

Dynamic Simulation of the Norne Heidrun 10" x 16" Dewatering Pig

Aidan O'Donoghue, Pipeline Research Limited, Glasgow, UK
(contact@pipeline-research.com, www.pipeline-research.com)

Introduction

The 10" x 16" Norne Heidrun pipeline presents a considerable challenge in terms of pig development for both pre-commissioning and operations. Provision of a pig for this duty involves: -

- A pig design which can operate effectively and safely in both a 10" line and a 16" line;
- A sealing system design which can overcome compression set in the 10" pipe in order to recover and provide sealing in the 16" line;
- A pig design that can negotiate tight bends, a Y-piece and other inline features.

The RFO (Ready for Operation) Department at Statoil in Stavanger has developed the pre-commissioning concept which employs five 10" x 16" Dual Diameter pigs, Figure 1, for pipeline dewatering. The Åsgard 42" x 28" Dual Diameter pigs are the basis for this concept [1, 2]. These pigs employ a wheel suspension system for centralisation in the large pipeline. Buckle Inducers are used for efficiently folding the 16" seals into the 10" line. Correct selection of seal geometry and properties allows the seals to buckle when required and recover sufficiently from compression set.

Figure 2 shows a schematic diagram of the Norne Heidrun 10" x 16" pipeline (Statoil). From the Norne FPSO, a 900m 10" flexible riser runs to the seabed, depth 300m. On the seabed, the pipeline expands to 16" after the riser termination hub. 18.5m downstream from this point, there is an asymmetrical 16" equal Y-piece for possible future tie-in or subsea launch of an inspection pig. From here, the line runs for 124km, where it ties into the Åsgard Transport Gas Export line along with the 16" pipeline from Heidrun.

The dewatering pig train consists of four pigs run with a glycol batch between each and a trailing final pig run in dry air or nitrogen, see Figure 3. As the final pig exits the 10" flexible and enters the 16" line, a potential problem arises. Due to the sudden drop in friction, the pig will accelerate suddenly to a relatively high velocity. Such acceleration can cause the pig to compress the gas in front of it, decelerate and finally reverse. Therefore, the final pig could potentially reverse into the 16" Y-piece thus damaging either the Y or the pig. This scenario must be avoided.

To investigate this problem, the dewatering operation was modelled using Piglab, a pig motion model from Pipeline Research Limited and the pig train designed to avoid this problem. This was verified by a number of low pressure, low volume tests, performed at K-Lab in Kårstø, Norway.

The Model

A model known as Piglab is used to allow dynamic simulation of pigs in gas pipelines to be investigated. An open source code is used to allow any changes to be incorporated and to make the model specific to the problem at hand. Such a model can provide the link between on-shore tests that cannot fully represent conditions in the pipeline and actual pigging offshore where it is not always possible to know how the pig is performing. The Piglab model can be used to provide a valuable insight into the pig performance as well as allowing several "what if" scenarios to be analysed cost-effectively.

Figure 4 shows the moving grid used to model the pig motion. The momentum and continuity equations either side of the pig are solved at each time-step. Immediately upstream and downstream of the pig a fine mesh is used in terms of distance and time increment, while a coarse grid is used elsewhere along the line. This is a question of accuracy and stability against computational time. Considering the force balance across the pig solves the pig motion. Figure 4, shows x and t coordinates and indicates how the next time step is solved.

Table 1 shows the input data used in the simulation: -

Table 1 – Input Data

PARAMETER	VALUE
Internal Diameter of 10" pipeline	257 mm
Internal Diameter of 16" pipeline	375 mm
Length of 10" pipeline	900 m
Length of dry air / Nitrogen slug	Varied between 20 m and 5000 m
Length of pig	2.014 m (Seals located at 332 mm, 429 mm, and 1263 mm. Pig differential pressure distributed equally over each seal)
Length of reducer	250 mm
Pig Differential Pressure in 10" line	2 bar to 3.5 bar
Pig Differential Pressure in 16" line	0.2 bar to 0.1 bar
Reverse Differential Pressure in 16" line	0.25 bar
Mass of pig	150 kg
System pressure	43 bar to 53 bar (47 bar average)
Velocity of glycol pig train in 16" line	0.25 m/s

Output

The initial dewatering scenario involved using a 3 km dry air slug in front of the final pig. This results in the reversal of the pig near the Y-piece, which is not acceptable, Figure 5. One possible solution is to increase the gas volume so that this reversal takes place much further downstream. The resulting peak velocity is much greater and for safety and pig integrity reasons this is not deemed a suitable solution, see Figure 6.

