The 2013 World Congress on
Advances in Structural Engineering and Mechanics (ASEM13)
Jeju, Korea, September 8-12, 2013

Effects of flow behavior on the design of transient operation scenarios

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ABSTRACT

Transient multiphase flow modeling is used in many different ways to make oil and gas production scenarios feasible and reliable. Consequently, it is important to understand the transient multiphase flow modeling for the engineers. This paper covers three transient operational modes based on the information of well fluid compositions and field architectures using multiphase flow modeling simulation tool. First of all, temperature profile in the pipeline during shutdown and hydrate formation temperature will be compared to calculate appropriate insulation thickness for the pipeline. Secondly, a liquid surge volume from the topsides will be calculated to determine proper drainage rate of separator. During production ramp-up, the flow regime in the pipeline will be studied and the liquid surge volume from the topsides will be also calculated to decide appropriate drainage rate of separator.

1. INTRODUCTION

The challenges associated with multiphase flow are as old as the oil business itself. The natural flow from most wells consists of some mixture of oil, gas, and water. Multiphase flow modeling is not uniform, even hard to predict exactly. But various task like line sizing, safety system analysis, slug catcher sizing, corrosion-inhibitor transport, hydrate and paraffin control and pipeline stress analysis is performed based on the multiphase flow modeling. (Dale 1999)
Most of the accidents in the offshore plant are occurred in the process changed from steady state to transient operation, and vice versa. In these transient processes, lots of design parameters are determined based on the multiphase flow modeling. Thus, an accurate understanding of transient multiphase flow modeling is required. In this paper, the important design parameters during the transient operational mode are studied using the multiphase flow modeling tool. (Djamel 2013)

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2. SYSTEM DESCRIPTIONS

Well fluid compositions and the information about field architectures are needed to use multiphase flow modeling simulation tool. First of all, well fluid compositions as shown in Table 1.

Table 1. Well fluid compositions

Component Name	Mole %
N2	0.03
CO2	1.23
C1	39.29
C2	7.65
C3	6.43
i-C4	2.14
n-C4	4.44
i-C5	1.99
n-C5	2.57
C6	4.35
C7	19.50
C8	3.62
C9+	6.76

The pipeline has a diameter of 0.12m and the innermost layer is the 9mm steel layer while the insulation layer is 25mm thick. The internal diameter of riser is 0.1m and a steel wall thickness is 7.5mm with no insulation. All pipe roughness is assumed to be 0.028mm. The diameter of wellbore is 0.101m with a 6.88mm steel wall and 600mm formation rock layer which roughness is 0.025mm. The property for the pipeline, riser and wellbore are shown in Table 2.

Table 2. Material property for pipeline, riser and wellbore

Material	Density [kg/m3]	Specific Heat [J/kg/K]	Thermal Conductivity [W/m/K]
Steel	7850	500	50
Insulation	1000	1500	0.135
Formation rock	2243	1256	1.59

The ambient temperature can be assumed to be 6℃ in the water. The heat transfer coefficient for the pipeline is 6.5 W/m^2/℃. Geothermal profile is used as an ambient temperature for the wellbore. It will be linear from 70℃ to 6℃. The overall profile according to the above information is shown in Figure 1.

Finally, boundary conditions should be decided to simulate transient operational mode. The reservoir pressure is 180 bara and the reservoir temperature is 70℃. The separator pressure is 50 bara. The minimum required arrival temperature is 27℃ to avoid wax formation.

