Abstract

Pigging of pipelines within the oil industry has been around for well over 100 years and has been used as the preferred (if not the only) internal method for cleaning, maintaining operational efficiency, data gathering and inspection for integrity management purposes.

The benefits in carrying out routine “operational” pigging cannot be underestimated and operational pigging to remove water, wax, scale and other debris which is formed during routine operations whilst transporting crude oil and gas is paramount in maintaining the integrity of any crude oil and gas pipeline system. The build up of such debris is common whether the pipeline is offshore between production platforms, from a production platform to onshore or a totally land based pipeline.

Similar problems are encountered to varying degrees dependent on pipeline size, location and type of the crude product being transported.

Pipelines are normally designed for a specific maximum flowrate, this maximum rate is generally maintained on a “plateau” for several years of a field’s life, during which routine pigging operation presents little or no real problem to the pipeline operator. The cleaning pigs which are used are generally designed for the “maximum” of “potential flowrate” which the pipeline is due to see during it’s plateau phase of operation. This assumption, that these pigs will be suitable for the life of field operations, is common place with pipeline operators and as such there is a significant increase in the risk that pigs will become “stalled” on a regular basis or potentially “stuck” causing significant disruption to operation, production and in the worst case scenario a very costly subsea intervention. As can be seen from Industry Analysts¹ there will be a decline in overall oil production not just from the UK Sector but from the North Sea Basin and Europe as a whole. Therefore the need to understand pigging operations in “low flow” modes of operation cannot be stressed highly enough.
Purpose of Paper

The purpose of this paper is to discuss pipeline pigging operations in an environment during late field life. The experiences detailed here are based within the North Sea, where, flowrates have dropped off significantly from their plateau and this has or will have the potential to cause significant challenges for the pipeline operators in terms of:

- Types of pig and pig design – optimisation of pigs for a low flow regime
- Pig bypass – understanding the need to have this correctly sized (both front and rear ports)
- Launch and receive operations – the best chance for success
- The importance of “pig speed”
- Increased potential for “stalled pigs” – recovery whilst maintaining production
- Higher water cut in ageing fields -maintaining operational pigging frequency
- Increased runtimes – the impact on the ability to optimise cleaning.

The topics discussed are not limited to operations within the North Sea but would be applicable to any crude oil pipeline where flowrates have significantly reduced from their “plateau”.

There are numerous other papers and articles which provide more detailed information on many of the topics contained within this paper. The intention is not to duplicate these but to provide some guidance and overview based on the experience gained within the North Sea which hopefully can be shared with pipeline operators to minimise pigging problems as crude oil production declines during late field life. In addition to provide guidance on operationally proven “non-intrusive” actions which can be taken to recover “stalled” pipeline pigs.

Types and Design of Pigs

The most common types are Bi-Directional Pigs. These are used to sweep lines of wax, debris and water. To make them more aggressive brushes or scrapers can be added to them so that the pipe-wall can be cleaned more thoroughly. If, for example, a pipeline has not been pigged for some time, a specifically designed “progressive” cleaning programme should be implemented starting with the least aggressive pig e.g Foam Pig.

If an obstruction within the pipeline is suspected a Slotted Gauge Plate can be fitted to a normal Bi-Di Pig. This gauge plate is usually a circular aluminium plate sized to 95% of smallest internal diameter within the pipeline system.

There are various other types of pigs and specialist pigging tools².

The pig design is at the operators discretion but it is recommended the operator works alongside a suitable pigging contractor to ensure that the pigs are designed for the current operating conditions of the pipeline i.e. Pressure, Flowrate and that all relevant pipeline characteristics are taken into account such as, but not limited to, Pipeline Length, Wall Thickness Range, Minimum Internal Diameter, Minimum Bend Radius / Angle and any Barred Off-takes.

Pig Velocity

Pig speed is critical for operational pigging, the reasons for this are:

- Optimisation of debris removal
- Prevent “stalling of pigs”
- Ensuring successful launch and receipt

The speeds recommended for cleaning pigs which allow optimal cleaning are in the region of 1 to 5 m/sec. This velocity (and sometimes even higher velocities) can easily be obtained in pipelines where fields are close to or at the “plateau” phase, however with numerous North Sea Oil Fields’ production declining, pig speed in some pipelines is nearer 0.1 – 0.5 m/sec!! This drop in pig velocity can cause several problems:
• Sub-optimal removal of free water and debris
• Increased risk of “stalled” pig
• Significant increase in pig run times
• Increased potential of “mis-launch”
• Increased difficulty in pig receipt

In practice however, pig velocity is dictated by process conditions and pipeline flowrates and the operator, in reality, has very little control over this factor as in general an oil field will produce at as high a rate as possible which obviously is beneficial to pigging operations.

