OVERCOMING THE CHALLENGES OF CLEANING AND INSPECTING WAXY PIPELINES IN MATURE OIL FIELDS

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Operators of mature oil fields are facing more and more challenges inspecting their aging crude oil pipelines. The installations are reaching or exceeding the end of their design life and accordingly require more thorough inspections. At the same time production decreases, resulting in reduced flowrates and increased accumulation of wax within the pipelines. Often the need for frequent maintenance pigging is underestimated. The requirement to carry out an extensive cleaning regime ahead of an ILI inspection is inevitable.

Several steps are required to ensure a smooth operation. First of all information from previous operations is reviewed. Together with an analysis of the product assumptions on the status quo of the pipeline can be made and a progressive programme consisting of different types of cleaning pigs is established. During the execution the results of each run are carefully monitored and compared against the pre-defined acceptance criteria until satisfactory results are achieved.

Even if all acceptance criteria have been met or exceeded some uncertainties towards the true condition within the pipeline remain. It is therefore crucial to identify an inspection method that is not sensitive to small amounts of residue. At the same time it must deliver highly accurate results to gain the full value of the extensive operation and minimise re-inspection requirements.

Experience shows that with sufficient emphasis on the planning phase and the right selection of cleaning pigs, followed by the use of appropriate inspection tools, an efficient operation can be carried out with a reasonable amount of effort.

NOTE: The paper refers to cleaning and inspection of waxy oil pipelines. However, nearly all aspects can be applied in the same way when dealing with other cleaning operations such as scale or dust in gaseous environments.

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Approach To Cleaning Waxy Pipelines

Maintaining waxy pipelines in a more or less clean state is a challenging task. A complex cleaning programme has to be established and executed, but more critically constantly monitored and adapted to achieve this successfully. High demands on personnel and equipment stand against little impact on the operation of the pipeline during day-to-day business. The lack of resources and - what is assumed to be - cost saving initiatives often lead to the approach of running a standard bidi cleaning pig "when possible". Record keeping is typically reduced to noting down launch and receive dates, details of type of wax and amount received are not evaluated - if available at all.

The only time this approach shows its shortcoming is when an inspection of the pipeline is due. To achieve optimum measuring results the inspection tools require a fairly clean pipe surface. Without a doubt the most critical technology is UT. Different strategies have been developed to prevent accumulation of wax on the sensor carrier and improve the overall inspection results. However, remaining wax layers on the pipe surface may prevent successful inspection of the complete pipe surface.

Known as a much more robust technology the versatile MFL is therefore often considered as a good alternative to UT. However, the physical requirements of yokes, magnets and brushes actually make these tools fairly efficient "cleaning pigs" (ref Fig1). In worst case this efficiency can lead to such a large accumulation of debris in front of the tool that an impact on the operation cannot be excluded.

Figure 1: MFL/Geo tool after run in insufficiently cleaned pipeline

To ensure a successful inspection the requirement of a considerable number of cleaning runs is widely recognized. However, the implementation in many cases seems more like a trial-and-error exercise. Often an initial programme is developed, cleaning pigs are run and the results are evaluated. Consequently modifications to the tools and the programme are proposed. Occasionally some sort of wax determination tools are used to support the evidence and monitor the cleaning programme until the pipeline is sufficiently cleaned and the inspection can commence.

Without a doubt this nearly scientific approach typically leads to the best possible cleaning results and is often the base for many success stories and case studies. Unfortunately, in hardly any case these results are achieved within the original time frame and budget, valuable resources are occupied over weeks or even months.

Especially for offshore operations with long turn-around times and much higher mobilisation cost, less flexibility and sometimes limited communications a more efficient approach is required. The key parameter to be considered are:

- **Progressive approach:** At any given time the integrity of the operation must take precedence over the desire to complete the programme in a period as short as possible. The only way to achieve this is by applying a progressive approach. The programme is split into well defined stages and only after a cleaning pig achieves an agreed result the next level commences.

- **Redundancy:** For each cleaning phase a sufficient number of cleaning tools must be available. The cost for mobilizing and then not using a cleaning tool is marginal in comparison to cost of standby and delays caused by mobilisation of additional equipment.

- **Knowledge:** The more historical information on the pipeline, the operational conditions and previous cleaning and inspection runs, the more appropriate the selection of the cleaning pigs. For the vast majority of today's pipeline this information is readily available, but it must be submitted to and sufficiently considered by the pigging operator.

