Simulation of Slug Flow Mitigation Techniques Using OLGA

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Abstract

The objective of this study is to gain insight into and eliminate slug flow behavior in pipeline systems using different techniques. Slug flow mitigation technique includes throttling and gas lift. OLGA simulator is used to simulate and mitigate slug flow in oil and gas pipelines for Libyan oil fields and others.

The selected case study was: "Bouri offshore field 12 inch trunk line". this system was simulated using OLGA software (version 7.0). The fluid properties were calculated using the PVTsim software (version 20), and typical transport system was analyzed according to the flow assurance guidelines. The simulation process included production

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instabilities and in the case instabilities exist, mitigation alternatives were checked until slug flow disappears.

According to the simulation applied on "Bouri Offshore Field" displays the profile of the flow system along pipeline in normal operation the flow instability. The simulation results show that topside choking with valve that is 12% opening eliminates slug flow upon arrival but flow is slug along the trunk line. For gas lift, flow rate of at least 5 mmscfd is needed to prevent the formation of slug flow at the reception facilities.

***Keywords**: eliminate slug, OLGA software, Bouri offshore*

1. Introduction:

Flow assurance aims to ensure the continued flow of oil and gas. To achieve this goal, flow assurance depends on an engineering analysis that ensures preventing instability of the flow in order to continue production at the required level. Although multi-phase flow occurs in many industrial processes, methods of transporting multi-phase fluids through pipelines and wells have progressed rapidly in recent decades. The behavior of multi-phase flow is more complex than single phase flow. With the complex nature of multi-phase flow, these conditions can often generate some flow phenomena, phenomenon can pose significant threat to oil and gas production facilities such as slug flow is the most undesirable flow system in multi-phase flow, due to the associated instability, that pose significant challenges to flow assurance in the oil and gas industry. Despite these challenges efforts are constantly being made to ensure maximum oil recovery.

Computer programs such as OLGA and HYSYS are poweful tool to evaluate flow parameters and study flow assurance. The Olga program was used to simulate a flow system. Olga is a multi-phase flow simulation program in pipelines with processing equipment included, determine fluid properties by PVTsim software. PVTsim is a versatile equation of state modeling software that allows the user to simulate fluid properties and experimental PVT data.

The objective of this study is to gain insight into and eliminate slug flow behavior in pipeline systems and conduct studies ensure flow for oil and gas pipelines from Libyan oil fields. Utilizing OLGA and PVTsim software.

2. Literature Review:

Petroleum is an important use, as petroleum is not only a raw material used for the production of fuel and oils, but also the basis for a large industry in many forms is the petrochemical industry, which produces a huge amount of precious materials.

The safe and economic transportation of oil produced by undersea pipelines requires methods to avoid any losses in offshore oil production. This has led to advances in multiphase transport technology.

Flow assurance is a term that refers to ensuring the successful and economical flow of liquid production from the reservoir to the production facility over the life of the field in any environment. That is, the transportation system must operate in a safe and reliable manner throughout the life of the field. And failure to do so has dire economic consequences, Flow assurance is closely related to multi-stage flow systems. flow assurance is the most critical task during production due to long distances, high pressures and low temperatures that causes financial losses based on production interruption and damage in pipeline due to solid deposits.

Flow assurance is used to assess the effects problems of oil and gas transmission lines such as severe stagnation, hydrates, wax, asphalt, corrosion, scales, emulsions and their ability to disrupt production in the multi-stage flow system. [1].

Slug Flow: It is a flow picture that occurs when the combined transport of hydrocarbon liquids and gases, It is characterized by a series of liquid plugs (slugs) separated by relatively large gas pockets, Gas and liquid flow into pipelines where bubbles accumulate and grow in size so that they are close to the diameter of the pipe in which they travel, then go in batches. These slugs may also be in the form of a surge wave that exists upon a thick film of liquid on the bottom of the pipe. Severe slugging is a phenomenon occuring in two-phase flow through a downward inclined flow line followed by a vertical riser at low gas flow rates. This can cause severe problems in downstream reception facilities such as spills and poor performance in separation units and control instability, when severe slug flow occurs, vibrations of piping is likely to occur.

In multi-phase flow systems, flow patterns depend on properties gas and liquid in the flow line, the most important of which is slug flow.

Some of the flow patterns that occur in the horizontal pipelines, and the flow patterns in the vertical pipelins are shown in figure (1) [2, 3].