By way of example, the 36 inch Brent Pipeline running from Cormorant Alpha to Sullom Voe Terminal in the Shetland Island, a distance of 152 km:

Current Pig run time 10 days @ 100,000 bbls/day - Pig Velocity 0.18 m/sec
Pig run time 1 day @ design flowrates 1,000,000 bbls/day - Pig Velocity 0.95m/sec

It therefore becomes critical that operational pigs are designed for prevailing pipeline conditions but even more critical is the calculation of “pig bypass”, a factor often overlooked by many operators but critical to operational pigging velocity and hence success.

**Bypass**

Pig Bypass (as mentioned in the previous section) is one of the most important (and most commonly overlooked) aspects during operational pigging with regard to pig velocity and maintaining the optimal differential pressure across the pig. For example, sometimes front bypass is closed more than the rear to ensure the pig is “driven” from the front. Consideration also needs to be given so that the discs do not flip over and stall the pig.

Usually pigs are designed with a number of bypass ports. The bypass ports are used to provide the pipeline operator the facility to “alter” the pig configuration and dependent on the number of open/closed ports the pig velocity will change significantly.

Pig velocity can be altered by changing port configurations and once fully understood by pipeline operators, operational pigs can be “set-up” to optimise runtimes and cleaning effectiveness.

However, one misconception is that in the event of a “stalled” pig, unless the pig has 100% bypass i.e. all ports are open, then there is a risk of stopping production in a pipeline. This in theory is possible, but a pig with little or no bypass becomes stalled for any reason it will be easier to “kick-start” as a higher differential pressure will be generated for a similar flowrate compared to a pig with full-bypass.

In reality operating experience has shown that pigs with all bypass ports open run a significant risk of becoming “stalled” in a low flow pipeline particularly if flow is interrupted by a process trip or other such operational problems.

With full bypass and a “stalled” pig, there will be significant problems “kick-starting” the pig unless some remedial action is taken e.g. altering flow conditions.

Using operational pigs with full bypass is fairly common place, from experience, unless there is good reason, a pig with full bypass should not be introduced into a pipeline with flow velocities under 1m/sec as the risks of this pig becoming “stalled” rises significantly and the velocity will be so low as to offer no real cleaning/debris removal benefit for the pipeline.

Pigs should be configured with the correct number of bypass ports open/closed to maximise the cleaning of the pipeline and also optimise the runtime to allow the recommended frequency to be maintained.

Additionally there may be value in increasing the number and size of bypass ports on pigs
used in low flow pipelines. By doing this, more flexibility will be available to the pipeline operator when calculating pig bypass. This modification can easily be carried out during refurbishment.

Pig Refurbishment

Pig Refurbishment entails checking the pig is still fit for the service. Minimum checks include: Cleaning (removal of debris), Polyurethane (PU) Disc wearing checks (discs will wear due to contact with the pipe wall), Load Testing (for pigs sizing 20” and above the lifting points need to be recertified every 6-months), checking nuts and bolts. Furthermore it is important each pig has a tag plate with a unique pig identification e.g. TAQA’s Cormorant Alpha has 5 different oil pipelines importing or exporting crude oil. Therefore unique identification is essential to ensure pigs are not “lost”. Other additional checks can be performed as per operator such as NDT on body of pig, shot-blasting and recoating.

There is no set recommendation for how often a pig should be refurbished as it is dependant on a number of factors such as “Length of Pipeline”, “Operating Conditions” and the judgement of the platform operational personnel along with the operators onshore pigging focal point. Performing this task in a phased/organised way prevents any delay to normal pigging i.e. ensure enough pigs are on the platform.

Launch/Receipt Procedures

The launch and receipt of operational pigs, despite being “routine” operations for the majority of pipeline operators, does not come without it’s own set of problems when dealing with “low flow” pipelines.

First of all if we consider pig launching, there are a few potential problems which may occur if the correct procedures are not followed leading to a “mis-launch”, the pig becoming stuck on topsides pipework or even worse the pig is damaged by the launcher isolation valves during its transit to the pipeline. This can be caused by a single or a combination of contributing factors:

- Insufficient differential pressure within the trap
- Damage or significant wear to pig sealing discs (not noticed at time of loading)
- Incorrect valve line up
- Insufficient flow through launcher

Additionally, the situation can be confused further if a pig signaller (not always present) does not work, which can happen thereby making it difficult for the platform operator to confirm if the pig has left the platform or not as the case may be.

In practice in a “low flow regime” it is essential that the kicker line valve is fully opened during launch to allow the maximum flow possible to the trap in order to build up sufficient differential pressure between the trap and the pipeline for the pig to move and prevent it stalling in the topsides pipework. Despite the majority of operating procedures stating this, in practice this does not always happen, and pigs can end up either not leaving the launcher or becoming “stalled” on leaving the pig trap or close to the barred tee.

