BENEFITS OF THE USE OF HIGH-BYPASS DE-SANDING PIGS IN CONJUNCTION WITH BRUSH PIGS FOR OPERATIONAL PIPELINE CLEANING

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Abstract

The use of high-bypass de-sanding pigs, either in isolation or in conjunction with traditional brush pigs, has been proven as an effective new method for mobilising and removing both waxy and particulate debris.

This case study discusses the execution and findings of an operational cleaning campaign targeted at the removal of both waxy and particulate debris from an ultra-deepwater oil production pipeline in West Africa. The campaign utilised traditional brush pigs as well as high-bypass de-sanding pigs to remove debris for the purpose of reducing the risk of under-deposit corrosion.

This paper reviews the design of pigs for the activity across the region, focusing on the findings of the first operational pigging campaign and related findings from a later ILI campaign in the same pipeline. It will describe the cleaning requirements and the tool types engineered for the operation, including the difficulties of design for the pipeline geometry and operating conditions. The paper will also review the high-bypass de-sanding pig; its design, function and operation, and how it complemented the capabilities of more traditional brush tools.

Introduction

As part of ongoing pipeline integrity management, a major operator required the engineering of a capability to carry out operational pigging in five ultra-deepwater oil production pipeline loops at two FPSOs in West Africa. Of the five pipelines, only two had been previously pigged, both for baseline ILI.

The region-wide pigging strategy put in place enables regular operational pigging in each of five pipeline loops on a routine basis and also as a response to particular production events, such as detection of gravel pack failure and significant sand ingress into the pipeline.

The need to commence regular pigging in each pipeline is triggered on a pipeline-by-pipeline basis once water cut in the produced fluids rises above 5%, due to the risk of under-deposit corrosion at high water cuts. Each pigging operation requires the pipeline loop to be shut-in and displaced, resulting in costly periods with no production. Pigging activities must therefore be optimised to reduce the production impact of pigging.

Regional pigging requirements

The primary requirement for operational cleaning in these cases is to remove debris accumulating in the pipeline to minimise the risk of under-deposit corrosion, assist flow assurance and reduce the extent of future pre-ILI cleaning campaigns.

Following a review of the operating conditions and production fluids in each pipeline, the likely debris types across the region were deemed to include wax, sand and potentially asphaltenes. Wax and sand were expected in the pipeline.

All five pipelines covered by the regional pigging strategy contain flexibles and CRA clad sections, limiting the aggressiveness and pig materials that can be used for cleaning. Additionally, a number of the pipelines are multi-diameter and include wye pieces, further complicating the pig design requirements. Therefore, the pigs needed to be able to pass a number of complex features and components whilst also retaining the ability to remove the likely debris types.

Design of pigs

Consistency of pig types and designs across the five pipelines was desired to simplify the process for the operations teams at each FPSO.

Three pig types were specified to be run as part of operational cleaning campaigns in each pipeline:
- Wire brush foam pig
- Brush cleaning pig
- De-sanding pig

The wire brush foam pig provides initial cleaning and scraping at a low risk of the pig getting stuck (especially applicable for the first operation in pipelines that have not yet been pigged).

The brush pig is a standard bi-directional pig with two brush discs, one on the front disc package and one on the rear disc package. As with most bi-directional brush pigs, the intention of the design is for the seal discs and brushes to scrape wax and other debris from the pipe wall which is then driven out entrained in the brushes and in front of the seals.

The de-sanding pig is uni-directional and fitted with segmented cups and sail discs for sealing. No cleaning elements are fitted to the de-sanding pigs. The cleaning capability is provided entirely by bypass flow designed through the core of the pig. Six bypass holes are machined through the spacer discs and retaining flanges in the front and rear disc packs, equivalent to a cross-sectional area of approximately 1.5% of the average bore of the pipeline. Bypass calculations show that at the preferred flowrate for 1m/s pig velocity and with a differential pressure of 1 bar across the pig, bypass through the pig is approximately 12% of the flowrate.