- **Experience:** A good understanding on the cleaning capabilities of each type of pig within any given environment is absolutely essential in order to define critical acceptance criteria for each phase of the cleaning programme.

- **Communication:** The acceptance criteria for each phase must be defined in a way that the entire cleaning programme can be safely executed by even lesser experienced operators. The flow of information must be designed in a way that a continuous operation can be guaranteed in a 24/7 environment. At the same time all critical decisions must be discussed and agreed on senior level.

- **Reliability:** The cleaning tools must be manufactured to high standard to achieve the best possible results within the given time frame.

The message behind this approach is quite clear: Use the most sophisticated cleaning tools in the market, designed and operated by the most experienced people to achieve good results within a pre-agreed timeframe and budget.

Pipeline and Pigging History

The more information is available at the outset the better the adaptation of the cleaning programme to the actual requirements. At any given time the validity of the information must be confirmed. Following a number of questions that can help form a base for an efficient cleaning programme:

1) What is known about the product?

It is essential to understand where the oil is coming from. What is the temperature the wax drops out - and of course - how does this relate to temperature profile in the pipeline?

2) Is there any maintenance pigging regime? What type of pigs are used?

Maintenance pigs are often based on standard tools, sometimes bidirectional, but too often also based on soft cups. Especially if the maintenance pigging work is subcontracted as a service one of the main criteria for the selection of the tools is cost. The pigs will deliver a fair amount of wax with each run leaving the impression that they are fit for the job. However, these tools often smear some wax along the pipe wall. Over time an increasing layer of then hard wax is created - this is what causes the biggest concerns for any inspection. What makes things worse is the fact that with these tools being so inefficient they do not deliver any indication of this wax layer. Consequently the cleaning requirements are underestimated or completely ignored.

3) How are the cleaning pigs maintained?

When pigging waxy oil pipelines wear of PU is typically not of concern. Accordingly the need to replace the PU on frequent basis is underestimated. Ageing PU changes its physical properties, it gets softer and loses its ability to remove medium to hard wax. In addition the material slowly adjusts to the inner conditions of the pipe. Eventually a once efficient disc cleaning tool shows the same poor behavior as a soft cup pig.

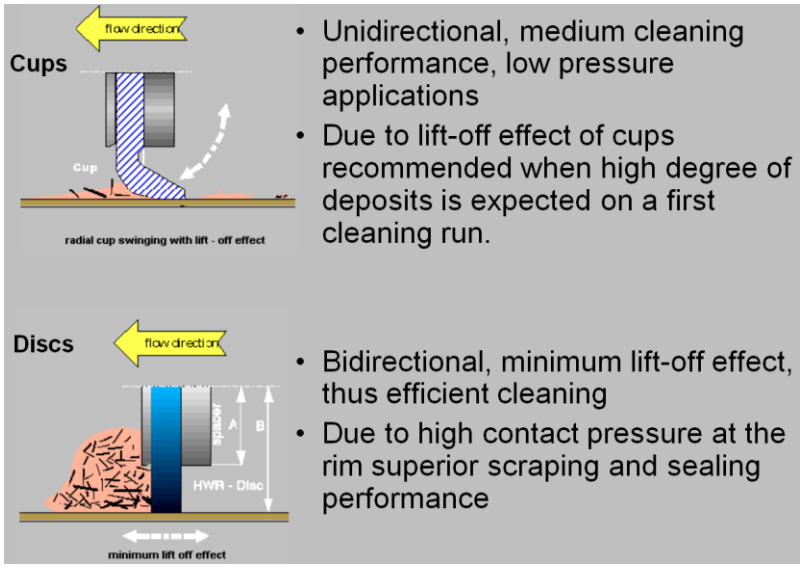

Figure 2 showing a comparison of cleaning efficiency between disc and cup pigs.

4) What type and amount of debris is received during maintenance pigging operations?

As shown above the selection of the cleaning tool and its maintenance has a dramatic impact on the efficiency of the maintenance pigging operation and needs to always be considered when evaluating cleaning results. Nevertheless the typical amounts of wax received during maintenance pigging deliver a good indication towards the required progressiveness of the programme. Good care should be taken if even seemingly inefficient cleaning tools deliver large quantities of wax.

5) At what frequency are the maintenance pigs run?

