ADVANCED FLOW ASSURANCE TOOLS TO MINIMIZE PIGGING RISKS IN CHALLENGING LINES

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Abstract

Pipeline cleaning pigging is often undertaken to maintain continuous production, improve throughput efficiency, remove liquid or solid deposits which may restrict flow or promote corrosion growth, and to prepare a pipeline for inspection. In certain cases, pigging operations are becoming increasing challenging with the development of more deep-water applications, the use of exotic materials and increasingly demanding operating conditions.

To address these challenges, ROSEN employs advanced flow assurance tools by combining flow analysis along with pigging feasibility studies in order to optimize pigging operations in very challenging pipelines. This integrated approach has shown significant benefit in quantifying risks, evaluating mitigation strategies, confirming pigging feasibility and optimizing pigging campaigns. The field case study presented in this paper will illustrate how the application advanced flow assurance tools were successfully employed to optimize a complex offshore pigging operation.

Introduction

It is estimated that there are around 3.5 million km of high-pressure pipelines for oil, gas and water worldwide with about 25,000 km of new pipelines are added every year[1]. However, around one third of these pipelines are deemed "unpiggable" using conventional free-swimming pigs. For many operators, pigging is often a non-routine or infrequent operation, making it an unfamiliar task. There can often be disagreement on the best way to proceed where pigging requirements are deemed to be non-standard or complex. From an integrity management perspective there is an increased desire to inspect so called "unpiggable" (or difficult-to-pig) pipelines to be able to demonstrate they can continue to be operated safely and reliably.

Pigging Challenges

The main challenges in such pipelines can be broadly classified into "construction challenges" and "operational challenges." Figure 1 summarizes some of the key technical and operational challenges and how they can typically affect pipeline piggability.