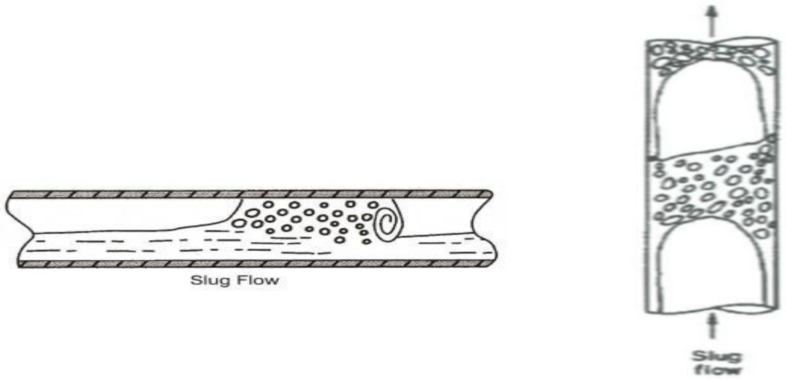

Figure (1): Flow patterns in a horizontal[2]. and in a vertical pipeline [3].

3. Methodology:

In the multi-phase flow. slug flow can be caused by any of the following[4]:

1. Hydrodynamic slugs.
2. Terrain-induced slugging.
3. Riser slugging.
4. Operational-based slugging.
5. Casing heading slugs in gas-lifted wells.
6. Density-wave slugs in long risers and wells.

To avoid severe slugging obstacles that occur in reception facilities and vibrations occurring in the pipeline should eliminate these slugs located at the bottom of the riser that increase as the length of the riser increases, also slugs located on along the length of the tube, these solutions are shown below:

1) **Gas Lift:** Inject gas at the base of the riser, which will lighten the fluid column and minimize vertical pressure losses. Injection of a specified rate of gas into the production flow line or riser base at the sea floor it is by the compressed gas in the pipeline, upstream of the riser base is separated and re-injected into the riser. Gas injection ensures flow stability and enhances production. It is not being economically feasible due to the cost of a compressor or pressurizing the gas for injection. But that does not solve the problem of transient slugging in which the liquid column is already formed before it reaches the riser base. crucial issue is the trade-off between the optimum point for gas injection and the amount of gas required to stabilize the system [5] concluded through their experiment that a high amount of gas is required to eliminate severe slugging in just a 3m high riser.

2) **Slug Catchers:** Primary separation and liquid storage are the objectives of slug catcher. It is a large diameter pipe connected downstream of the main pipeline. and the gas and liquid phases are separated. The liquid is pumped to the surface with the gas free flowing to the platform through a separate riser. It may be difficult to design a slug catcher to cope with the magnitude of terrain slugs.
3) **Topside Choking:** Choking at the top of the riser can be used to minimize severe slugging. This method is used to suppress severe slugging where the choking converts the unstable gas-liquid flow in the riser to a stable flow, i.e. leads to a restriction in the flow line which leads to a decrease in the flow rate. That "choking eliminates severe slugging by increasing the back pressure and acting as a flow resistance proportionally to the velocity of the liquid slug in the riser" [6]. Choking is done by placing a valve from the upper part of the riser, valve is manually choked from the fully open position until the system becomes stable. This is a low cost, slug mitigation option.

❖ **Severe slugging phenomenon**

The probability of slugging at the descending inclination of the pipeline ending to the riser increases, the accumulation of fluid at the decrease leads to the formation of liquid slugs, which increase as the length of the riser increases. When slugs of length greater than 10 – 50 meters is experienced, the flow is given the name severe slugging. Severe slugging is developed through four steps, as shown in figure (2)