A comparison of results can further help establish the base for the progressive cleaning programme. Especially changes in quantities that coincide with changes of the duration between two pig runs deliver valuable information on the formation of wax within the pipeline.

6) Were the operational conditions consistent during the runs that are being evaluated?

Changing conditions can easily invalidate any conclusions drawn from a comparative analysis of wax recovery and needs good attention. At the same time such information can help identify sources of wax, e.g. individual wells producing more wax than others or fields feeding into the pipeline causing additional headache. A careful consideration of such information may lead to the selection of an optimised cleaning/inspection window. Especially in warmer countries and onshore already the temperature difference between summer and winter can have such a dramatic impact on the entire operation that the selection of the inspection window ascertains success or failure.

7) What is the receiving procedure (and is it followed)?

Possibly surprising to some, but the receiving procedure can have a significant impact on amount of debris found in the trap. Specifically the time between tool arrival and isolation of the trap plays a major role. While the pig sits in the trap the bypassing product flushes all debris through the drain pipe. During maintenance pigging this effect is helpful to reduce the amount of wax that needs to be handled, but clearly does not allow an assessment of the efficiency of the operation.

Progressive Cleaning Strategy

Following an assessment of the available pipeline records the cleaning strategy can be developed. To achieve the goals defined in the beginning of this document it is advisable to split the work into phases. With the exception of the initial bore proving and gauging typical only one type of tool is used within each phase. The tools are run until the desired outcome for the particular stage has been achieved. Acceptance criteria are based on the cleaning progress and compared to the maximum amount the particular type of tool is able to deliver. A good understanding of the capabilities of specific cleaning tools within comparable environments is absolutely essential.

During the **bore proving and gauging phase** the overall condition of the pipeline and the cleaning status is established. If the pipeline has not been pigged before or not been pigged over a longer period it is recommended to commence the operation by running a bore proving tool or so-called "easy-pig" (*Fig. 3*). This specifically configured tool typically consists of a smaller diameter body for increased passage capabilities rather than using the typical guiding/sealing disc arrangement this tool features only soft PU to minimise its cleaning efficiency. As a result only soft debris will be removed from the pipeline.

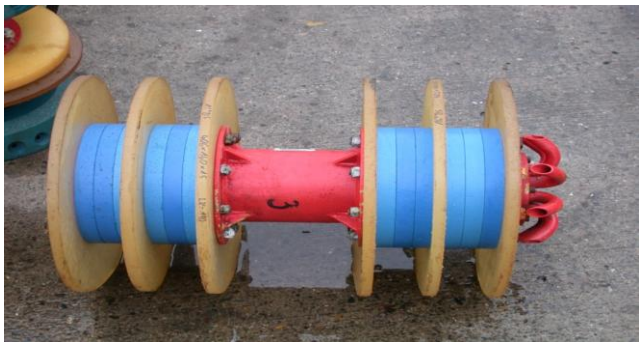

Figure 3: Easy-pig

The second tool within this phase is the gauge pig (*Fig 4*). This tool is based on a standard bidi-tool and - in addition to its gauging capabilities - has already a fair amount of cleaning capability. The debris received with this type of tool often exceeds the amounts that are typically removed during standard maintenance pigging. The main function however is based around the gauge plate. Following the run this tool delivers a good understanding on the minimum bore of the pipeline - essential for all subsequent pigging operations.

During the **standard cleaning phase** bi-directional cleaning pigs with brushes are used (*Fig. 5*). These tools typically require no customisation to allow them to remove all soft to medium-hard wax from the pipeline.

Figure 4: Gauge pig

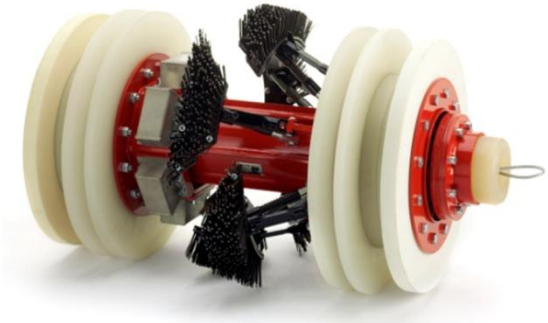

Figure 5: Standard brush pig with magnets

An **optional intermediate phase**, can help remove more of the harder type of wax from the pipe wall. Various options can be considered, but typically increasing the diameter of the guiding discs already achieves the desired outcome.

