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# The Control Method of Pigging Slug Flow for Multiphase Subsea Pipeline

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**Abstract**. This paper analyses the causes of the large number of slug flows by OLGA software and analyses its control methods. It can be seen from the simulation that closing the high-production gas well to control the pigging flow rate and venting time can effectively control the volume of the pigging slug flow, thereby reducing the volume of the slug flow trap and reducing the platform area, thereby reducing the overall engineering investment.

## 1. Introduction

As the main way to develop and transport production fluids in offshore oil and gas fields, submarine pipelines connect offshore oil and gas fields, oil storage facilities or land terminals into an organic whole, so that all aspects of offshore production facilities form interconnected and coordinated production systems through submarine pipelines. Submarine pipelines can be regarded as the lifeline of offshore oil and gas field development. Therefore, the flow safety of submarine pipelines is a necessary condition for maintaining oil and gas field production, and the occurrence of slug flow in submarine pipelines is one of the serious problems that threaten the safety of submarine pipelines [1-2].

The slug flow refers to the gas-liquid two-phase flow state in which a gas column and a liquid column alternately appear in the pipeline. Liquid slug flow often occurs in oil-gas two-phase flow mixing pipelines, gas long-distance transport pipelines, and riser outlets, which appear as two-phase slug flow. Due to the high flow rate and high kinetic energy, liquid slug flow can cause mechanical problems. At the same time, due to liquid level fluctuations, impacts and blockages, slug flow can also cause process problems, posing a serious threat to the safe transportation of submarine pipelines [3].

The damage caused by the slug flow to the normal operation of the pipeline system and the downstream production equipment of the pipeline is mainly manifested in: causing the pipeline pressure to fluctuate greatly; intensifying the corrosion of the pipe wall, especially the corrosion of the riser pipe wall; causing the overflow of the pipe outlet separator or interrupted flow, making the slug flow trap unstable and difficult to operate; causing mechanical damage to the pipe joints and struts, causing cavitation of the pressurized equipment (such as multiphase pumps and compressors) during pumping and reducing the efficiency of pumping and work reliability; in severe cases, it can cause the platform or even the entire oil field to be shut down [4-6].

The slug flow is mainly divided into normal working condition slug flow and pigging condition slug flow. The pigging condition pipe slug flow refers to the front end of the pigging ball due to the difference of gas-liquid flow rate in the pipe when the gas-liquid mixed pipeline is in pigging condition. The accumulation of liquids forms a pigging slug flow, and the control of pigging slug flow is particularly important when producing offshore platforms. Because the slug flow trap is generally provided at the end of the pipeline, the size of the slug flow trap cannot be too large due to the

influence of the platform area and economy. Therefore, the maximum slug flow volume in pigging condition should be controlled in production.

The method for controlling the pigging slug flow is: reducing the amount of liquid in the pipe before pig the pipe (ie, closing the source water well or the production well); controlling the pigging speed (ie, increasing the back pressure of the pipe or shutting in the high-production gas well); increasing the liquid phase outlet flow rate of slug flow trap; due to the difference in height and the difference in oil-water density, in addition to the attention to the liquid phase slug, some pipelines also need to pay attention to the change of the flow rate of the oil phase and the water phase of the pipeline outlet.

## 2. The cases simulation of slug flow
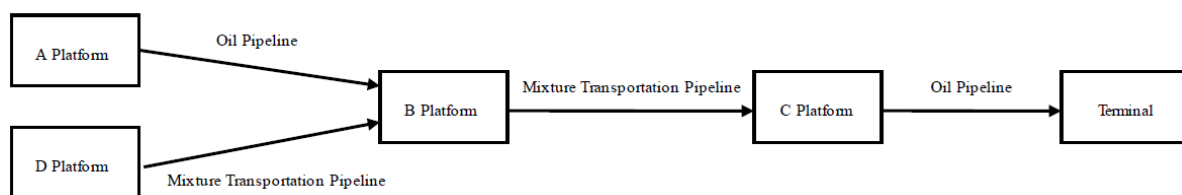
### 2.1 Oilfield overview



**Figure 1.** Schematic diagram of an offshore oilfield development

An oilfield area consists of 5 platforms and 4 pipelines. The development diagram is shown in Figure 1. This paper simulates the pigging conditions of the oil and gas-water mixed pipelines from the B platform to the C platform through software, and then analyses the pigging slug flows.

### 2.2 Basic data
The B to C mixed submarine pipeline is about 15.9 km long. The water depth in this area is about 25 m, the pipe diameter is 10 in, and the outlet pressure is 1500 kpaA. It is a double-layer insulation pipe with an average mud temperature of 4.8 °C. The gas-liquid-liquid ratio of the pipeline is 38.9. It belongs to low-viscosity high-condensation crude oil. In this paper, the typical working condition parameters of three years are selected for simulation calculation. The specific transmission parameters are shown in Table 1.