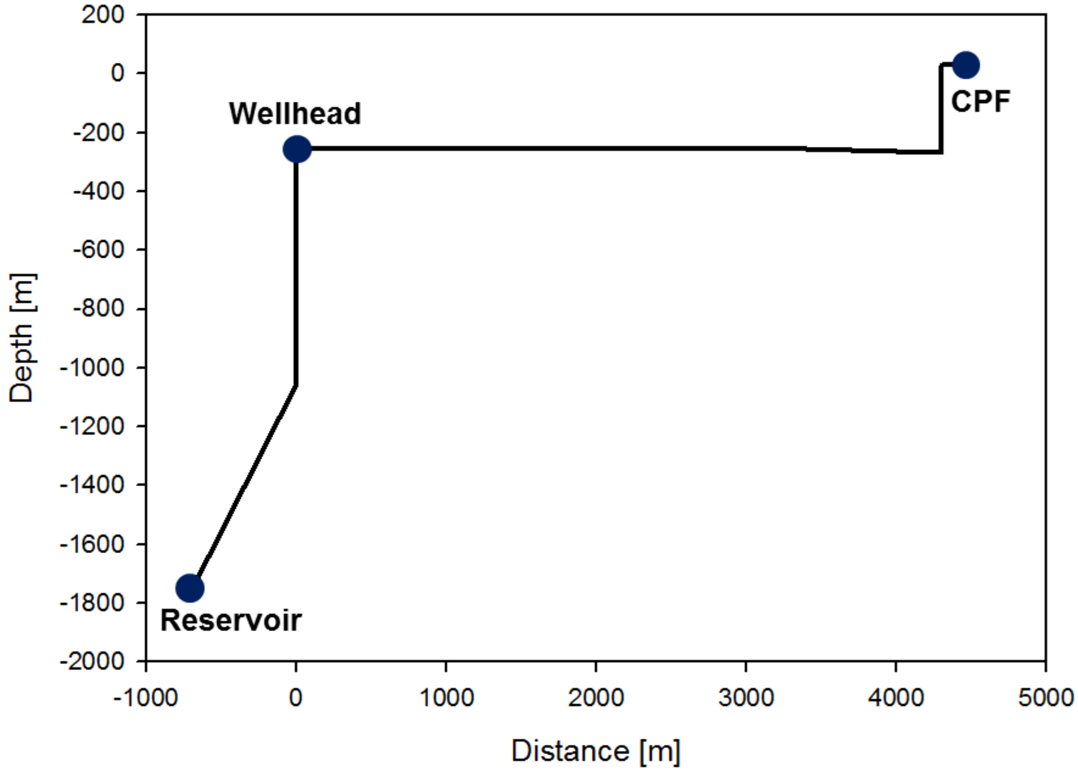

Figure 1. Overall layout

3. SIMULATIONS

There are several transient operational modes. Among them, only three modes will be covered in this paper. To simulate the transient operational modes, two valves are needed. One is a wellhead valve. It is located near the wellhead. The role of the wellhead valve is to control the flow of well fluids during the production. The diameter of wellhead valve can be assumed to be 0.0.89m. The other is a choke valve on the platform. Choke valves are subjected to typically extreme conditions which can cause erosion, corrosion and other damage. This can include high fluid velocity, slugging, sand production and multiphase of oil, gases and water. Also, choke valve has to have a very high turndown capability as it has to cover a wide range of flow rates. The diameter of choke valve in the platform can be assumed to be 0.1m.

3.1 Shutdown

Shutdown is classified into planned shutdowns and unplanned shutdowns from a steady state and unplanned shutdown during warm-up.

After shutdown, the flowline temperature is decreased due to the heat transfer from the surrounding water. The insulation of the flowline should be designed to keep the temperature of fluids above the hydrate formation temperature until the “no-touch time” has passed.

When considering minimum cool-down times, the “no-touch time” is the one in which operator can correct problems without having to take any action to protect the subsea system from hydrates. Operators always want a longer no-touch time, but it is a cost and benefit balancing problem and is decided on a project-by-project basis. Analyses of platform operation experience in West Africa indicate that many typical process and instrumentation interruptions can be analyzed and correct in 6 to 8 hours. (Bai 2010)

In this simulation, shutdown period will be 8 hours. First, it will be 2 hours at steady state conditions, followed by an 8 hour shutdown. To compare the temperature of fluids and the hydrate formation temperature, hydrate curve are shown in Table 3.

Table 3. Hydrate curve data

Temperature [℃]	Hydrate pressure [bara]
-20	2.1
-15	2.7
-10	3.4
-5	4.2
0	5.3
5	11.4
10	23.3
15	48.6
18	78.2
20	138.9
21.1	200.0

3.2 Start-up

Slug will form in the start-up operation process due to the transformation from a steady state to a transient process. Start-up process will be simulated using the results of the above shutdown process. Start-up simulation period will be 4 hours. It is a reasonable time period to minimize the peak liquid flow rate (liquid surge) at the outlet.

3.3 Ramp-up

Ramp-up slugs are especially important for gas and condensate systems because the increased flow rate can sweep out large volume of liquid. Consequently, it affects the design of slug catcher. Therefore simulation of flow rate ramps should be performed from turndown rates to intermediate and full production rates over the life of the field. In this simulation, mass flow will be controlled from 5 kg/s to 15 kg/s over time. Simulation is started with 5 kg/s, then after 1 hour mass flow will be changed to 15 kg/s to cause production ramp-up.