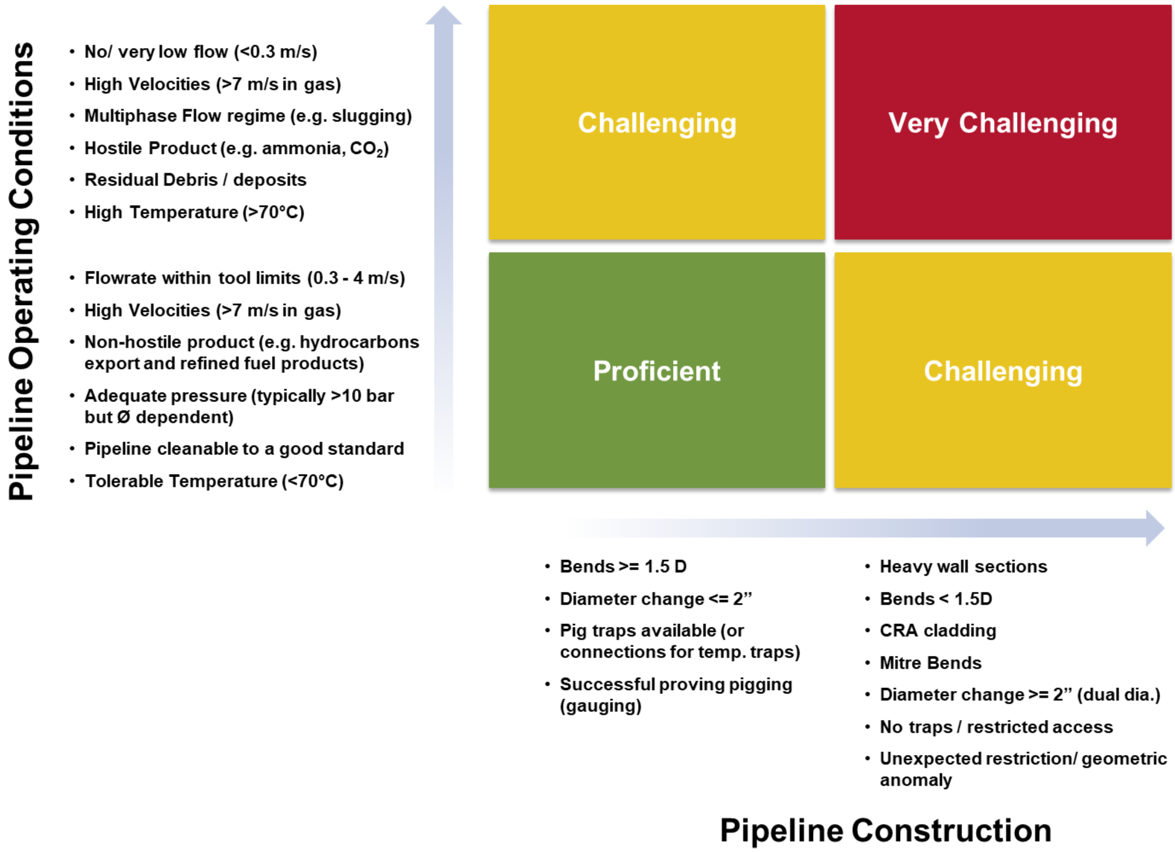


Figure 1: Pipeline Piggability Challenges

Pigging & Pipeline Integrity Management

Pipeline pigging is an integral part of a pipeline asset integrity assurance program. This can include maintenance pigging as part of a corrosion management strategy, helping to minimize excessive liquids or debris holdup to improve operational capacity or to perform an in-line inspection (ILI) operation.

With any pigging operation, it is important in the first instance to be clear about the ultimate objective before configuring the pigs ahead of operational execution. In the case of ILI pigging operations, this includes carrying out a threat assessment, to understand the credible integrity threats to ensure the correct choice of inspection technique(s) and ILI host tool[2]. Based on an assessment of perceived integrity threats, a range of inspection technologies can be considered to detect and size all significant anomalies. The selected ILI tool option(s) may also need to be tailored to the pipelines configuration and operating conditions.

Pipeline operators often address the complexities and challenges posed by ‘difficult-to-pig’ pipelines via performing a pigging feasibility study. This upfront review should consider the overall pigging project objectives, investigate the range of options available to demonstrate and predict the viability and cost of a chosen option. In addition to the obvious risks and practical challenges, such studies can be structured to address other potentially significant external factors as contributors to the full lifecycle costs of a pipeline.

Many of the aspects that need to be considered when preparing and executing complex pigging operations at times present major technical or operational challenges to operators, accompanied by real (or sometimes perceived) risks and significant economic barriers. The challenge is to analyze all factors objectively drawing on previous experience where possible, to make an informed decision – and to act on it. Figure 2 shows the process adopted for this by ROSEN.

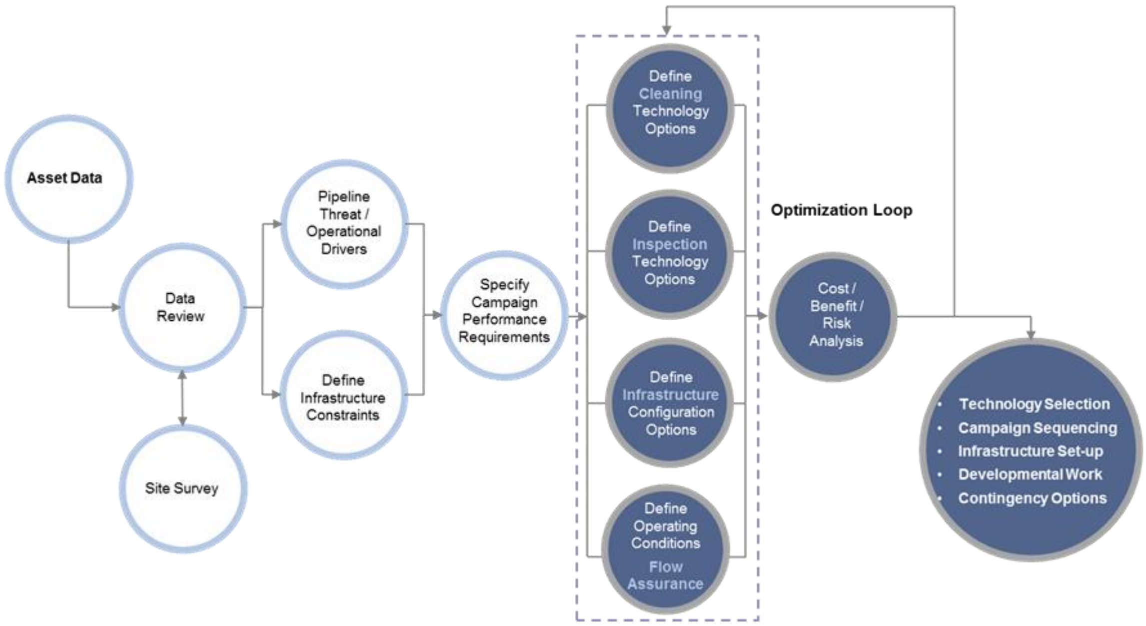


Figure 2: Piggability Assessment Process

Depending on the outcome of the pigging feasibility study, a standard 'off-the-shelf' ILI may tool prove to be adequate, but it is often necessary to implement a strategy – and custom-build a tool – that addresses any and all complexities of the pipeline system.