The pigs used during the final **aggressive cleaning phase** are designed to remove the hard layers of wax that accumulate on the pipe wall. A number of different solution can be considered for this task. Known as being one of the most efficient solutions in the market are the ROSEN's de-scaling/de-waxing tools (*Fig 6*). Here studs with tungsten-carbide balls are mounted in cups. The design ensures just the right pressure on the pipe wall, efficiently removing all wax layers, at the same time avoiding damage to the inner surface of the pipe. The design allows an easy customization of the wanted aggressiveness of the tool by simply changing the number of studs used.

Embedding the studs in cups further ensures that the debris is pushed ahead of the pig thus increasing the overall cleaning efficiency as no tools are needed to collect the debris these pigs leave behind.

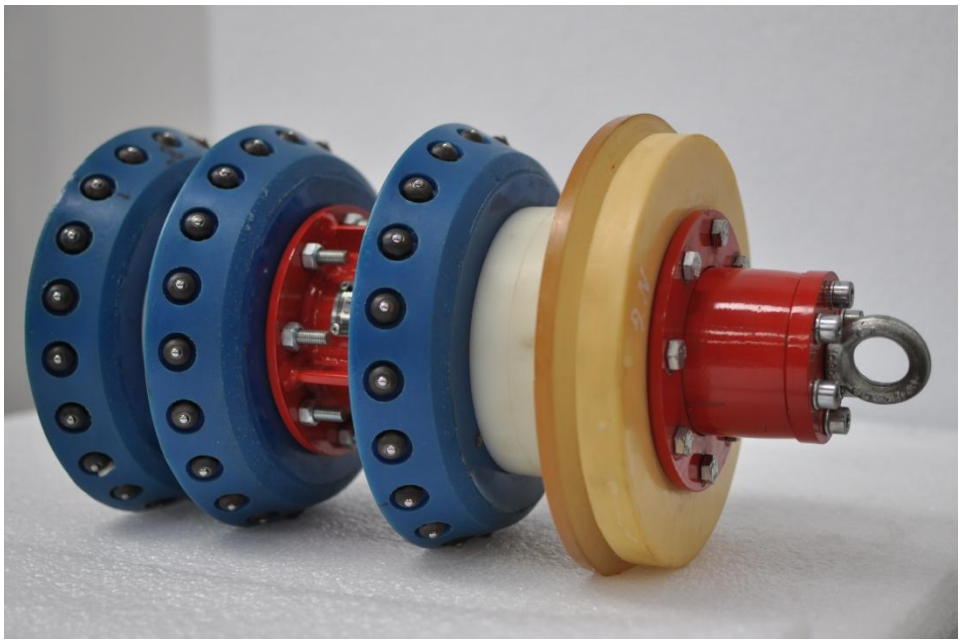

Figure 6: Example of ROSEN de-scaling/de-waxing tool

Execution of Cleaning Programme

Based on above assumptions a cleaning programme is developed consisting of 3 or 4 phases. It is absolutely essential that the acceptance criteria for each phase are well defined to allow an operation without interruption. The flow diagram in *Fig. 7* shows an approach that allows to complete the operation without specialist personnel onsite.

A few simple, but critical questions need to be looked at after each run:

- Have there been any operational issues during the run (e.g. pressure peaks)?
- Was the amount of debris that excessive that it lead to problems in handling?
- Was the type and amount of debris different to what was defined in the programme?

Only if the answer to all of these question is a clear NO the operation can proceed as planned, otherwise changes to the programme need to be considered in order to avoid unnecessary risks for the operation.

In most cases however, the operation can continue as planned and within the shortest possible period of time the pipeline is in a sufficient clean stage for the subsequent inspection.