4. RESULTS AND DISCUSSIONS

4.1 Shutdown

After shutdown, the flowline temperature is decreased due to the heat transfer from the surrounding water as mentioned earlier. Figure 2 shows temperature behaviors during shutdown period. It is affected by the geometry of pipeline and riser.

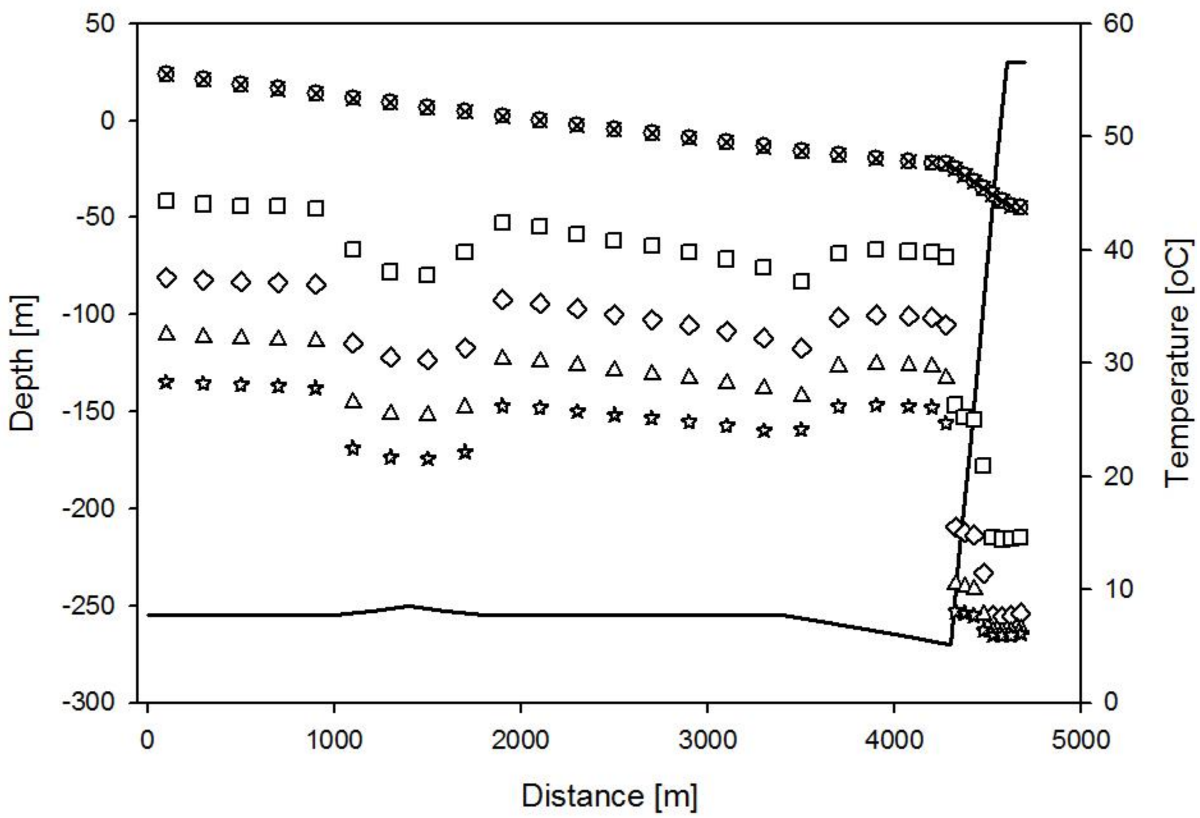

Figure 2. Temperature profile during shutdown period. The solid line means geometry

with pipeline and riser. (○: 0 hrs, X: 2 hrs, □: 4 hrs, ◇: 6 hrs, △: 8 hrs, ☆: 10 hrs)

In this simulation, the fluid temperature can be assumed to be at a minimum of 5℃ above hydrate formation temperature during an 8 hour shutdown period. To find appropriate insulation thickness, Figure 3 shows the temperature difference between fluids and hydrate formation data after 10 hours according to the insulation thickness. During shutdown process, a point after 10 hours from the beginning of the simulation is the most severe cases, so it will be a standard to decide the insulation thickness. To keep the design temperature, 55mm thickness of insulation can keep 5℃ above hydrate formation temperature from the fluids temperature.