It should also be noted that the term "challenging" is often a function of the project economics. Accurately costing a campaign is critical to choosing between options. A robust cost model should account for the global impact of a campaign over the full project lifecycle. Some campaigns can be very difficult to cost at the feasibility stage and should therefore contain appropriate contingencies or be based on analogous undertaken jobs previously. Contemplation of ancillary support services such as chemical injection and subsea intervention costs need to be considered and a scoring system used to help identify the optimum pigging solution.

Flow Assurance and Pigging

Flow assurance is broadly defined as the ability of a production system to transport fluids from wells through the pipeline in a safe and economical manner, over the life of field. Economics of any production asset depends on the reliable deliverability of the system. Pipelines can plug due to hydrates, wax and asphaltenes severely reducing the production capability with an eventual risk of blockage. Loss of integrity could occur due to corrosion, erosion or severe slugging. Any deep-water intervention may result in costly downtime with a high environmental and safety implications.

From a pigging perspective, flow analysis is essential to estimate the amount of solid deposits (such as sand, wax) and liquid accumulation during production. Transient pigging analysis is performed using flow simulation tools to assess the sufficiency of pigging pressure, suitability of pig design and its configuration. A worst case scenario, which could result in a pig getting stuck due to excess deposits, can be determined. This allows for optimization of the pigging frequency required to avoid excessive deposits, which is a function of the rate of solid/liquid accumulation and the processing constraints of the pig returns at the downstream facility.

In certain cases, bypass pigging is advantageous to maximize production flowrates during pigging operations. Bypass ports allow pigs to "bypass" production fluid through the pig body via bypass ports (see Figure 4). Bypassing production fluid through the pig body helps to reduce the pressure drop across the pig, and therefore reduces its velocity when compared to the bulk fluid velocity[3]. This means that the cleaning pigging operation can effectively be performed at increased production flowrates, and with decreased load on the downstream liquid handling capacity.

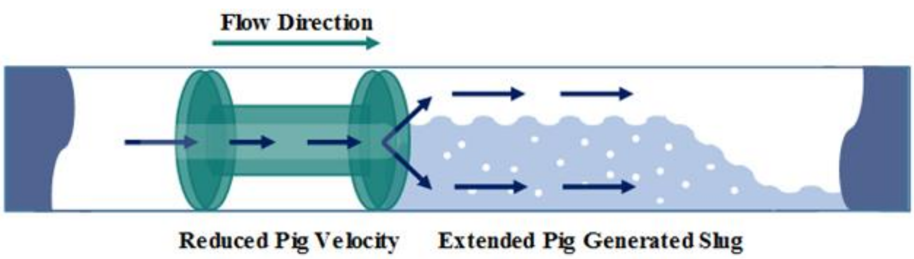


Figure 4: Bypass Pig – Working Principle

The calculation of an optimum bypass opening requires careful consideration of the fluid properties, pigging flowrates, system backpressures, liquid holdup, slug handling volume, drainage rate, tool design and pig-pipe wall frictional forces alongside the pipelines infrastructure. Flow modelling is used to model the bypass pig behavior and effectively size the bypass port opening.

Advantages of combining Flow Assurance and Pigging Feasibility

Every pipeline asset has a unique process operational envelope (Figure 5) bound by the limits set by the production targets, costs, design constraints and allowable process limits. Similarly a pigging operational envelope exists for a conventional cleaning pig and more importantly, for in-line inspection pigging.

For an "unpiggable" system, flow analysis plays an important tool to determine the flexibility of the process and pigging operational envelopes. In most cases, depending on the pipeline asset, the process operational envelope may be modified to suit the pigging envelope or the pigging envelope may be modified to fit into the process operational envelope. In some cases, neither the pigging nor the operating envelope can be modified which may classify the pipeline asset as "unpiggable." However, a thorough flow assurance analysis combined with a detailed pigging feasibility study, may allow one to tailor the pig type, design, configuration and pigging strategy, along with the process conditions to ensure piggability of the system.