**Table 1.** Typical working condition parameters

| Case | Oil $m^3/d$ | Water $m^3/d$ | Liquid $m^3/d$ | Gas $10^4 Sm^3/d$ | Water Cut % |
|------|------|------|------|------|------|
| 1 | 2925.1 | 731.3 | 3656.4 | 15.9 | 20.0 |
| 2 | 4266.1 | 1066.5 | 5332.7 | 19.7 | 20.0 |
| 3 | 4083.2 | 1020.8 | 5104.0 | 19.8 | 20.0 |

### 2.3 The stimulation of slug flow in pigging condition
This paper uses OLGA software to build a dynamic model of the pipeline for simulation. After simulation, the calculation results of the pipe slug flow in the typical years of B-C mixed submarine pipelines are shown in Figure 2~Figure 4. As can be seen from the figure, a large number of slug flows are generated when the pipe is in pigging condition.
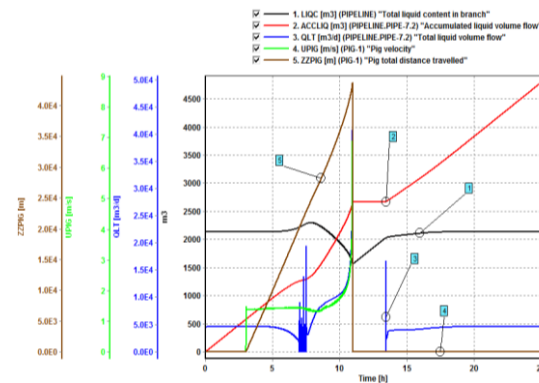
**Figure 2.**  B to C mixed pipeline case 1 pigging condition slug flow calculation result
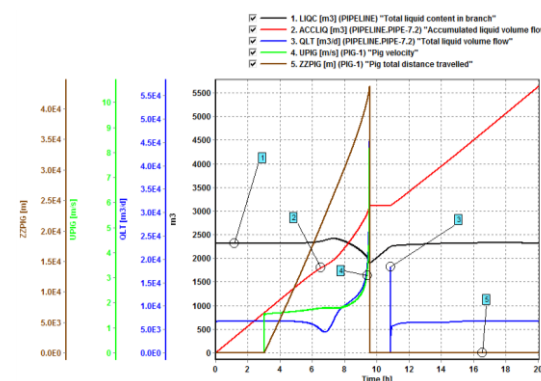


**Figure 3.**  B to C mixed pipeline case 2 pigging condition slug flow calculation result
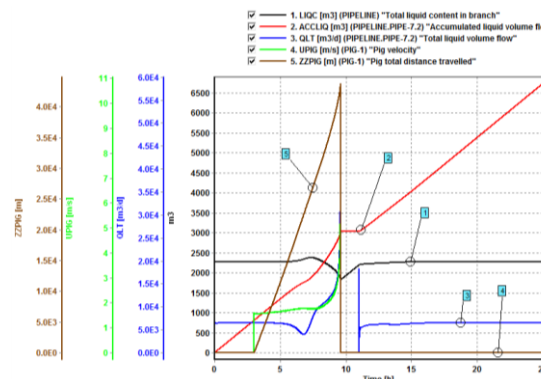


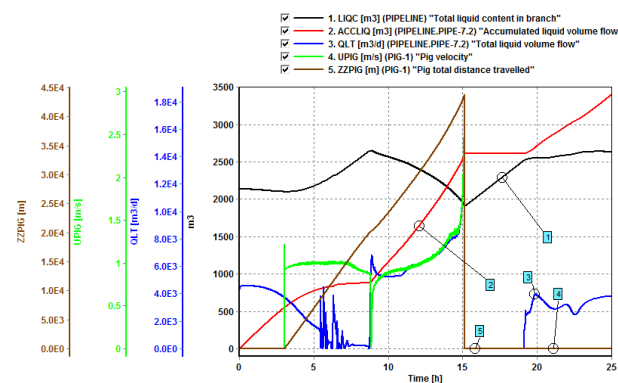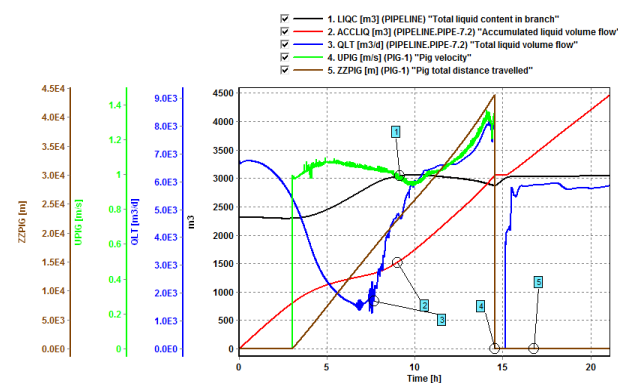**Figure 4.**  B to C mixed pipeline case 3 pigging condition slug flow calculation result

The results of the slug flow analysis are shown in Table 2. It can be seen from the analysis results of Table 2 that the volume of slug flow in the pigging period of the case 1, the case 2, and the case 3 is large. Therefore, it considers taking full advantage of the equipment of the downstream C platform. The plug flow trap on C platform has an effective capacity of 60 m$^3$ and the closed vessel capacity is 24 m$^3$. Therefore, the total volume of the slug flow can be stored on the C platform is 84 m$^3$. After deducting this volume, there is still 391 m$^3$ pigging slug flow that cannot be stored. If the volume of the slug flow trap is increased, the platform deck area is enlarged too much, and the overall project investment is correspondingly increased.

