DEVELOPMENT OF THE PATHFINDER FOAM CALIPER PIG

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Background

In 2005, Total were planning to carry out an inspection of two 32" gas and condensate pipelines running 92 km from the South Pars field in the Persian Gulf to the shore terminal at Assaluyeh in Iran. The pipelines were overdue for inspection but it was known that hard scale deposits were present in the line which would present significant difficulties to the passage of either MFL or Ultrasonic tools. Total were therefore planning to carry out an acid clean of Sea Line 1 to remove the scale prior to the use of the inspection pigs. Our company was asked if we could run a multi-channel caliper tool through the line to measure the thickness and the distribution of deposits and to provide the information to the pipeline engineers to allow them to optimise the acid clean. In due course we successfully carried out the caliper run and from the data, we were able to map of the distribution of the scale and an estimate of the total volume of the deposits. From this information, Total were able to determine the quantity of acid required and optimise the soak time to ensure all of the scale was removed. Following the acid clean, we were asked to return and run the caliper to confirm that all of the deposits had been removed. In fact when we did the run we found that some of the thickest deposits had not been removed so a mechanical cleaning pig was used to remove the remaining deposits allowing the MFL inspection to be carried out.

In 2006 we were invited back to carry out the pre-cleaning caliper survey of the second pipeline – Sea Line 2. Foam pigs had been run through this pipeline but no hard bodied pigs. We therefore offered a smart gauging pig to run in the line first to get an idea of the size and location of the major restrictions before running our caliper tool.

Figure 1: Gauging Pig After Recovery from Sea Line 2

However, when the gauging pig was run, it was severely damaged and the rear disc stack was completely stripped off the pig and left in the line (Figure 1). Clearly the restriction in this line was much more severe than in Sea Line 1. Fortunately the pig had not been completely stuck in the line and by measuring the damage we were able to figure out the key design parameters of a caliper pig which should be able to get through the restriction in the bend at the bottom of the riser.

Figure 2: Caliper Pig After Recovery from Sea Line 2

With help from the engineers at Propipe, a caliper pig was produced and much to our relief, it passed through the line without a hitch. Once again, data from the caliper run was used to produce a mapping of the scale deposits and this time the post cleaning caliper run showed that the deposits had been successfully removed.

Development

Developing the Concept

The experience we had gained in carrying out the South Pars project gave us an insight into the difficulties of cleaning and pigging pipelines that had not previously been pigged. It was clear from this work that there was a significant benefit to be gained from measuring the deposits in a pipeline before, during and after cleaning in order to optimise the cleaning process. Indeed, 5 years previously, PII had developed the Scale and Wax Assessment Tool (SWAT) specifically for this purpose, although at that time the product had been discontinued.

However, it was also clear that running pigs in pipelines that had not been pigged before could be operationally risky. Pipelines are routinely cleaned with foam pigs but at some stage hard bodied pigs must be introduced and unless there is some knowledge of the location and distribution of any remaining deposits (or of any other restrictions in the line) then there is always the risk that the hard bodied pigs may become stuck.

It was our view therefore that a new type of pig was required which could be used to prove the line before running hard bodied pigs. This new pig would need to be capable of surveying the pipe bore along its full length and identifying, measuring and characterising localised restrictions in the bore. However, the new pig would also need to be very flexible to allow it to get through significant restrictions in the line. And so the idea of the foam caliper pig was conceived.

Unfortunately, shortly after completing the second phase of the South Pars project in 2006, our company was sold to BJ Services and for the next three years we were unable to work on developing the concept. However, in 2009 we were released from our obligations and we formed a new company called Pipeline Innovations with the specific aim of developing the foam caliper and other new types of inspection technology.

Pathfinder Design

The key design features that we were aiming to achieve were:

- Multi-point caliper measurement of the pipe bore along its full length and on-board data storage for download and analysis at the end of the run.
- Detect and measure restrictions, dents and ovality and provide recognisable responses to bends.
- Measure the roll orientation (clock position) of features in the line
- A flexible pig body to allow the pig to negotiate 90 degree elbows of <1D bend radius and pass restrictions of up to 50% of the nominal pipe bore.
- No external mechanical moving parts which may be damaged or ripped off during a run
- Simple to operate so that it could be used by pipeline operators or cleaning companies with no experience of running any type of intelligent pig

We quickly decided that the ideal carrier pig would be the polyurethane foam pig which is routinely used for cleaning all types of oil and gas pipelines. The medium density foam pigs are known to be very tough and yet they can get through most types of restrictions, providing there is sufficient pressure to drive them through.