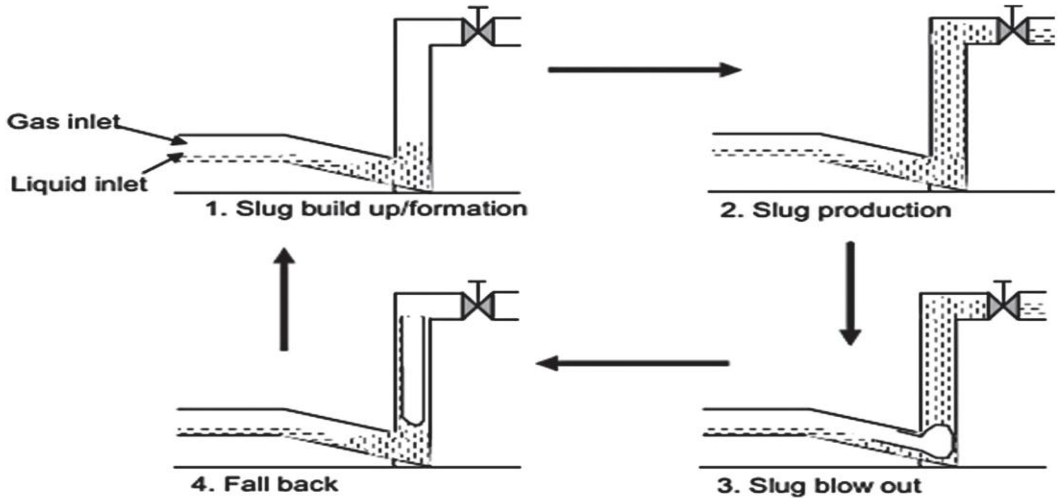

Figure (2): Different stages of severe slug[6].

Stage 1- Liquid Slug Generation. The presence of dips in the pipeline causes the accumulation of liquid in it due to gravity, and thus the liquid blocks the flow line and prevents gas flow.

Stage 2 - Liquid Slug Production. The accumulation of liquid in the riser stopped the flow of gas, as the fluid level in the riser increased and thus only the liquid phase is produced.

Stage 3- Liquid fallback. The gas phase pressure increases as the fluid level in the riser increases because the gas phase pressure is greater than the static pressure of the liquid column, which allows the gas to expand and penetrate the liquid and push it out from the riser to the separator.

Stage 4- Gas Blowout. When all the liquid has left the riser, the gas phase reaches the separator, the gas is produced and its pressure drops. The velocities are so small that liquid falls back in to the low-point of the riser and starts to accumulate again.

" Bouri Offshore Field"[17]:

Bouri offshore field is part of the block NC-41, which is located 120 km north of the Libyan coast in the Mediterranean Sea. The field was discovered in 1976. The field's first production started from the two oil platforms (DP4, DP3) in 1988. Bouri field includes several subsea wells connected to the platform in dependently DP3 through safety valves under the sea. The wells drilled for the first time in 1994-1995.

The field is estimated to contain 720,000,000 cubic meters in proven recoverable crude oil reserves and 3.5 trillion cubic meters of associated natural gas with an annual production potential of 6 billion cubic meters.

The NC-41 block contains two production platforms: DP4 and DP3. The last platform is linked to the DP4 platform, which is about 8 km away. The DP4 platform is permanently connected to a connected single point (floating production storage) of 1.5 Mbbl (240,000 m3) capacity**.**

Available Data:

The DP3 platform stands in 160 m of water and it is located 8 km from the DP4 riser base witch stands in 160 m of water. The oil flow lines from the field is directly combined with the Dp3 trunk line to obtain a multi-phase flow.

A schematic of the system is shown in figure (3). The pipe diameter of 12 inch and A common pipe roughness is assumed to be 0.028 mm. The test Separator pressure is constant 197 psia. The pipeline inlet pressure is 300 psia. The flow temperature upon arrival is assumed to be constant at 97.35°F.

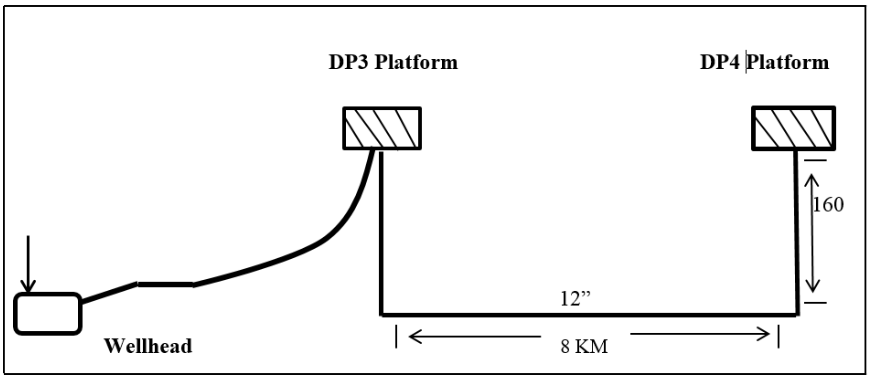

Figure (3): Schema of the production system at Bouri Field

The minimum ambient temperature can be assumed to be 42.8°F, and the ambient heat transfer coefficient (from the outside of the pipe structure to the surroundings) can be assumed to be 1.1447 Btu/Ft^{2}hr°F for the entire pipeline-riser system. By using HYSYS, live production (oil, gas, water) from the field was mixed directly with an oil trunk line on the DP3 platform to obtain a multi-phase flow as shown flowsheet in figure (4). The properties and geometry of pipeline is given in tables (1), (2) and the composition of the fluids are given in table (3).