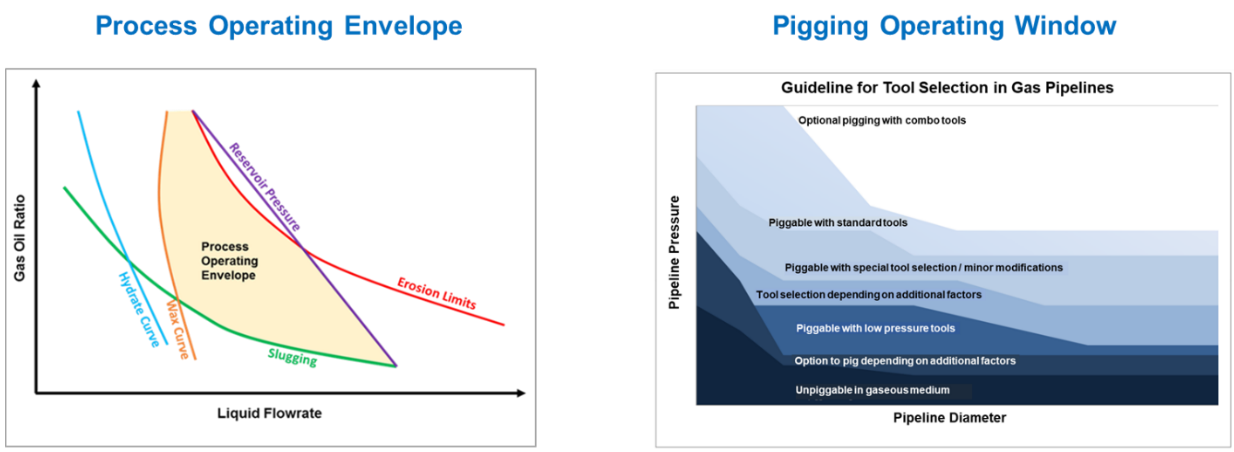


Figure 5: Example - Process & Pigging Operational Limits

Cleaning Pigging Strategies

In challenging applications, a particular cleaning pigging methodology[4] ultimately chosen for a specific pipeline is a function of several factors including:

- Process operating conditions (flows, pressures, temperature)
- Risk of the pig blocking the line
- Time available for cleaning operations
- The degree of cleanliness to be achieved
- Operational constraints

A progressive pigging strategy may be required depending on the internal conditions, operational limits, pipeline geometry and the types of pigs considered. A progressive pigging campaign involves running a series of pigs that progressively increase in aggressiveness in order to remove deposits gradually during each run.

Prior to performing pigging however, the flow conditions in the pipeline should be ascertained by performing flow tests to minimize the associated risks:

- Eliminate the presence of restrictions due to excessive deposit build-up
- Confirm the communication of fluids end-to-end of the pigged section
- Identify if the system is configured correctly

Typically, the aggressiveness of the subsequent pig run will be determined from the results of the previous run. In cases where significant deposits are suspected present in the line, a scout pig such as a medium density foam pig may be used. This pig is designed to pass through restrictions and potentially disintegrate where the passage due to the restriction is too narrow due to the restriction, possibly caused by stubborn heavy deposits. However, once passage is confirmed this may be followed by solid body pig(s) increasing in aggressiveness with each run. If the pig returns a lower amount of deposits, then a more aggressive pig can be considered for the next run. An aggressive pig may use a combination of cup/discs with brushes, studs, magnets, bypass etc.

Flow assurance analysis is essential in the development of pigging programs to understand the internal conditions in the pipeline, quantify the associated risks and eventually optimize cleaning pigging campaigns.

Case Study: Feasibility of Pigging Operations in a Deep-water Multiphase Pipeline Asset

Scope

An operator requested ROSEN to undertake feasibility studies for proving, cleaning and in-line inspection of a dual 22”, and ~ 79 km multiphase flowline system of an offshore deep-water asset situated 1,500m depth in the Asia Pacific region, which produced to the Topsides facility located in a water depth of approximately 100 m. The study required ROSEN to provide a review of the pipeline’s construction, pigging plan and supporting specifications and procedures to allow the operator to enable ILI specialists to inspect the pipeline. As part of this scope, ROSEN was required to analyze the impact of cleaning and ILI pigging on production using industry-recognized flow modelling tools and extensive in-house knowledge of flow assurance.

The overall scope of this extremely challenging deep-water project was executed by an in-house multi-disciplined project team, including personnel from pigging feasibility, corrosion management and flow assurance expertise.