Whilst the foam pig provided the flexibility to get through restrictions, its very flexibility provided a significant challenge to the development of a caliper measurement system. Embedding wires, cable and mechanical linkages in the foam tends to create weak points causing the foam to tear when under stress. Also, foam pigs are virtually single use and anything which is embedded in the pig would have to be disposed of with the pig body at the end of the job.

An in depth research project was carried out in which number of ideas were tried with varying degrees of success. On completion of the project, the method assessed to be the most viable was to use a method of measuring the deflections at the surface of the foam pig body by measuring the compression of the foam material inside the pig body using sensors mounted inside of a pressure vessel in the centre of the foam pig body. This method has the advantage that the sensors, electronics and batteries are housed in a single pressure vessel located in the centre of the foam pig body with no external wires, cables or mechanical devices connected to the pig body. This allows the pressure vessel to be easily removed from the pig after a run for downloading of data and charging the batteries. Another design feature is that the pressure vessel containing the electronics is a permanently sealed housing made from plastic which keeps the production costs to a minimum.

Operations

By late 2011 we had developed and successfully tested prototypes in our test loop facility in Northumberland and we were ready to produce our first operational units. Our preference was to look for opportunities in the UK oil and gas sector but unfortunately UK operators will not approve the use of equipment in zoned areas without ATEX certification. This of course is a major hurdle to the development and introduction of new equipment in the UK and it has had a significant effect on the roll out of this new technology. Submitting equipment for ATEX assessment and certification is an expensive process and until the equipment has been field tested under operational conditions then the design can not be frozen. Inevitably this would lead to multiple ATEX certifications being required to bring the equipment into operational use. In the end, our first opportunity came in the form of a decommissioned pipeline in Italy owned by Exxon Mobil.

Pathfinder Inspection of 12” Refined Products Pipeline

The first job that we were offered for the Pathfinder tool was a refined products pipeline owned by Exxon Mobile in Naples, Italy. The 12” x 3.5km pipeline runs from a dockside terminal to a tank farm on the outskirts of Naples. The pipeline had been decommissioned in preparation for MFL inspection. As the line had never been pigged, a standard soft foam pig had been run through the line followed by a bi-di gauging pig. The gauging pig had become stuck in the line and following the cut out of the pig, it was evident that internal ring anodes had been dislodged by the gauging pig, causing it to hang up as it traversed a bend. Since the pipeline records contained no information concerning these anodes, the extent of the problem would have to be determined before running MFL or UT pigs or even a standard calliper pig through the pipeline.

Figure 3: Bi-Di Pig With Dislodged Anodes

Pipeline Innovations Ltd. (PIL) was approached regarding their new Pathfinder Foam Caliper tool which at this stage was in the final stages of development. As the tool had never been used on operational pipelines, PIL proposed a series of tests in their flow loop facility to prove the performance of the tool in a range of pipe bores and with a simulated internal ring anode. These tests were subsequently carried out and multiple runs took place to assess wear and damage to the pig from the anode. It was confirmed that the Pathfinder was capable of detecting bore changes and pipe features including the simulated anode. The final pig design was then produced and at the request of the client, an EM transmitter was included to aid location of the pig in case it became stuck. Acceptance testing comprised witnessed tests in the loop, which had been modified with an arrangement of back to back 1.5D bends and an extra simulated anode positioned on the exit from the bend. These tests were successfully completed and Exxon agreed to run the Pathfinder tool in their line.

Figure 4: Loading Caliper Module and Transmitter

The foam caliper survey was carried out in April 2012 in conjunction with Tecma Pipeline Services S.r.l, who provided the operations support for running the pig. From launch to receive, the pig run took approximately 3 hours, with the pig running at an average speed of about 0.3m/s. When the pig was removed from the receiver, it was observed that the foam at the front of the pig body had been damaged but the rear section, where the caliper system is located, was in relatively good condition. Communications were established with the caliper data-pack and it was found that a full dataset had been recorded and the quality of the data was good.