The flow through the tool is intended to generate a jetting effect and turbulent liquid flow immediately ahead of the pig, bringing particulate-type debris that may have settled on the bottom of the pipe into suspension within the flow, and carrying it out of the line. Such pigs are not uncommon for use in dry gas lines to remove particulates that may settle on the bottom of the pipe but are less commonly used in liquid lines where brush pigs are predominantly used for removal of wax and other debris types.

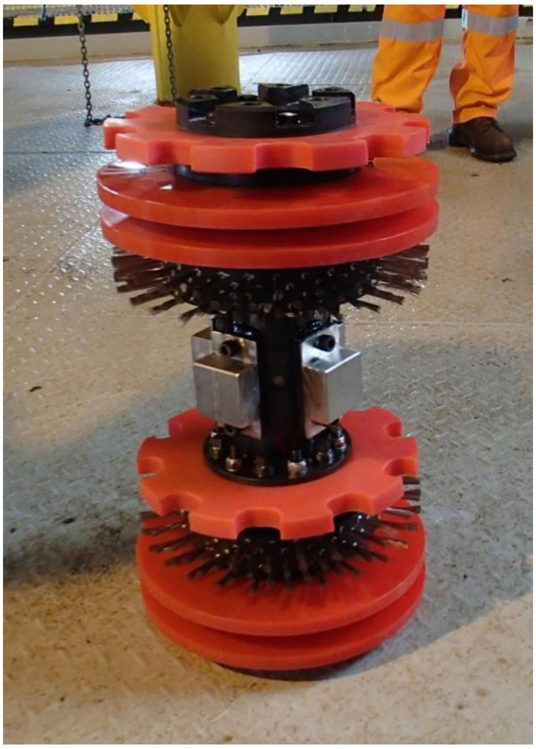

Figure 1: Brush pig

Figure 2: De-sanding pig

First operational pigging campaign (2014)

The offshore pigging operation described in this paper was conducted in one of the multi-diameter pipeline loops (12”/14”) which exhibits a bore variation from minimum to maximum ID (including acceptable manufacturing tolerances) of almost 30%.

The pigging loop consists of a service pipeline and a production pipeline, with hybrid rigid and flexible risers at either end connecting the subsea infrastructure to the FPSO. Pigs are launched to the service riser and recovered from the production riser having passed through the subsea pipeline loop at 2000 m water depth.

The pipeline had never been pigged during operation, and commissioning pigging had not been completed fully, meaning additional magnets were fitted to the brush pig body to collect metallic debris potentially left in the pipeline from installation. The quantities of installation and operational debris to be expected were not well known due to the lack of past pigging activities in the pipeline, but the expectation was that a significant quantity of hard wax was highly unlikely due to:

- The operating temperature of the line being consistently above the wax appearance temperature since production start-up
- The lack of any long-duration shutdowns which could have led to product cooling, wax drop-out and solidification

Given the anticipated debris was mostly soft wax, the expectation prior to the first pigging operation was that the wire-brush foam pig and brush pig would return more debris than the de-sanding pig, which had been specified to mobilise and remove any particulate-type debris which wasn’t already entrained within the waxy debris brought out by the brush pig.

FPSO operations required that water flushing and nitrogen purging of the pig receiver had to be carried out prior to opening the door and retrieving each pig. It was therefore not known how much of any returned debris had been washed away through the drain system prior to opening the door.

A very small amount of soft, sludgy wax debris was retrieved with the wire brush foam pig. A larger but still very small quantity of similar debris (c. 800ml of soft wax with entrained particulate (corrosion by-product)) was returned with the brush pig, with the majority held to the magnets fitted to the body and spacer discs (see Figure 3) and no retrievable volume of debris found in the receiver itself. It was therefore considered unlikely that measurable debris returns would be retrieved from any of the pig runs as there was either minimal debris in the pipeline, or whatever debris was being returned was being flushed away before the pig receiver was opened.