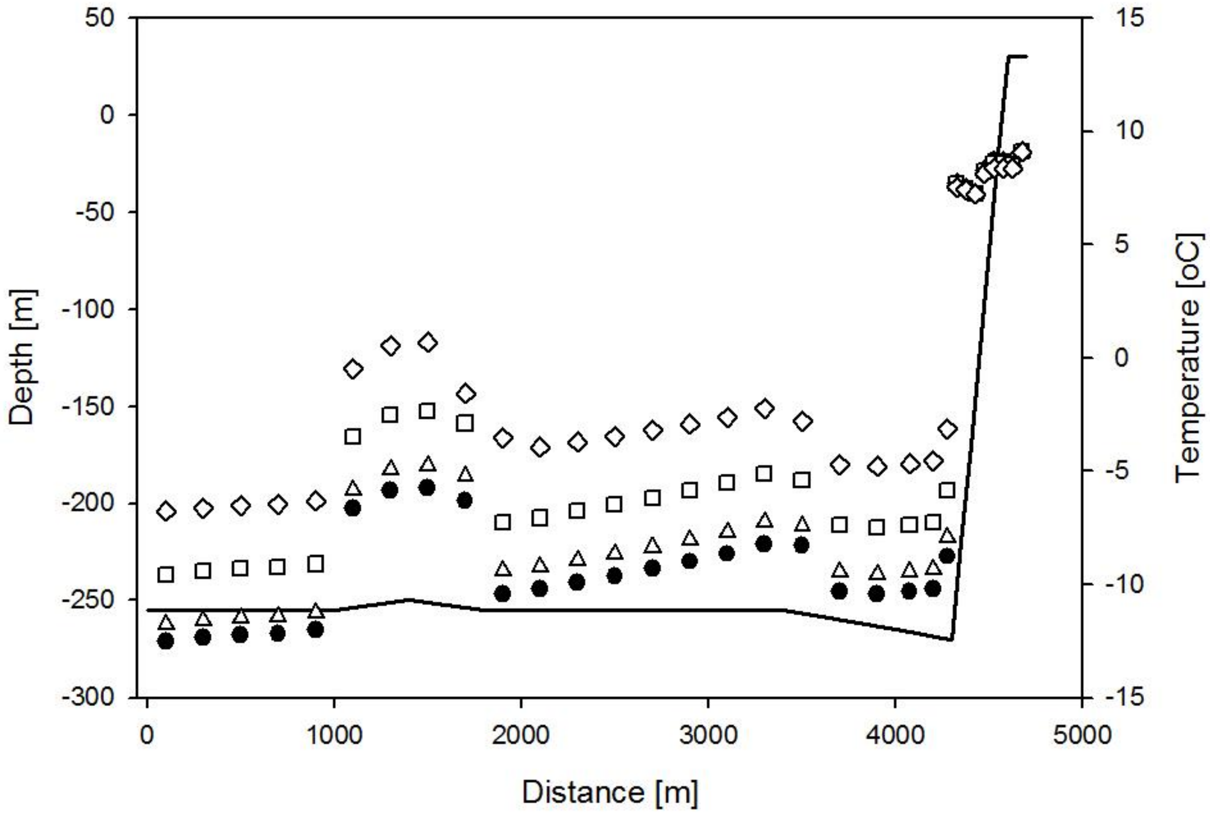

Figure 3. Temperature difference between fluids and hydrate formation data after 10 hrs. The solid line means geometry with pipeline and riser. (● is the case which insulation thickness is 55mm, △ means the case insulation thickness is 50mm, □ means 40mm, and ◇ means 30mm)

4.2 Start-up

First, it should be checked the flow regime in the pipeline. The flow regime in the wellbore immediately after the shutdown process is classified into three phase. It is started with stratified wavy flow from the reservoir. In the point which changes the slope, flow regime is changed to the dispersed bubble flow. Finally, it will be the annular flow near the wellhead. As time passes, it is started with stratified wavy flow and then changes to the dispersed bubble flow instantly. The flow regime in the pipeline is affected by the geometry of pipeline and riser. Stratified wavy flow and annular flow is generated alternately based on geometry. As time passes, hydrodynamic slugging is occurred.