Figure 5: Anode Retaining Strap Embedded in Pathfinder Pig Body

Using the roll sensors, the tilt sensor and the characteristic response of the caliper sensors it was possible to identify the type and direction of a total of 80 bends in the pipeline. By reference to the strip maps of the pipeline it was possible to correlate bends identified in the data with bends indicated on the maps. As the bends were distributed along the length of the pipeline, this provided regular 'markers' in the time based data, allowing the location of other features in the line to be accurately identified. Anode features in the line were identified by comparison with the caliper response to simulated anodes in the test loop at PIL. A total of 144 internal anode features were positively identified and using the bend marker data, the location of each of the anodes on the strip maps was pinpointed.

Pathfinder Inspection of 12" Crude Oil Pipeline Offshore Sicily

In December 2012, a 12" crude oil line running from an offshore platform to a shore terminal on the mainland of Sicily was due for an MFL inspection. The line was 17 years old and it had not been pigged since it was constructed. Tecma Srl were employed to carry out the cleaning and gauging of the line and as the line had not been pigged for many years, they proposed the use of the Pathfinder tool to prove the line and identify any significant pipe restrictions or scale and wax deposits which might affect the ability of the MFL tool to successfully inspect the pipeline. The pipeline operator agreed and they also proposed to run their own foam pig with their environmental logger with DP and accelerometer sensors behind the Pathfinder.

The Pathfinder run was carried out on 1st December 2012. The run was completed uneventfully and the Pathfinder was received in good condition and undamaged. However, when the data was downloaded, a large anomaly was identified in the data about 12 minutes into the run.

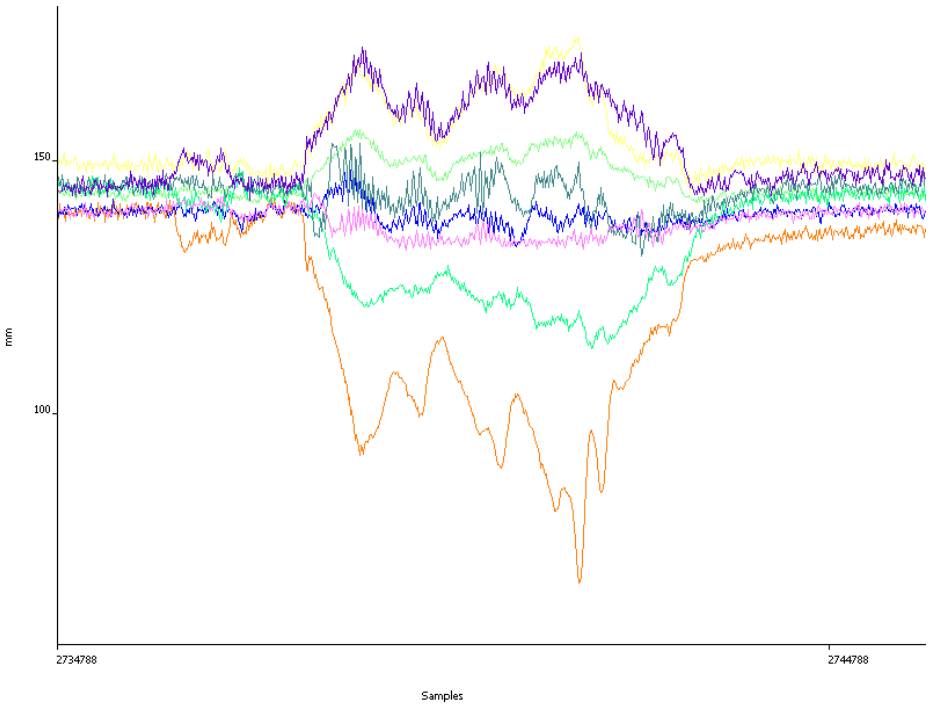

Figure 6: Caliper sensor Plot – Run 1

The data from the environmental logger on the second pig was examined and there was no indication of a restriction at this location. The pipeline operator therefore requested that two repeat runs be carried out to check the validity of the results of the survey.