For additional safety, it was decided to use nitrogen for the gas slug at this stage in the pre-commissioning planning. This introduced a cost and space consideration. The volume of nitrogen used should be as low as possible to reduce costs and due to storage space limitations onboard the Norne Vessel. It was therefore considered an advantage to reduce the length of the slug to a minimum, while still allowing the remaining liquid in the line and from tees to be collected.

The main drivers at this stage were: -

1. The second last pig, at the rear of the liquid train, should be clear of the Y-piece by the time the final pig emerges into the 16" line;
2. The final pig, in the gas should accelerate and reverse early and then achieve a steady state motion before negotiating the Y-piece;
3. The pig should not stop in the reducer. This could stall the pig, as there is some induced bypass past the rear module. Additionally there should be no possibility of the pig reversing back into the reducer;
4. The slug length should be reduced in length as far as practical for economic reasons;
5. The slug length should be adequate to allow the remaining liquids in the pipeline and from off-takes (tees and the Y-piece) to be collected.

Consideration of these issues placed the gas slug length in the region of 20 to 200 m. A sensitivity analysis was then performed to see the effect of variation in the main variables such as pig differential pressure, system pressure, inlet gas velocity (high case and low case) and velocity of the penultimate pig. A stiffest system case, a softest system case and the most likely case were investigated. The final slug length was set at 50 m. Figure 7 shows the output for this case with steady state motion occurring after about 6 m.

Conclusion

This case study demonstrates the successful use of dynamic pig simulation, using Piglab, in decision-making and problem solving for pigging operations. A sensitivity analysis is used to design out of a problem region, i.e. reversal back into the Y-piece. Although not all input variables were known accurately in advance, this approach allowed many possibilities to be investigated and a final slug length of 50 m to be set to avoid difficulties during dewatering. A sensible range of input values can be agreed upon for use in such a sensitivity analysis. The simulation approach also allows flexibility insofar as any changes can be included in the model and reanalysed, relatively inexpensively, when compared with testing.

The resulting slug length is likely to be different depending on the line sizes, the details of the particular pipeline, system pressure and pig type. It is also possible to estimate the forces acting on the pig modules, on the coupling between the pigs, or any potential sit-down effects on the suspension unit, using this model. Since Piglab is an open source program, it is possible to make it specific to each problem under investigation.

Thanks to Gjertrud Hausken, Jarleiv Maribu, Phil Burman and Stein Rimestad and the team at Statoil for the opportunity to develop this work.

[1] Pigging the Åsgard Transport 42" x 28" Pipeline – Breaking new ground, A Vingerhagen, Chris Kershaw, Aidan O'Donoghue, Pipeline Pigging Conference, Stavanger 1999

[2] Multi diameter pigging for Åsgard, Commissioning and pigging the 710km 42" x 28" Åsgard Pipeline, Christian Falck, Claus Svendsen and Aidan O'Donoghue, OPC, Oslo, 2000