System Description

The subsea production wells are tied in to a Pipeline End Manifold (PLEM) and produce into the flowlines connected to a Topsides platform as shown in Figure 4. Flowline 1 is mainly used for the transport of production fluids to the topsides whilst Flowline 2 is used to supply recycled dehydrated gas from Topsides to Flowline 1 via a crossover at the PLEM, effectively creating a loop to maintain a minimum turndown flowrate (for the purpose of maintaining a low liquid inventory).

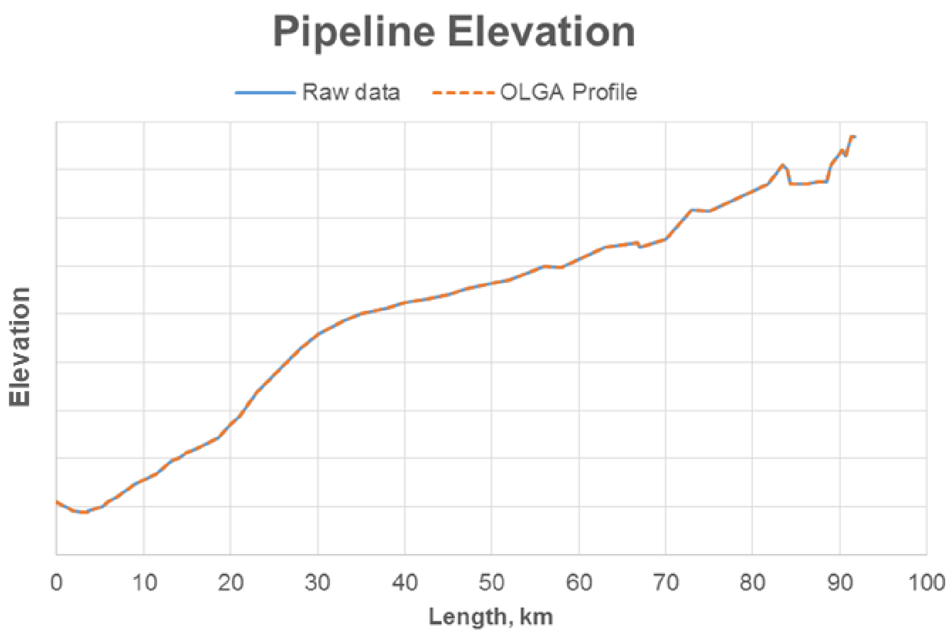


Figure 4: Case Study – Production System Schematic

The Challenge

The clients preferred option was to pig the flowlines whilst ensuring that the production was "online" and maximized. This would be achieved by driving the pig with the dehydrated gas from the topsides into the Flowline 2. The pig subsequently enters Flowline 1 traversing the PLEM pigging loop where the production fluid commingled with recycle gas would return the pig back to the topsides. This complex production asset presented the following challenges:

- The nature of the operating conditions and pipeline elevation profile meant large quantities of liquid holdup (>1,500 m^3) would be present in the flowline, but with a limited liquid handling capacity of 50 m^3 and ~700 m^3/hr drainage rate at the Topsides, it would not be possible to remove all liquid in a single run.
- Production in deep-waters poses many challenges such as high hydrostatic head and insufficient driving pressure (required for pigging) and potential for wells backing out.
- The dual flowlines operated with different service fluids (compressible gas in Flowline 2 and multiphase fluid in Flowline 1), which meant the pig had to be designed to handle different line velocities and fluid properties, depending on the production profile expected over life of field.
- Maintaining pig velocities within the production flowline is challenging as additional flow (production fluid) is introduced at PLEM after pig traverses from Flowline 2 into Flowline 1. This meant that the operator would have to monitor the pig and then switch off the recycle gas compressor at Topsides after pig traverses into Flowline 1 to avoid excessive flow and therefore pig velocity as the pig traversed the PLEM and entered Flowline 1.
- Developing an "online" pigging program presented significant risks considering the single source of production and importance of maintaining supply bearing in mind that this asset produces most of the client's revenue.

The Solution

Mechanical feasibility study identified a range of inspection technologies capable of inspecting the system however the optimization loop identified MFL technology as the most suitable (Ultrasonic testing was ruled out avoiding shutdown or complex batching operations).

The dual flowline system was modelled in Schlumberger's OLGA Multiphase simulator to estimate the liquid inventory in the flowlines expected throughout the life of field of operations.