If a pig becomes trapped on one of the isolation valves, damage can be severe. The pig can be “held up” by the pig launcher isolation valve after a mis-launch. This occurred in a North Sea pipeline recently and in this case, the pig did transit the full length of the pipeline to allow removal but the run time was extended significantly with numerous attempts to recover it before it finally reached the platform. However, catastrophic damage has the potential to take place in which case the pig may have broken up leaving a very difficult recovery job with the added risk of pipeline damage from the resultant debris. Additionally damage to the launcher / receiver isolation valves may take place. If this occurs and damage is severe, isolation of the launcher / receiver may not be possible delaying future pigging operations until repaired.

Pigs stalling at the barred tee are not so much of an issue, as experience has shown that a
“dummy launch” with the subsequent “kick” in flowrate is enough to move the pig. There is one exception, during the launch of a foam pig, it is essential that it does not stall at the barred tee as there is a potential for the pig to break up.

Pig signallers can aid in detection of pig launch and it is imperative that these are maintained and in working order to ensure that conformation of pig launch can be made by operations staff. Also, the use of non-intrusive equipment - eg “PigSpy” can be used to determine the arrival of a pig. This type of device is not “fixed” in one location but can be moved between pipelines. This can be useful if there are several launchers or receivers on a single installation.

Receipt of pigs can also be problematic when dealing with low flow conditions. Again the problems can be similar to those with the launching of pigs. The key factors during receipt are:

- Ensure trap is exposed to 100% of the pipeline flow
- No flow through bypass during receipt operations
- If pipeline is “waxy” flush the wax through the receiver
- Correct valve line up

Experience has shown that during receipt operations when the full flow is not routed directly through the receiver; difficulties may be encountered in getting the pig into the receiver with an increase chance of the pig becoming stuck in the riser or topsides pipework. This is a particular problem if the pig receiver is vertically inclined.

Additionally another problem which can exacerbate the receipt of a “stalled” pig is a build up of a wax “candle” in front of the pig. This can be a problem if the line has not been pigged for some time, again if the line is waxy, it is better to “flush” the receiver prior to bringing the pig into the trap. By doing this the risk of getting the pig “stalled” on topsides pipework can be reduced significantly. The disadvantage is that the pig trash (wax, debris, water) which gives a good indication of pipeline condition is lost.

Stalled Pig

The implications on production and pipeline integrity of having a stalled pig in a pipeline are potentially very severe. Usually pigs will be designed to allow a flow of product through the body, in this case there is no immediate concern as platform production can continue as normal. However, if no action is taken to remove the pig a number of issues will become apparent:

- Wax will build in front of the pig making it more difficult to move with potential of a full blockage;
- No pigging will result in losing internal pipeline integrity (water will collect at the 6 o’clock position and eventually start corrosion) Timescale can be as low as 12-18 month depending on current pipeline history;
- Inability to get corrosion inhibitor into pits as water cannot be “swept” from the line;
- Potential to limit production;
- A high Differential Pressure at pig location (due to small flow area).

If the worst case scenario is that the pig has no bypass, and the discs flip, then the risk is potentially stopping production and requiring an expensive intervention to cut it out. The difficulty here is that “normal” operational pigs do not routinely have tracking devices fitted. In order to locate a blockage a second pig with a tracker may be sent. Using this method, an ROV can be deployed to identify the location. The limiting factor of this equipment is the battery life of the transmitter.

Another example of pig damage in the North Sea was when a pig stalled in a 20” pipeline for 3-months. On receipt the PU Discs were flipped and stressed. This is minor damage and required a new set of discs at refurbishment.
Non-Intrusive Actions

In the event of a pig becoming stalled in a “low flow” pipeline, there are several “operational” options available which can be tried to get the pig moving. These are all non-intrusive and as a result are reasonably low risk. In addition they will have very little impact on production; indeed some of the options may boost it! See appendix 1 for typical recovery flowchart.

Checking Platform (Steps 1 and 2)

Check platform logbook of launch time, date and more importantly pig tag number. Confirm from onshore this was the pig to be launched. In addition perform a check of the pig launcher and the platform for this pig number. Furthermore a quick check on PII Process Book or relevant data system to trend Pressure, Temperature and Flowrate over the pig run time. This could uncover any anomalies (for example a pressure spike could indicate there’s an obstruction).

Checking Topsides Pipework (Step 3)

A very simple and effective check is to ensure the pig has left the topside pipework from the launch platform. Similarly a check can be carried out on the receive platform. The methods are as follows:
- Thermography (temperature)
- Acoustic Monitor (sound)

Dummy Launch (Step 4)

This can dislodge the pig if it is stalled topsides.