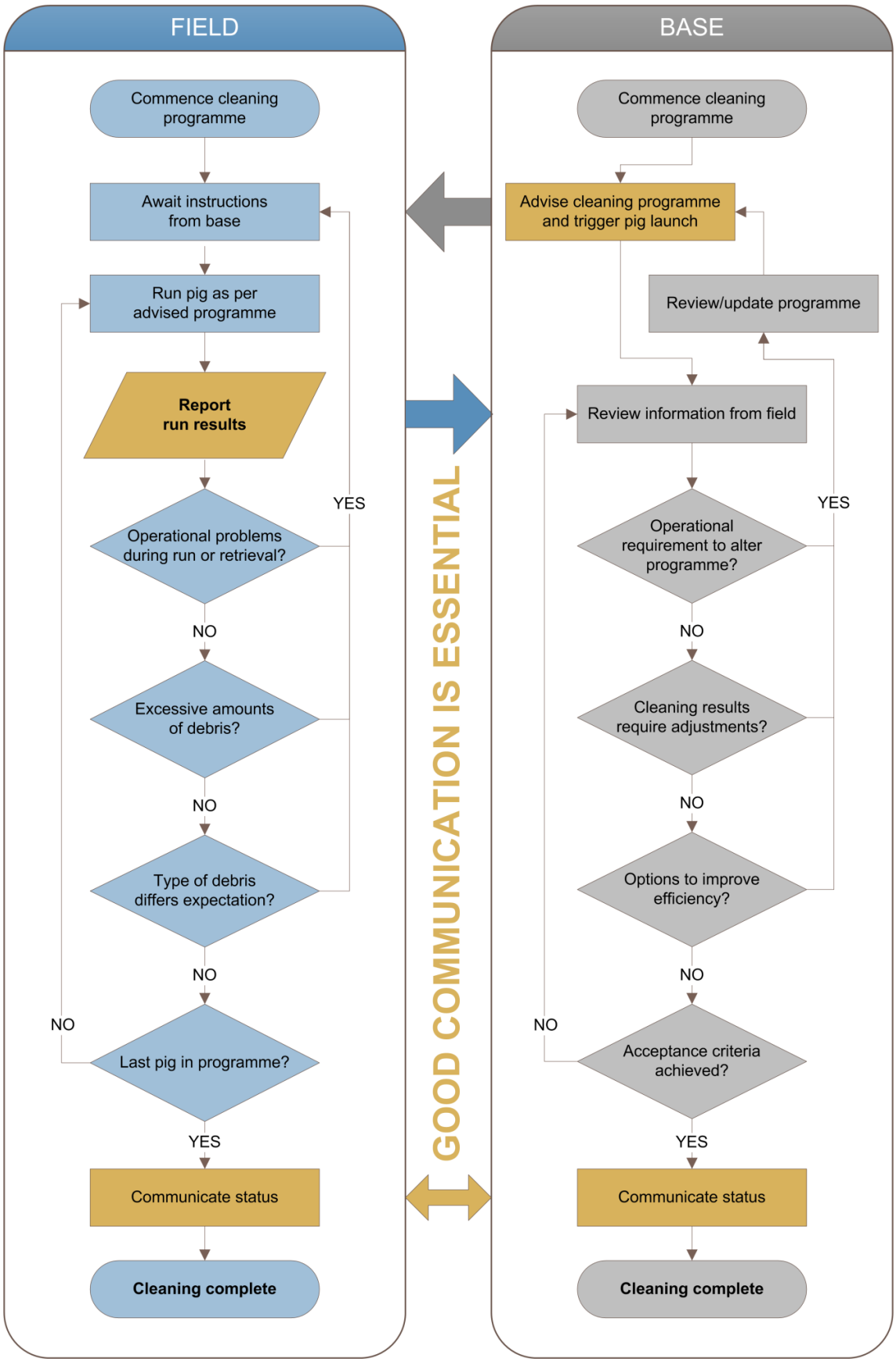

Figure 7: Flow Diagram for execution of cleaning programme

Inspection

If the cleaning programme has been completed as described above the pipeline is now in a state that could be described as “as clean as reasonably possible” and the inspection can commence. Consideration needs to be given to the selection of the most feasible inspection technology. With the advances of combined inspection technologies there is in fact no reason to decide on a single methodology. A proven “winning team” for applications in challenging environments such as waxy oil pipelines is e.g. the combination of MFL and SIC (*fig 8*). The measuring principles and general benefits have been discussed in depth already in various papers e.g. [1] and [2], and shall not be subject of this paper.