During the shutdown period, liquid will be accumulated inside the pipe. These accumulated liquid will be pouring out to the separator on the topsides while the start-up process begin. If the separator is not designed considering the capacity of pipeline, flood will be occurred. To prevent these accidents, a drainage rate of separator should be designed to considering the capacity of pipeline. Figure 4 shows surge liquid volume of the separator according to the drainage rate. Solid line uses the default value, 1307.98m3/day as the maximum drainage rate. In this case, surge liquid volume in the separator will be increased as time passes. The risk of flood will be increased. Dashed line set the maximum drainage rate as 1334.53m3/day. This value is equal to the average steady state liquid production. In this case, as time passes surge liquid volume tends to decrease.

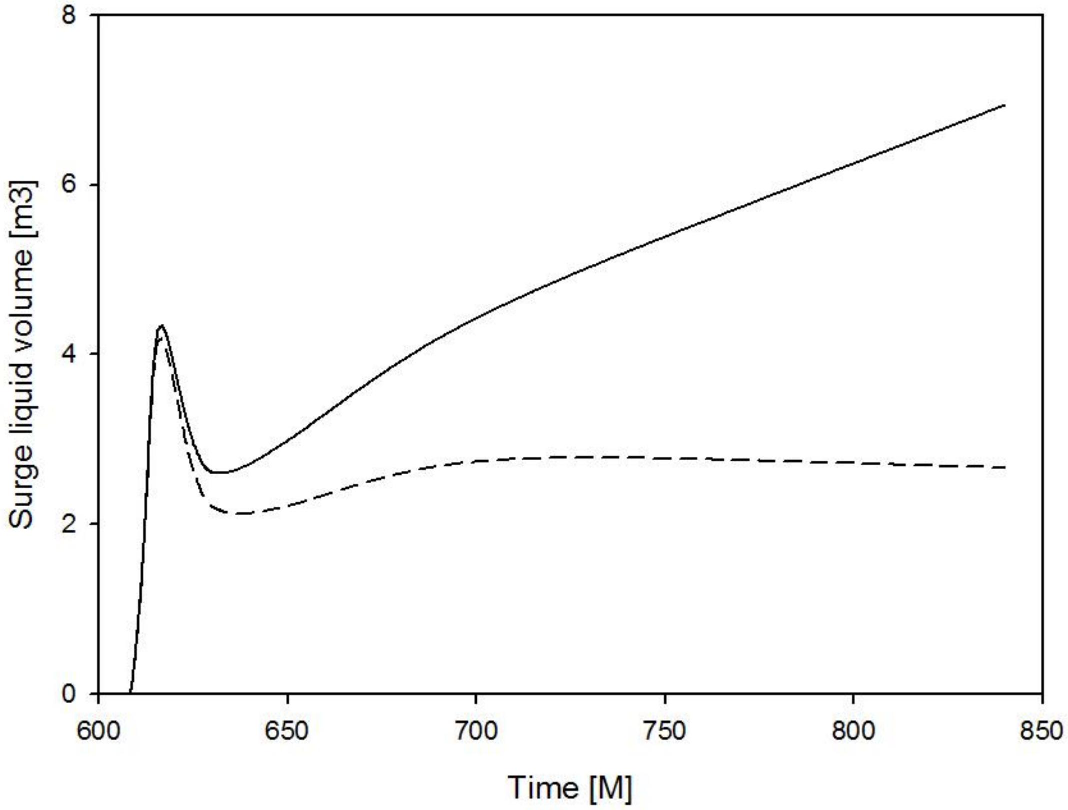

Figure 4. Surge liquid volume at the topsides separator during start-up process. The solid line is a case the drainage rate is $1307.98m^3$/day. The dashed line is a case the drainage rate is $1334.53m^3$/day.

4.3 Ramp-up

First, it should be also checked the flow regime in the pipeline. In the case of 5 kg/s, it is occurred stratified wavy flow and hydrodynamic slugging according to the geometry. Near the riser, dispersed bubble flow is occurred. After the mass flow is increased to 15 kg/s, hydrodynamic slugging is occurred in overall pipeline.

Surge liquid volume is increased because the inlet mass flow is increased. To reduce the possibility of accidents, maximum drainage rate of separator is well-designed. Figure 5 shows surge liquid volume of the separator according to the drainage rate. Solid line is a case that maximum drainage rate is default value, 963.55 m3/day. In this case, surge liquid volume is increased rapidly. Dashed line is a case that maximum drainage rate is 1494.83 m3/day. This value is setting considering the maximum inlet mass flow. This value is appropriate to design separator.