**Table 2.** B to C mixed pipeline pigging condition slug flow calculation result

|  |  | Slug Flow | | Downstream Process Equipment Processing Capacity | Downstream Process Equipment Processing Volume Capacity | The Volume Of Slug Flow That Needs To Be Stored | Slug Flow Trap Volume + Closed Vessel Capacity | Can the Slug Flow To Be Stored |
|---|---|---|---|---|---|---|---|---|
| Case | Year | Time | Volume |  |  |  |  |  |
|  |  | min | m³ | m³/min | m³ | m³ | m³ |  |
| 1 | 2019 | 163 | 1220 | 5 | 815 | 405 | 84 | No |
| 2 | 2021 | 135 | 1138 | 5 | 675 | 463 | 84 | No |
| 3 | 2022 | 133 | 1138 | 5 | 663 | 475 | 84 | No |

*2.4 Simulation and analysis of control method for pigging slug flow*

According to the method of controlling the pigging slug flow, combined with the actual situation of no source water well in the oilfield, it is considered that the effect of controlling the outlet back pressure to control the pigging slug flow is not obvious. Therefore, it is decided to control the slug flow volume by means of closing the high-production gas well so that when the pigging is carried out, the slug venting time is prolonged, and the speed of the pigging ball is reduced. Therefore, according to the production schedule, it is considered to close three wells with a large gas production during the pigging. Figure 5 to Figure 7 show the simulation results of the plugging conditions of the B-C mixed pipeline after shut in the gas wells, and Table 3 shows the analysis results of the simulated slug flow. It can be seen from the analysis results that the slug flow can be stored after the high-production gas wells are shut in.



**Figure 5.**  B to C mixed pipeline case 1 pigging condition slug flow result after shut in wells



**Figure 6.**  B to C mixed pipeline case 2 pigging condition slug flow result after shut in wells
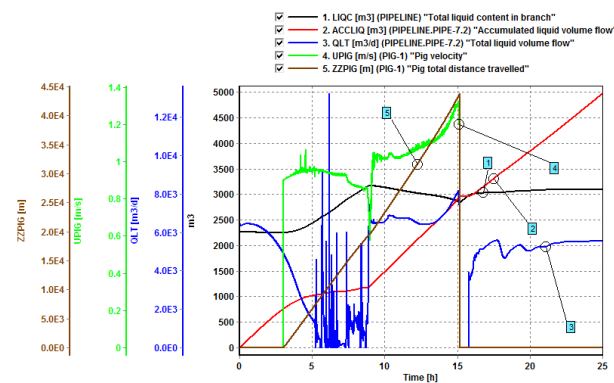
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**Figure 7.** B to C mixed pipeline case 3 pigging condition slug flow result after shut in wells

**Table 3.** B to C mixed pipeline stimulation results after reducing the volume of gas production

| Case | Year | Pre-pigging Flow Rate | | | Flow Rate During Pigging | | | Slug Flow | | Downstream Process Equipment Processing Capacity | Downstream Process Equipment Processing Volume Capacity | The Volume of Slug Flow That Needs To Be Stored | Slug Flow Trap Volume | Can the Slug Flow To Be Stored |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oil | Gas | Water | Oil | Gas | Water | Time | Volume | | | | | |
| | | m³/d | 10⁴Sm³/d | m³/d | m³/d | 10⁴Sm³/d | m³/d | min | m³ | m³/min | m³ | m³ | m³ | |
| 1 | 2019 | 2925 | 15.9 | 731 | 2365 | 6.5 | 591 | 96 | 553 | 5 | 480 | 73 | 84 | Yes |
| 2 | 2021 | 4266 | 19.7 | 1066 | 3706 | 4.6 | 926 | 66 | 390 | 5 | 330 | 60 | 84 | Yes |
| 3 | 2022 | 4083 | 19.8 | 1020 | 3523 | 1.8 | 880 | 58 | 315 | 5 | 288 | 27 | 84 | Yes |

## 3. Conclusion

The pipe slug flow will have a great impact on the safety of the submarine pipeline. This paper analyses the causes of the large number of slug flows by OLGA software and analyses its control methods.

It can be seen from the simulation that closing the high-production gas well to control the pigging flow rate and venting time can effectively control the volume of the pigging slug flow, thereby reducing the volume of the slug flow trap and reducing the platform area, thereby reducing the overall engineering investment.

In actual production, the control method for a pipe slug flow needs to be considered in combination with actual operation conditions, operator requirements and economic investment.

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