pha và ước lượng các thuộc tính của hỗn hợp dầu khí ở những điều kiện áp suất và nhiệt độ khác nhau. Dòng chảy đa pha sau đó được mô hình hóa bằng phương pháp Beggs & Brill để xác định sụt áp của dòng chảy và phương pháp Hasan & Kabir để xác định phân bố nhiệt độ dọc theo đường ống. Cụ thể là các tính toán sụt áp được thực hiện dựa trên các tương quan thực nghiệm theo đó các chế độ dòng chảy có thể được nhận dạng và sự sụt áp được tính tương ứng với từng chế độ dòng chảy. Ngược lại, các tính toán truyền nhiệt được dựa vào hướng mô hình hóa cơ học theo đó phân bố nhiệt dọc theo đường ống có thể được ước lượng. Sau cùng, mô hình truy vết nút lỏng được xây dựng để xác định đặc trưng dòng chảy nút lỏng với những thuộc tính cơ bản như tần số xuất hiện các nút lỏng, chiều dài và thể tích của các nút lỏng. Mô hình này giúp nhận biết sự hiện diện của dòng chảy nút lỏng bên trong đoạn ống nâng để dự đoán hậu quả mà nó có thể gây ra cho các thiết bị bề mặt

Kết quả nghiên cứu cho thấy hướng tiếp cận tích hợp là phù hợp với bản chất đa vật lý của bài toán đảm bảo dòng chảy đang xét. Dòng chảy nút lỏng có thể xuất hiện bên trong đoạn ống nâng 68 m với hơn 20 nút lỏng dài 2m xuất hiện sau mỗi 1.5 giờ.

Từ khoá: Mô hình hóa ứng xử của chất lưu, mô hình hoá dòng chảy đa pha, đặc trưng hóa dòng chảy nút lỏng, đảm bảo dòng chảy

[1]*Khoa Kỹ thuật Địa chất & Dầu khí, Trường Đại học Bách Khoa Tp.HCM (HCMUT), Việt Nam*

[2]*Sinh viên năm 4, Văn phòng Đào tạo Quốc tế (OISP), Trường Đại học Bách Khoa Tp.HCM (HCMUT), Việt Nam*

[3]*Đại học Quốc Gia Tp.HCM, Việt Nam*

Liên hệ

Mai Cao Lân, Khoa Kỹ thuật Địa chất & Dầu khí, Trường Đại học Bách Khoa Tp.HCM (HCMUT), Việt Nam

Đại học Quốc Gia Tp.HCM, Việt Nam

Email: maicaolan@hcmut.edu.vn

Lịch sử

- Ngày nhận: 16/5/2021
- Ngày chấp nhận: 23/9/2021
- Ngày đăng: 04/11/2021

DOI : 10.32508/stdjet.v4iSI3.841

Trích dẫn bài báo này: Tân N H, Lân M C. **Mô hình hóa dòng chảy đa pha trong đường ống thu gom dầu khí từ giàn đầu giếng thuộc mỏ X đến giàn xử lý trung tâm mỏ Y**. *Sci. Tech. Dev. J. - Eng. Tech.;* 4(SI3):SI84-SI95.