Figure 1 – The 10" x 16" Norne Heidrun Pig

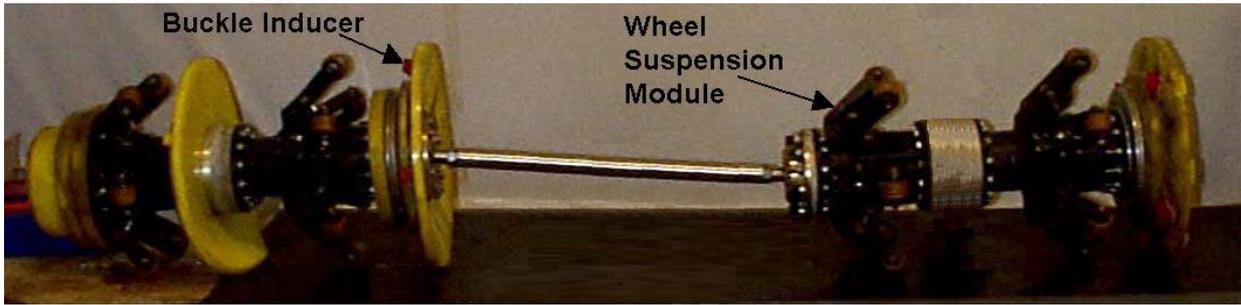


Figure 2 – The Norne Heidrun 16" Pipeline

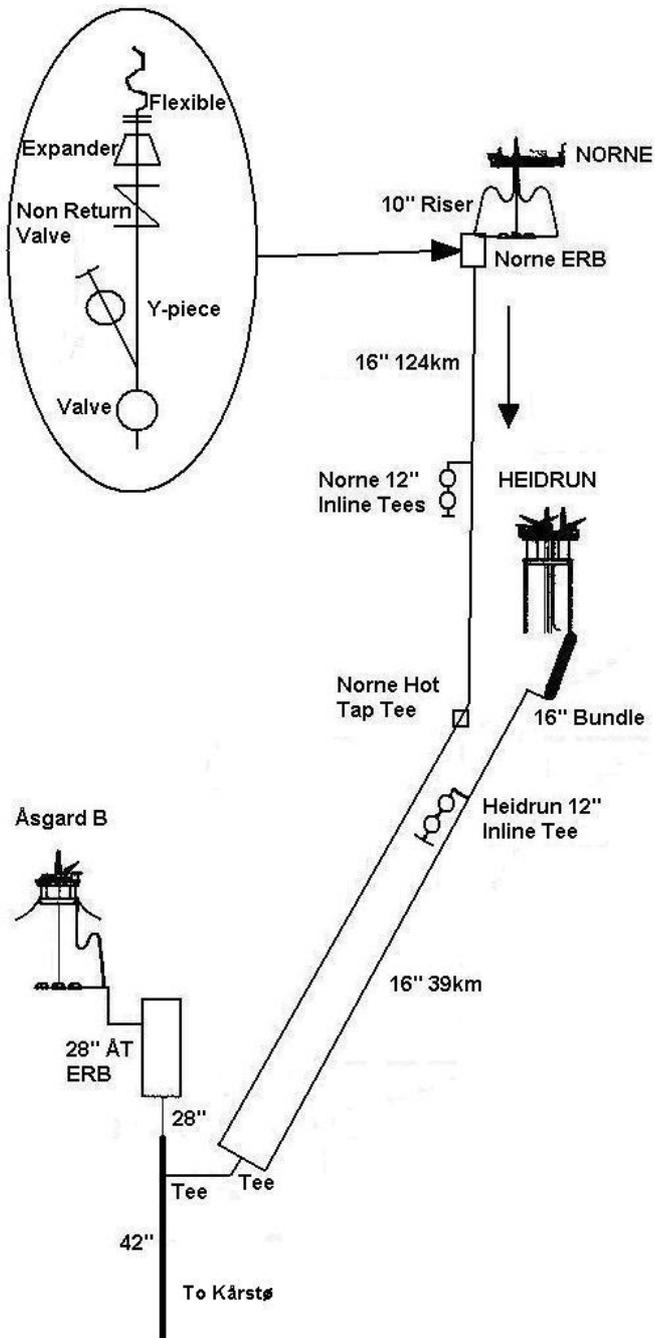


Figure 5 – 3km Gas Slug resulting in pig reversal