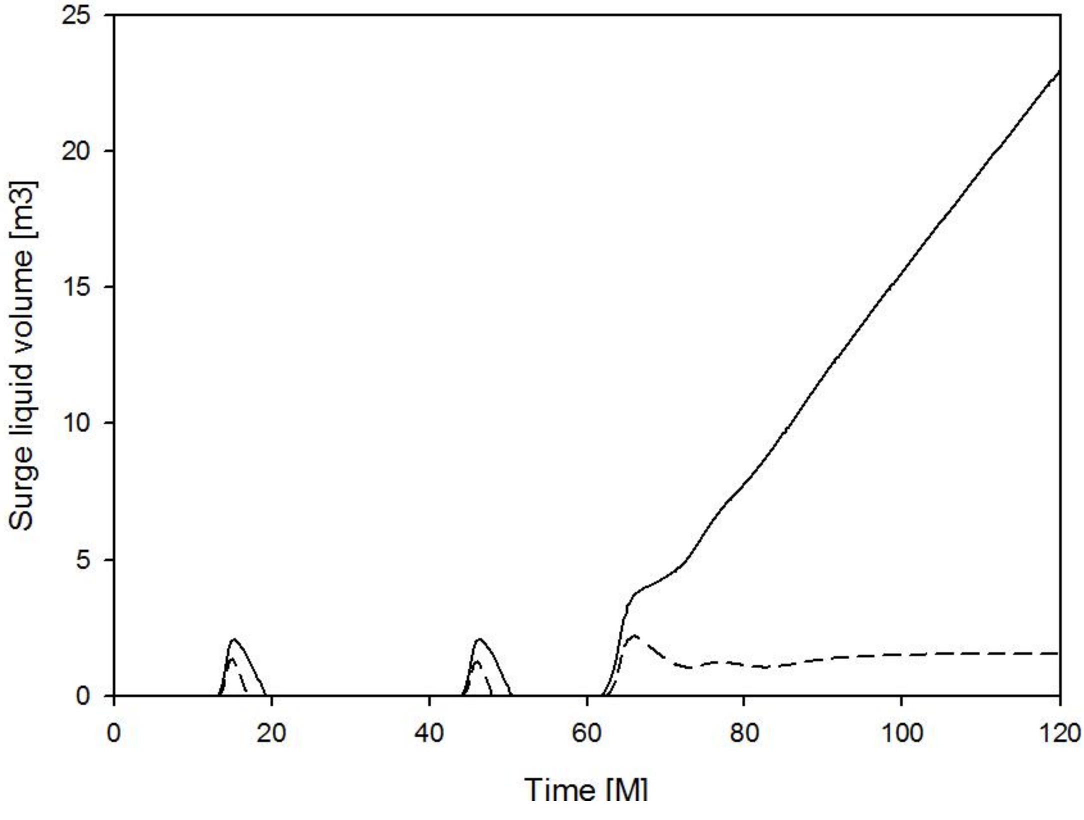

Figure 5. Surge liquid volume at the topsides separator during production ramp-up process. The solid line is a case the drainage rate is 963.55m^3/day. The dashed line is a case the drainage rate is 1494.831m^3/day.

5. CONCLUSIONS

This paper covers three transient operational modes. Several parameters are important to design proper equipment. During shutdown period, the fluids temperature is important parameter. It is decreased due to the heat transfer from the surrounding. To prevent hydrate formation, the insulation thickness is well-designed considering the temperature difference between the fluids temperature and the hydrate formation data. During start-up and ramp-up process, liquid surge volume is important parameter to design proper drainage rate of separator.

6. ACKNOWLEDGEMENT

This work was supported by Industrial Strategic Technology Development Program (Development of flow assurance and organic acid/calcium removal process for the production of offshore opportunity crude, 10045068) funded By the Ministry of Trade, industry & Energy (MI, Korea).

REFERENCES

Dale D. Erickson, Michael C. Mai. (1999), “Application of Transient-Multiaphse-Flow Technology”, *Journal of Petroleum Technology*, Society of Petroleum Engineers, **51**(4), 84-87.

Djamel Lakehal. (2013), “Advanced simulation of transient multiphase flow & flow assurance in the oil & gas industry”, *The Canadian Journal of Chemical Engineering*, Canadian Society for Chemical Engineering, **91**(7), 1201-1214.

Bai, Y. and Bai, Q. (2010), *Subsea Engineering Handbook*, Elsevier, Massachusetts, USA.