As such, when pigging simulation was performed without any operator intervention and with a standard pigging tool, a worst-case liquid surge was predicted using OLGA software (configuration 1 shown in Figure 5). A few other configurations of operator intervention (e.g. ramping up flowrates, using dry wells etc.) with special pig designs were simulated. ROSEN's tool options with active bypass include the EcoSpeed and the Speed Control Unit (SCU) tool were initially considered, however due to the liquid content and multiphase slugging which would occur during the inspection these technologies were ruled out in favor of fixed bypass which had a lower operational risk. An optimized solution, which minimizes the generated liquid slug during pigging, was found by introducing a pig with a fixed bypass port after sweeping the line with gas at high flowrates (configuration 4 shown in Figure 5).

A bypass port helps to slow down the pig whilst maintaining high production rates. This can be observed from the liquid holdup profiles as predicted by OLGA in Figure 6 and Figure 7. When compared to a standard pig with no bypass (Figure 6), a slower traversing bypass pig (Figure 7) generates the same slug volume but removing it at a slower rate thus making the slug handling manageable at the Topsides facility. Another consideration when utilizing fixed bypass is the ability to launch and receive the pig, too much bypass and limited kicker line flow would result in the pig not moving from the pig trap.

By removing significant amount of fluids during the fixed bypass pre-inspection pigging campaign, the inspection would be carried out in two phases running down each flowline independently with recycle gas would ensure a smooth velocity within the inspection capabilities of the ILI tool.