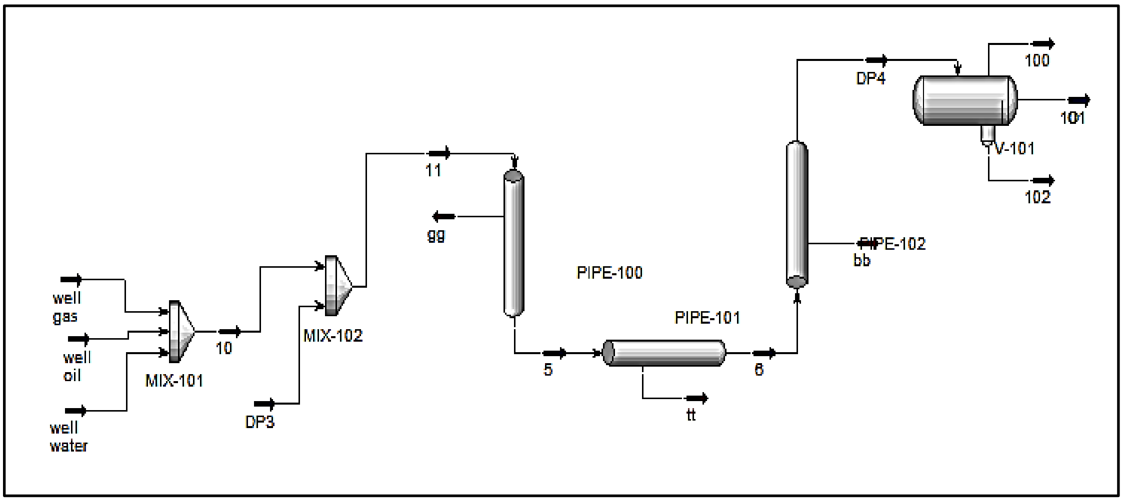

Figure (4): Flowsheet of the production system at DP3

Table (1): Pipeline materials properties.

Material	Density Kg m^{-3}	Specific heat J Kg^{-1} C^{-1}	Thermal Conductivity W m^{-1} C^{-1}
Carbon steel	7850	500	50
Insulation	2500	800	1

Table (2): Pipeline geometry.

X(m)	Y(m)
0	-160
1000	-160
2000	-160
3000	-160
4000	-160
5000	-160
6000	-160
7000	-160
8000	-160
8100	15

Table (3): Fluid composition

Component	*Mol. %*	*Mol.wt.*	*Liquid Density g/cm³*
H_2O	25.51	18.05	0.9990
N_2	28.6	28.014	
CO_2	13.6	44.010	
C_1	7.70	16.043	
C_2	15.5	30.070	
C_3	17.6	44.097	
iC_4	0.41	58.124	
nC_4	1.07	58.124	
iC_5	0.57	72.151	
nC_5	0.64	71.151	
C_6	1.13	86.178	0.6640
C_7	1.83	96	0.7380
C_8	2.34	107	0.7650
C_9	2.92	121	0.7810
C_{10}	2.76	134	0.7920
C_{11}	2.32	147	0.7960
C_{12}	1.89	161	0.8100
C_{13}	1.91	175	0.8250
C_{14}	1.84	190	0.8360
C_{15}	1.66	206	0.8420
C_{16}	1.30	222	0.8490
C_{17}	1.26	237	0.8450
C_{18}	1.30	251	0.8480
C_{19}	1.17	263	0.8580
C_{20}	1.17	275	0.8630
C_{21}	0.87	296.582	0.7911
C_{22}	0.93	310.609	0.7937
C_{23}	0.76	324.636	0.7961
C_{24}	0.73	338.662	0.7984
C_{25}	0.73	352.689	0.8005
C_{26}	0.61	366.716	0.8024
C_{27}	0.06	380.743	0.8043
C_{28}	0.55	394.770	0.8060
C_{29}	0.52	408.797	0.8077
C_{30}	0.43	422.824	0.8093
C_{31+}	11.35	436.851	0.8108

4. .Results and Discussion

The study cases in flow assurance are simulated through using OLGA software, and typical transport systems are analyzed according to the flow assurance guidelines. Results are presented and discussed on the basis of flow assurance principles, in order to avoid any flow problems such as future pauses and the need to intervene.