Figure 3: Brush pig with debris

On receipt of the brush pig, benzene (a known carcinogen) had been detected resulting in the receiver being left open to aerate for a few minutes before the pig could be removed. As such for the subsequent de-sanding run, the flushing and purging operations were carried out for longer to reduce the probability of benzene being present, lowering further the expectation for any recordable level of debris to be recovered when the receiver was opened.

On unloading the de-sanding pig however, around 10kg of sludgy wax debris with entrained particulate debris was present in front of the pig, around 15 times the quantity returned by the brush pig run before it.

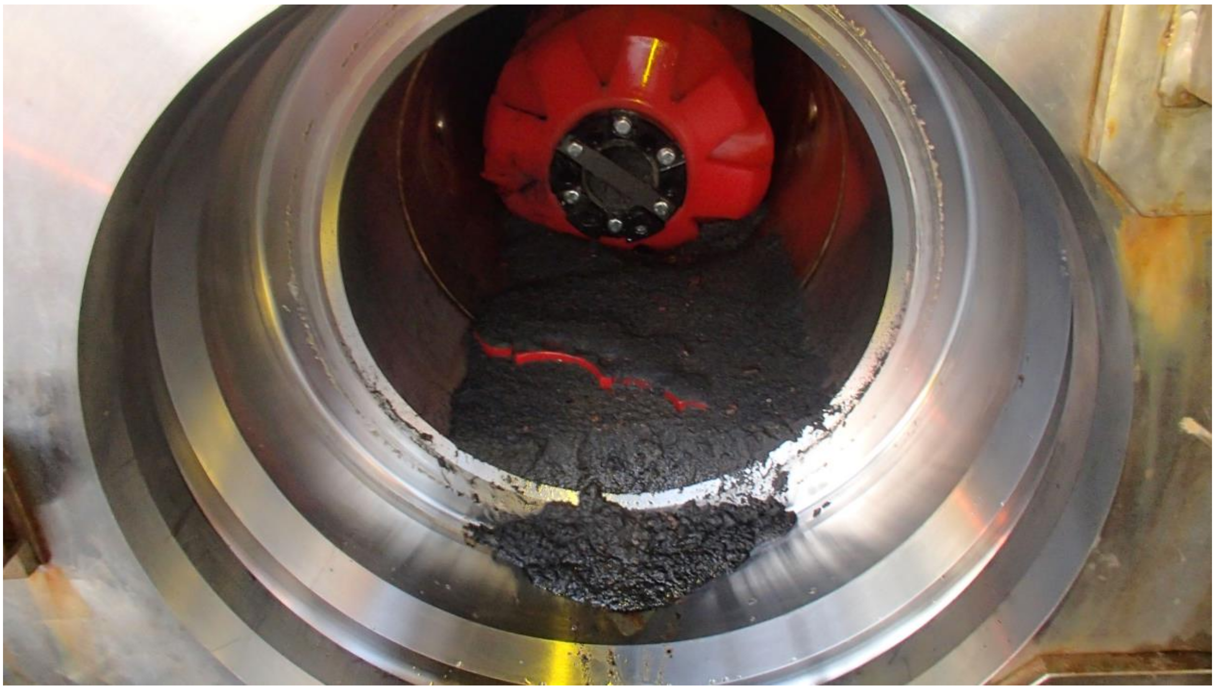

Figure 4: De-sanding pig and debris in receiver during operational cleaning

Although the exact quantities of debris returned by each pig are unknown due to the flushing and purging operations, the same process was carried out prior to unloading each pig and therefore comparison of the quantities still present in the receiver after flushing and purging gives a good indication of the relative cleaning efficiency of each pig run. Furthermore, the extent of flushing was greater for the de-sanding pig which still returned significantly more debris than the traditional brush pig.