Check Receivers / Signallers (Steps 5, 7, 10 and 12)

Allow a normal pig run time before opening up receiver as per platform procedure. Potentially check signallers once per shift.

Flowrate Increase (Step 6 and 9)

Increasing flowrate has the effect of restarting the pig from its stalled position. However, it should be noted that this is more effective in shorter lengths of pipeline ~ < 40km. The options available to do this are:
- Increase separator level with production fluids
- Increase separator level with produced water
- Increase flow rate in pipeline with water injection (temporary water pump)

The Role of Wax Inhibitor /Wax Dissolver (Step 8)

Dependent on the type of crude oil being transported, in the event of a pig becoming “stalled” in a pipeline for an extended period, there may be a considerable risk of significant wax build up. Wax will tend to be deposited on the pipewall (where we would normally expect to see it) but also and more importantly in front of the “stalled” pig. This, dependent on wax quantity and quality, may have serious implications in attempts to “mobilise” a pig after it has been static in a pipeline for some time. If this is the case, consideration should be given to the injection of wax inhibitor.

Wax inhibitor can be used to prevent/limit further build up of any wax deposits in a pipeline and may be of use if pipeline crude is particularly waxy or the pipeline has a history of significant wax build-up.

Wax dissolver could potentially be used to remove any wax build-up in front of a “stalled” pig.
Wax dissolver should be seen as potential option once less aggressive non-intrusive methods have been tried/ruled out. However there are risks with the deployment of such chemicals and these include:

- “Slug” of chemical required
- Difficulty in deploying dissolver to location of pig
- Potential to remove wax upstream of pig (this may exacerbate problem)
- Consents may not be in place to allow deployment
- Chemicals tend to be fairly aggressive

Launch a Foam Pig (Step 11)

The launch of a foam pig would result in sealing up the pig bypass ports and potentially push both the mechanical pig and foam into pig trap. However dependent on the density of the foam, they are designed to withstand a certain Differential Pressure (circa 20bar) and will extrude through the pig. Foam break-up could provide some process issues in which the debris would enter valves, receiver and separator. One of the disadvantages of using a foam pig is that a pig “cassette” may be required and delays may occur whilst relevant modifications to accept the foam pig are carried out offshore.

Launch of 2nd Mechanical Pig (Step 13)

If all other options are unsuccessful then the launch of a second BI-DI pig is required. Firstly a quick check to calculate if the pig receiver can accept two pigs is required. If suitable then a Pig may be designed with zero bypass to ensure best chance of recovery. This is a potentially high risk operation in that two pigs may become stuck and production may require to be curtailed until the intervention takes place.

Conclusions

As can be seen, there are many actions which a pipeline operator can take to reduce the risk of a pipeline pig becoming “stalled” or, in the worst case scenario, “stuck”. The majority of can be made “proactively” before the pig is even sent to the launching station/platform, it does however require that the pipeline operator does understand fully the pipeline operating conditions, type and design of the “pig fleet” and ensuring all procedures for launch and receipt are up-to-date and are fully understood and adopted by all operations personnel.

More importantly it is imperative that operators understand the “non-intrusive” options available if a pig does become “stalled” and these are provided within the flowchart in this paper. This shows the possible investigative/and operational options open to pipeline operator whilst dealing with this type of issue. The thought process and logic used to create the chart has been gained during experiences in dealing with such issues within the North Sea, whilst it may not be complete, the logic has been proven to work on several occasions.

The use of such a “logical” flowchart process can ensure that all options and possible issues are covered and exhausted prior to making a decision which may introduce a higher risk to operations e.g. launch of a second pig or other intrusive actions to aid pig recovery.

References

1. Department of Trade and Industry, Analysis and Forecast, LBST;
2. An Introduction to Pipeline Pigging by Pigging Products and Services Association.
Appendix 1 Recovery Flowchart

1. Check Pig Launch is in Platform Log & Pig Tag No.
2. Check Platform for this Pig. Open Up Launcher and check if Pig is present.
3. Try Thermography and/or Acoustic Monitor on Topsides Pipework to aid pig detection
4. Carry out Dummy Launch
5. Check Pig Receiver
6. Flowrate – oil
   Increase Separator Levels to allow max flow for as long as operationally possible
7. Check Pig Signallers and Pig Receiver
8. Use Wax Inhibitor / Dissolver.
9. Flowrate – water
   Inject Produced Water to increase flowrate for as long as operationally possible
10. Check Pig Signallers and Pig Receiver
11. Launch Foam Pig
12. Check Pig Signallers and Pig Receiver
13. Launch Metal Bodied Recovery Pig

Evaluate Non-Intrusive Options
Ensure Pig Signallers on Traps
Repeat Step 6 and 7.