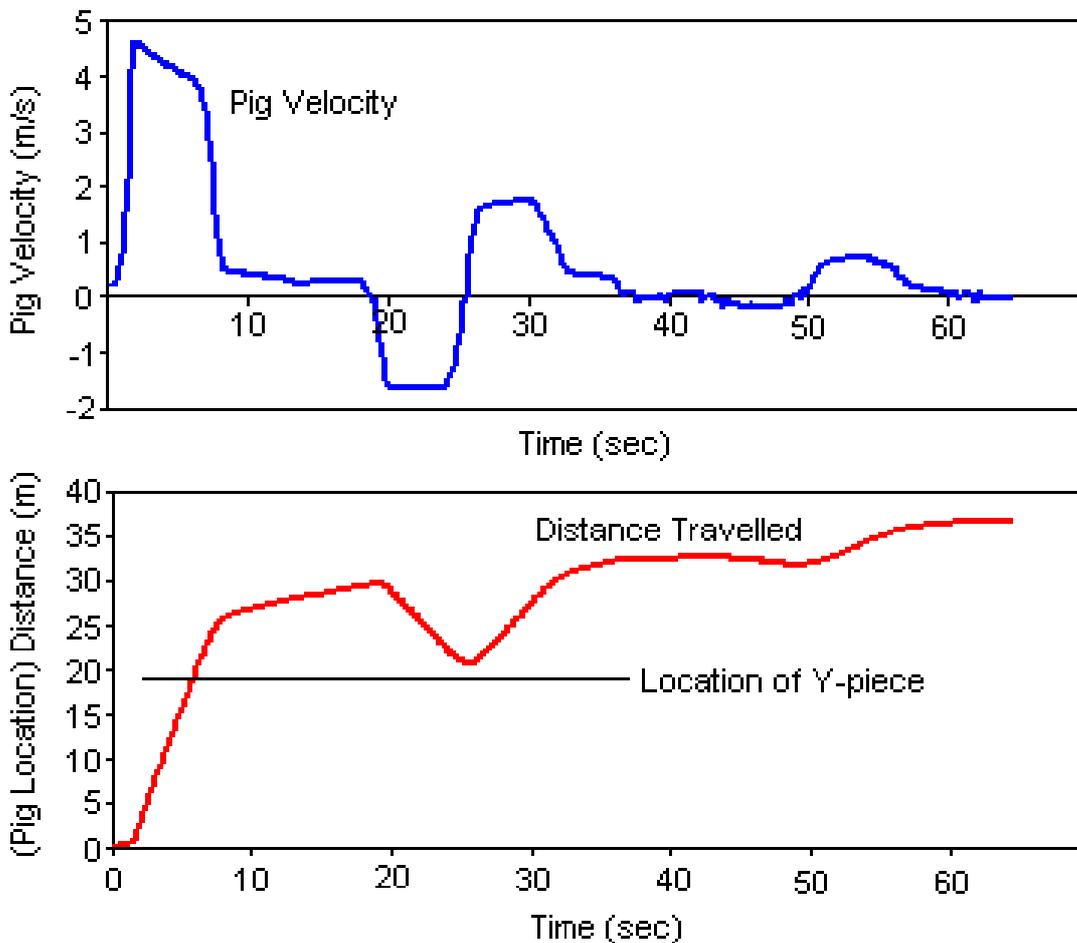


Figure 6 – 5km Slug Length resulting in higher velocity

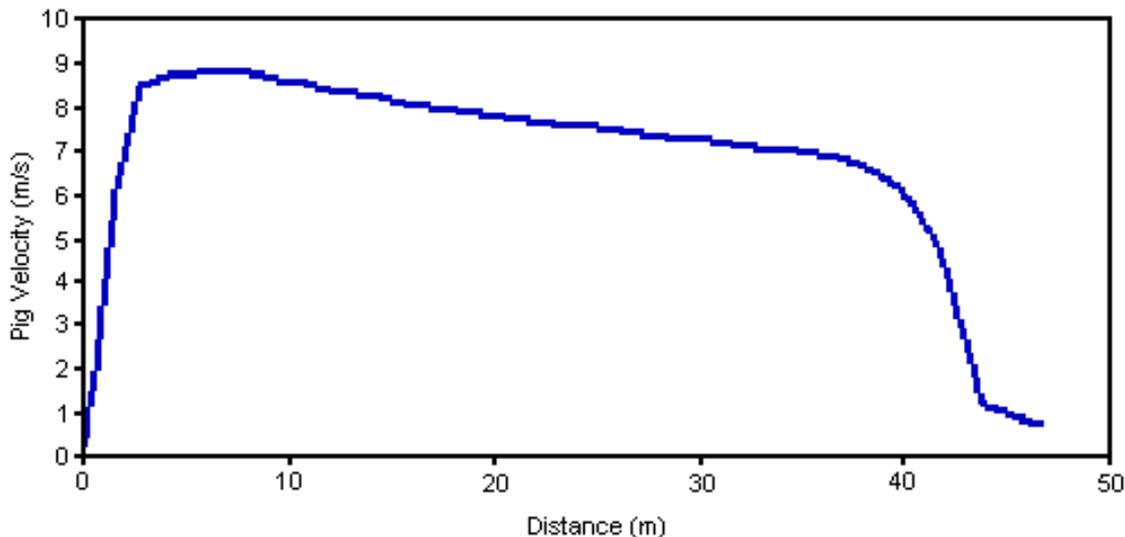


Figure 7 – 50m Gas Slug Length case