Pre-ILI cleaning campaign (2015)

A year after the initial operational pigging campaign, an ILI campaign was executed in the same pipeline loop using pigs of the same design with some minor changes. During this operation, nine pigs were run including plain foam and wire brush foam pigs, a de-sanding pig and brush pig, gauge runs, dummy ILI run and finally a UT ILI tool. Benzene was detected on opening the receiver for all pigs and, as such, the extensive flushing and purging operations were once again carried out.

Most pigs (including the brush pig) were unloaded with little or no debris retained in the receiver, which was unsurprising given the extent of flushing and purging. However, as with operational pigging the year before, the de-sanding pig brought back 15kg of soft wax mixed with particulate debris. Figure 5 and Figure 6 show the equivalent debris returned by the de-sanding and brush pig respectively on opening the receiver (both photos taken immediately after opening the door, before any trap cleaning had taken place).

Figure 5: De-sanding pig and debris in receiver during pre-ILI cleaning

Figure 6: Brush pig in receiver during pre-ILI cleaning

Benefits of de-sanding pig use

Improved efficiency of operational cleaning and reduced risk of failed ILI runs

Soft wax, although easier to remove from pipelines than hard wax or scale deposits, can be very problematic for in-line inspections, especially for UT tools, as the wax can cling to individual UT sensors or clusters of UT sensors and result in signal loss and reduced quality of data.

The use of de-sanding pigs in progressive cleaning campaigns or in conjunction with brush pigs may allow for pre-ILI cleaning to be completed more effectively for certain debris types and with fewer runs than with brush pigs alone.

Increased suitability for use in multi-diameter lines

It is very difficult to optimise a brush pig for cleaning in multi-diameter lines.

Typically, if the brushes are sized for the larger bore section, the risk of a stalled or stuck pig in the tighter bores increases. Alternatively, if the smaller section is traversed first, the brushes will be permanently deformed backwards (Figure 7) before they reach the large bore section they have been designed to clean. Similarly, if the brushes are sized for the smaller bore, they will not adequately clean the larger bore sections.

The de-sanding pig design is significantly more flexible than a brush pig design due to the use of flexible cups. There is also no need for any cleaning elements to interact directly with the pipe wall.

This increases its value in multi-diameter lines as the cleaning mechanism is equally effective in both the larger and smaller bore sections.

Figure 7: Brush pig with brushes permanently deformed backwards after passage through multi-diameter pipeline

Reduced cleaning aggressiveness for vulnerable pipeline components

Brush pigs are generally (but not always) compatible with vulnerable components within some pipeline systems, such as flexibles, CRA clad pipe sections etc. The de-sanding pig offers a non-aggressive method for cleaning soft and particulate debris from pipelines where it may not be advisable to run brush pigs; or where brush pigs are required to be less aggressive to avoid damaging CRAs etc.

Additionally, the jetting effect may facilitate removal of debris from the grooves in the internal carcass of flexible sections, where brushes would not be as effective.

Conclusions

A basic conclusion of the two cleaning campaigns carried out is that the de-sanding pigs are a credible complement to traditional brush pigs for the removal of soft wax and debris from oil pipelines. This is an expansion of their more typical use in dry gas lines.

The efficiency of the de-sanding pig may be optimised when run in conjunction with a pig utilising brushes, although currently there is insufficient field evidence to conclusively prove this. It is possible that the brush pig disturbs soft wax from the wall of the pipe but is not particularly efficient at removing it, most likely due to the soft wax being disturbed but then smeared back onto the pipe wall by the rear discs on the brush pig. The de-sanding pig with the high-bypass jetting effect can then be used to remove this disturbed debris by generating turbulent flow.

However, during the pre-ILI cleaning campaign, the de-sanding pig was run before the first hard-bodied brush pig (but after a wire brush foam pig), indicating that de-sanding pigs may also operate equally efficiently at removing sludgy-type debris in isolation.

Further field experience using these pigs in other pipelines is vital in validating the findings of the two campaigns described in this paper. However, there is indicative evidence that such pigs should be more commonly used in cleaning of oil pipelines where hard wax is not expected to be an issue but some soft wax deposition is likely.