Live production (oil, gas, water) from the field was mixed directly with an oil trunk line on the DP3 platform. The purpose is to study the stability of the multi-phase flow system in trunk line extending 8 km down to the DP4 platform where difficulties are expected due to slug flow upon arrival and encountering problems in reception facilities. Therefore, slug flow mitigating is needed, suitable mitigation methods have been proposed and implemented to prevent severe slugging. Slugging have been eliminated using gas lift and throttling techniques. The study of this case is to prevent the formation of slugs to ensure the stability of the flow. OLGA simulator is used to simulate a steady state flow of 28000 bpd . The pipeline profile as show in figure (3). **Results:**

Figure (5) shows that the flow regime is slug and the flow is unstable. Therefore, slug flow mitigating is needed.

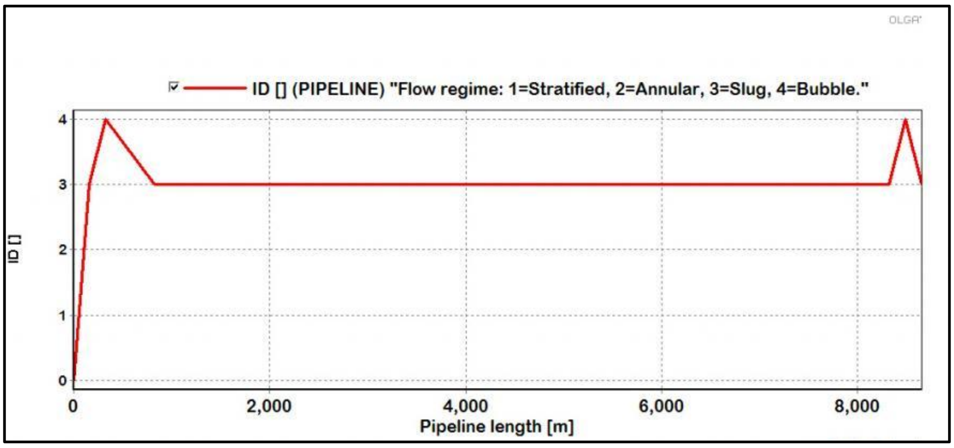

Figure (5): Flow regime profile.

Proposed solutions:

A number of mitigation options have been identified to prevent severe slugging in the riser.Two of them are:-

- Choking the flow at the top of the platform
- Injecting gas at the bottom of the riser

Topside Choking

A valve is added and Define a choke at the end of the riser (PIPE-10, section boundary 2). Start with a value for OPENING of 0.12 (i.e. 12% of full cross sectional area). Changing the openings as: 0.04 and 0.02, and comparetion the results of the different openings.

➢ **Results**

Figures (6) and (7) present the flow regime for a valve openings of 12% and 4%. The flow regime is still slug along the trunk line. figure (8) presents the flow regime for a valve opening of 2%. The flow regime stratified along the trunk line.