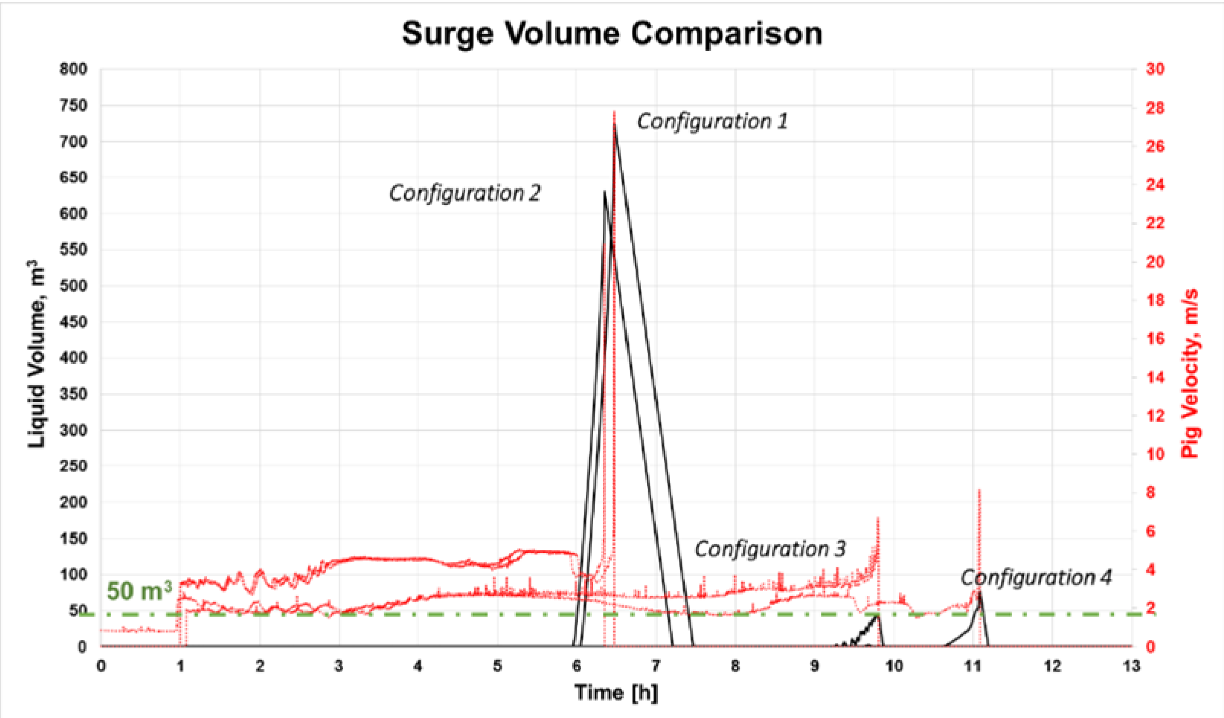


Figure 5: Pigging Configurations vs. OLGA Surge Volume Generated

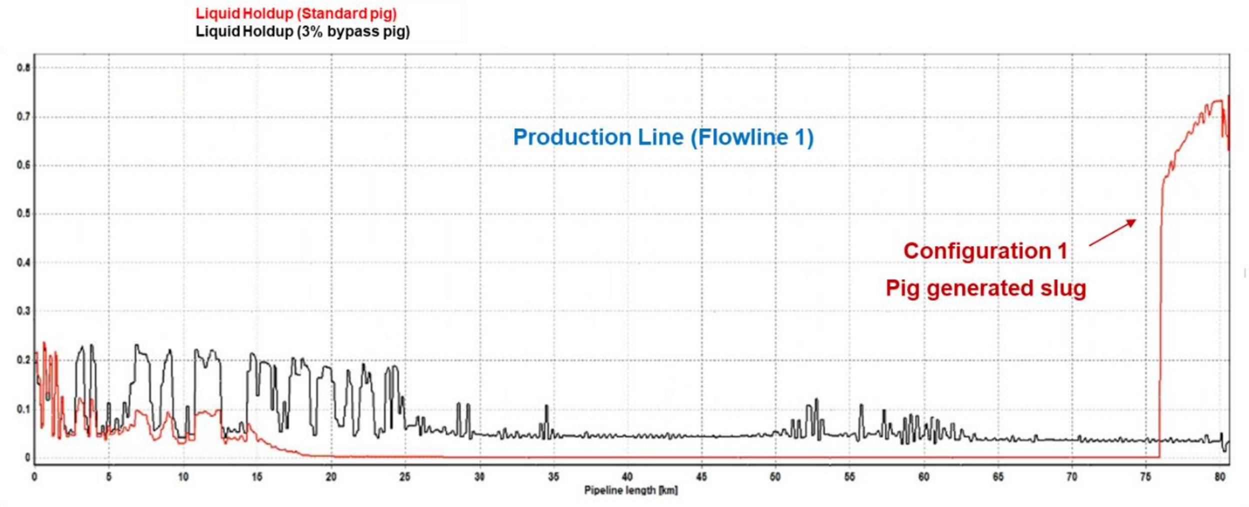


Figure 6: Configuration 1 – OLGA Liquid Holdup profile during Pigging

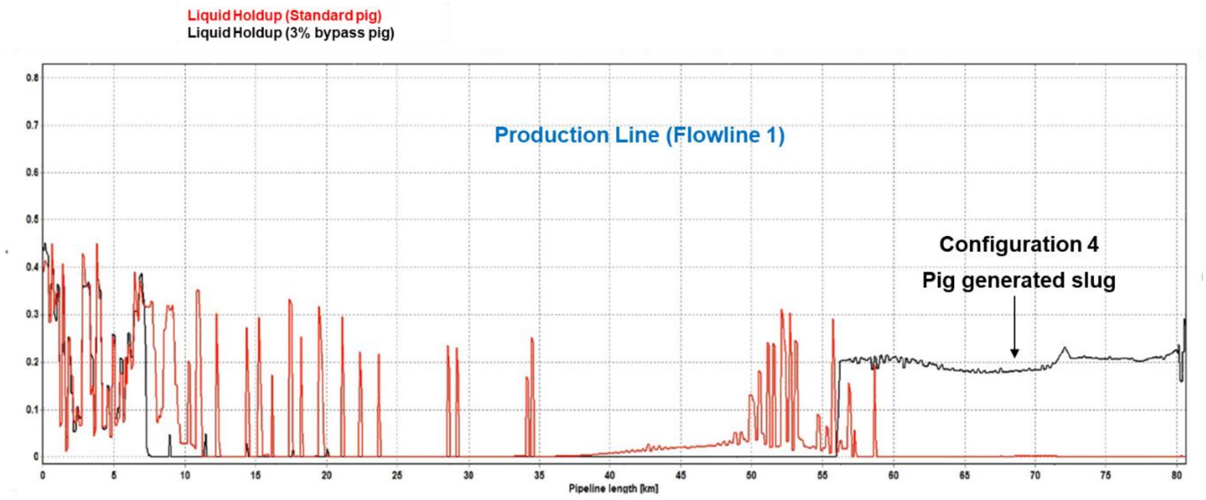


Figure 7: Configuration 4 – OLGA Liquid Holdup profile during Pigging

Further simulations were performed to optimize flowrates required to ensure ILI (MFL) pig velocity (as shown in Figure 8), was maintained within the recommended range to maintain a high level of magnetic saturation in the heavy wall flowlines, and to provide the highest inspection resolution.