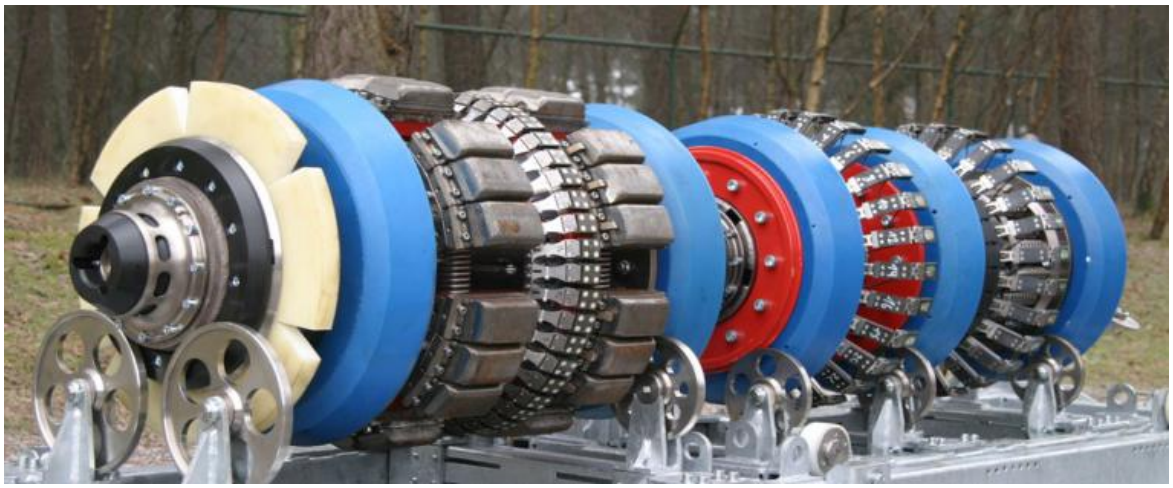

Figure 8: Combined MFL/SIC inspection tool

The ROSEN MFL tools have historically achieved good results also in waxy environments. The key behind this success is the robust design of the tool. In particular the yokes in combination with the strong “brushes” ensure that good direct contact to the pipe wall is maintained. This arrangement further helps protect the sensors and allows an overall much better measuring performance in comparison to e.g. fixed yoke arrangements with long soft bristles or air gaps (fig 9).

Figure 9: MFL tool after successful run in waxy pipeline

In combination with the SIC technology, that in fact has found its first application in an extremely waxy pipeline in the Northern Sea, the final inspection can deliver results that go far beyond specifications that could be achieved with any other technology. The clear benefit of the eddy current based SIC tool is the lift-off compensation of the signal. Even without a direct contact to the pipeline an absolute measurement of Shallow Internal Corrosion is possible (*Fig 10*).

The combined evaluation of MFL and SIC data delivers an outstanding base to allow a reliable and accurate assessment of the pipeline's integrity.

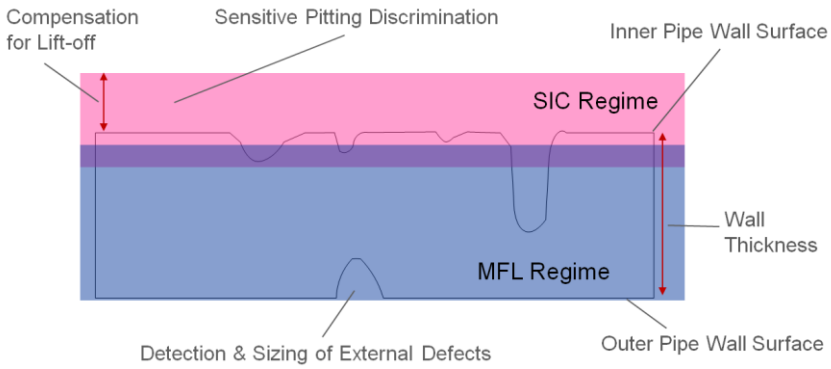

Figure 10: Comparison of absolute SIC and relative MFL measurement

Conclusion

The correct approach to addressing cleaning issues in waxy pipelines is the key to a successful inspection. Only where essential pre-requisites such as experience, a good selection of efficient cleaning pigs and reliable inspection technology are brought together an inspection project can be completed within a well defined time and budget.

Reference

[1] Shallow Internal Corrosion Sensor Technology for Heavy Pipe Wall Inspection. Stawicki et al. 2009 PPSA Seminar

[2] Record Inspection of the World's Longest Subsea Gas Pipeline. Brockhaus, Lindner, et. al. 2010 Pipeline and Gas Journal

[3] Improvements in the accurate estimation of top of the line internal corrosion of subsea pipeline on the basis of in-line inspection data. Huyse, Beuker, Palmer, et. al. IPC-2010