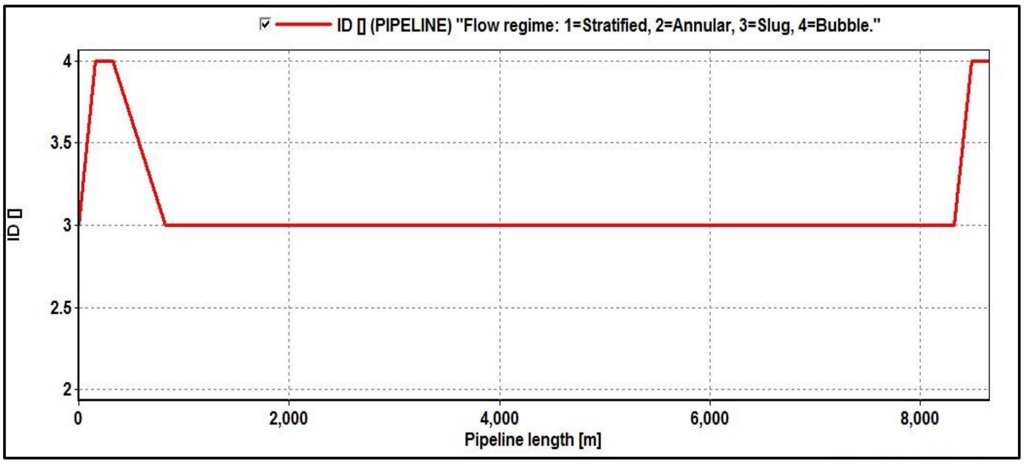

Figure-5.2: Flow regime profile with opening valve %12.

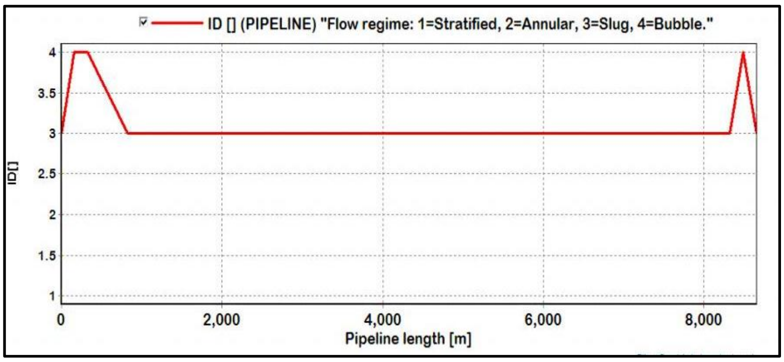

Figure (6): Flow regime profile with opening valve %4.

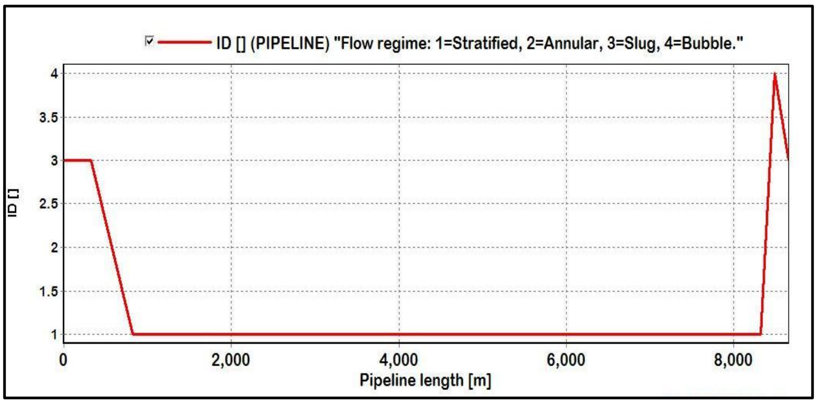

Figure (7): Flow regime profile with opening valve %2.

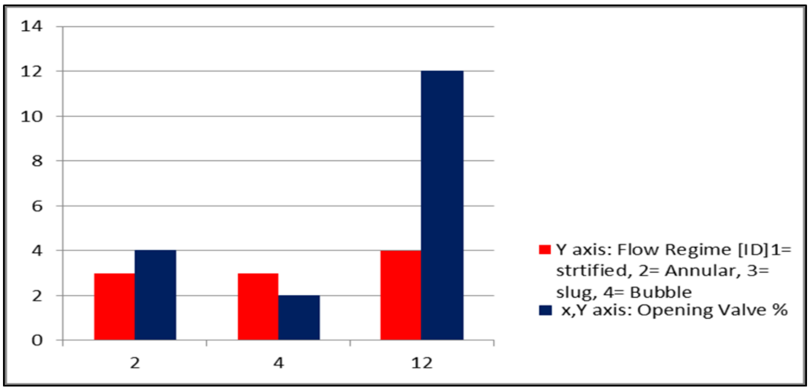

Figure (8): Flow regime profile with opening valve %2, %4, %12.

Although the flow is unstable and a slug flow along the pipeline, upon arrival the flow changes from slug to bubble flow making the results of choking on opening valve 12% appropriate somewhat. As for opening valve 4%, it did not work to prevent the formation of slug flow. However, when opening valve 2% the flow was stable, but upon arrival the flow changed from stratified to slug flow and this does not achieve the goal to reduce slug flow at the reception facilities.