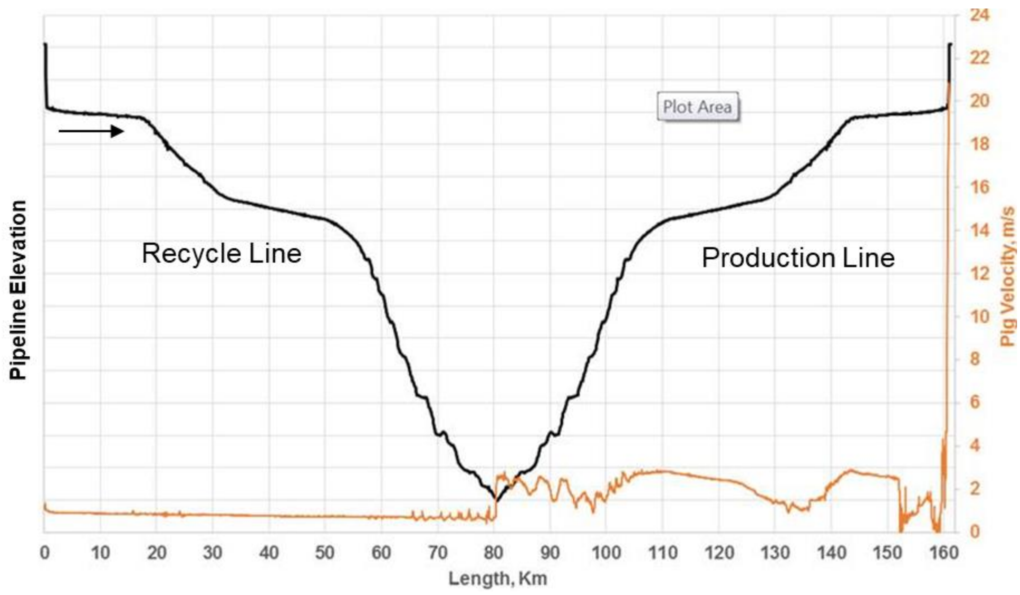


Figure 8: Inspection Pig Velocity

After discussions with the engineering teams, “offline” production pigging options requiring a production shutdown were also proposed in order to minimize the associated risks. The engineering team proposed a number of “offline” options including:

- Subsea receiving – launching topsides and running down each recycle gas line in a controlled manor to a subsea receiver.
- Shutting down the wells and utilizing the gas export pipeline to provide additional gas to drive pigs around the system. This would gradually increase the pressure in the system with each pig run but would be undertaken in a controlled manner.

The operator discounted these options due to the commercial implications which included the loss of production and the high risks and costs associated with subsea intervention.

Study Outcome

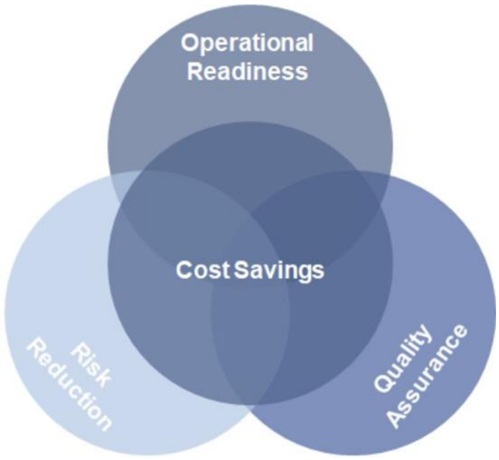
Although full production could not be maintained due to the velocity in the production pipeline, following an extensive flow assurance and pigging feasibility analysis, an optimized “online” cleaning and ILI pigging program was recommended for solids and liquid holdup removal and to ensure first pass success. The benefit of performing the flow assurance study was to provide reliable and cost effective confirmation that an acceptable level of production could be maintained during execution of the proposed campaign. Without the use of flow assurance techniques, the average industry “rules of thumb” would have either:

- Blocked the pipeline due to hydrostatic head suffocating the wells
- Overwhelmed the liquid handing capacity of the platform – causing a shutdown
- Caused potentially dangerous speed excursions leading to tool and or pipeline damage.

Flow assurance techniques combined with pigging knowledge allowed the client to pig the pipeline whilst still maintaining a level of production thus avoiding a costly shutdown.

Conclusions

Flow assurance and pigging feasibility studies allow detailed assessment and quantification of risks of performing pigging in challenging pipelines.



Combined together, such studies can provide pipeline operators with cost-effective solutions to minimize and manage threats in complex operating scenarios on challenging assets, providing assurance of pigging and operational readiness to support safe operations.

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