Table (4) presents the steady state results including values opening valve, and an indication of the flow regime at arrival (figures-5.2, 5.3, 5.4).

Table (4): Pseudo steady state results for values opening valve %12, %4, %2.

Values Opening Valve %	Flow Regime At Arrival
12	No Slug Flow
4	Slug Flow
2	Slug flow

Gas Lift

Gas lift means addition of a gas stream at the riser base. In attempt to prevent flow stability a gas flow rates of 2, 5 and 8 MMscfd have been investigated, and results are compared.

- **Results**

Figure (9) presents the flow regime when the gas lift rate 2 MMscfd. Result show that the flow is unstable. Figures (10) and (11) present the flow regime for the gas lift rates 5 and 8 MMscfd. Result show that the flow is stable.

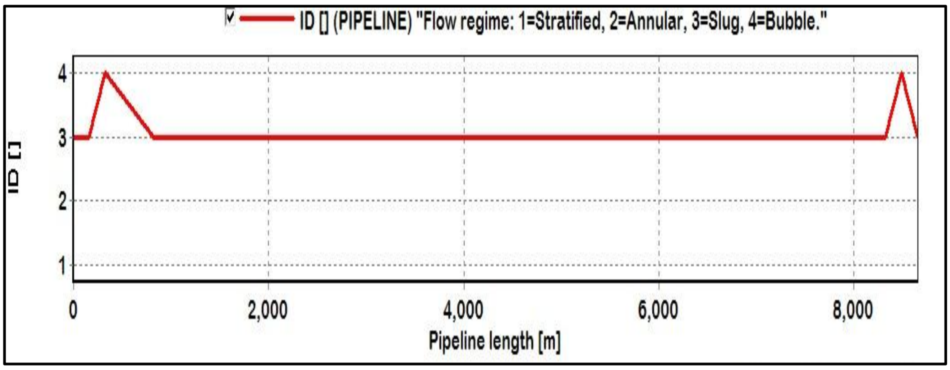

Figure (9): Flow regime profile with lift gas rate 2 MMscfd.

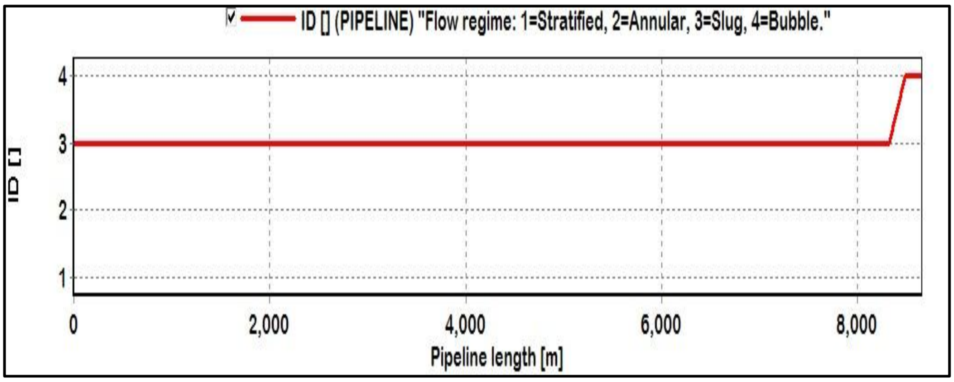

Figure (10): Flow regime profile with lift gas rate 5 MMscfd.

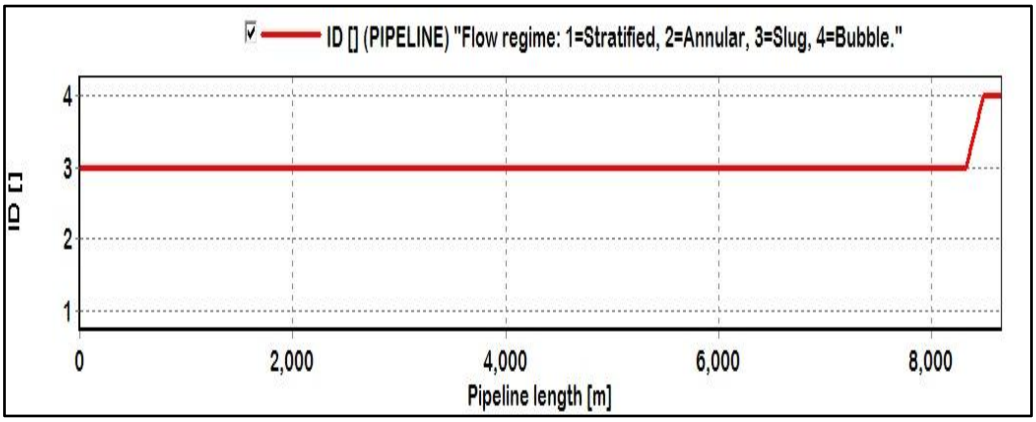

Figure (11): Flow regime profile with lift gas rate 8 MMscfd.

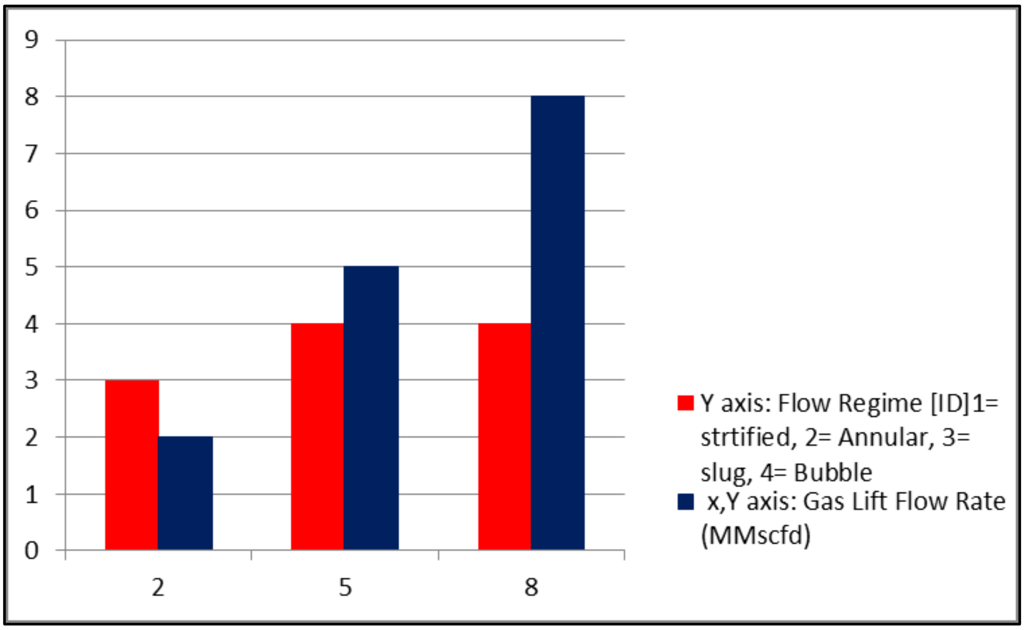

Figure (12): Flow regime profile with lift gas rate 2, 5, 8 MMscfd.

The flow regime changes from slug to bubble flow for gas lift rates 5 and 8 MMscfd, it may be concluded that a gas lift rate of least 5 MMscfd is needed to prevent the formation of slug flow at the reception facilities.

Table (5) presents the steady state results including gas lift flow rates, and an indication of the flow regime at arrival (figures (9), (10), (11)).

Table (5): Pseudo steady state results for gas lift flow rate 2, 5, 8 MMscfd.

Gas Lift Flow Rate MMscfd	Flow Regime At Arrival
2	Slug Flow
5	No Slug Flow
8	No Slug Flow

Conclusion:

It was shown in this project that OLGA is one of the best simulation programs that can analyze the flow assurance phenomenon. Based on the results of the cases studied in this paper the suitable mitigation methods have been proposed and implemented to prevent severe slugging in 12-inch-diameter oil production line. Slugging have been eliminated using gas lift and throttling techniques. According to the simulation results state the proposed solutions and but parameters obtained when no slugging is achieved is Topside choking with valve that is 12% opening eliminates slug flow upon arrival but flow is slug along the trunk line. For gas lift, flow rate of at least 5 mmscfd is needed to prevent the formation of slug flow at the reception facilities.

Recommendations:

After studying slug flow effect on production performance, and after modeling and studying cases, we recommend:

- Recommend use OLGA simulator model to test the production scenarios and Keep updating.
- Carry on a comprehensive flow assurance study to test all the factors that affect the production performance and the reception facilities in conditions limit in the future.

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