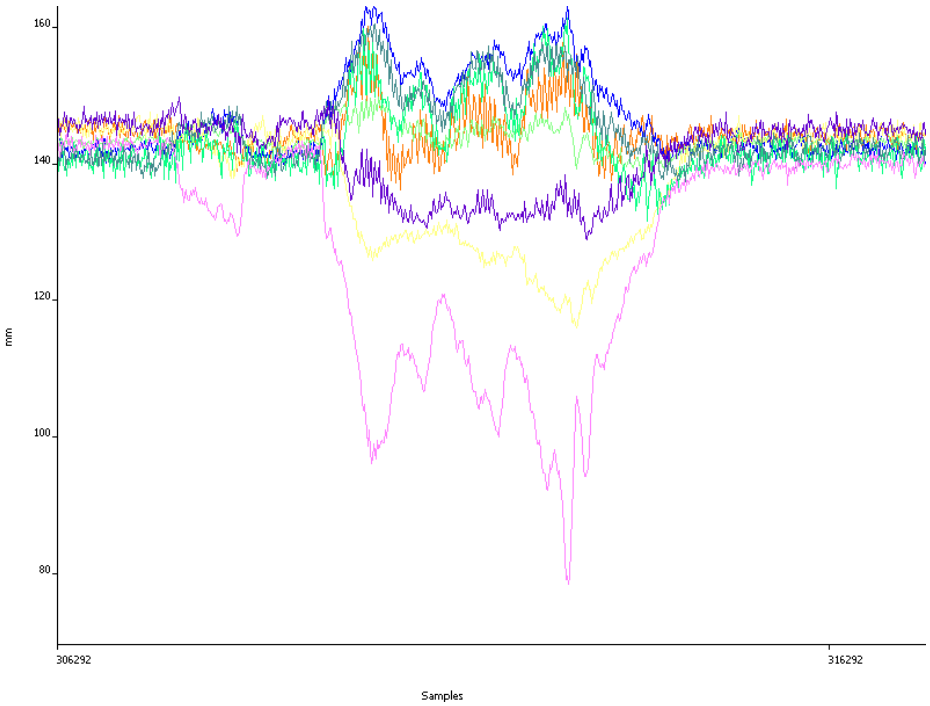

Figure 7: Caliper Sensor Plot – Run 2

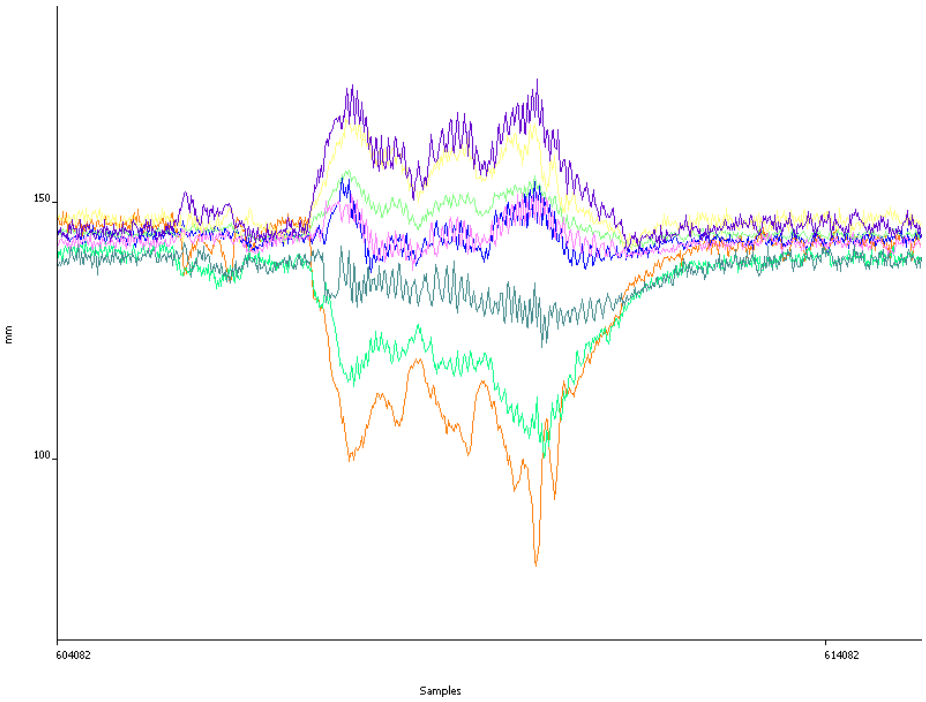

Figure 8: Caliper Sensor Plot – Run 3

The shape of the deformation, as measured by the foam caliper sensors, was found to be very repeatable between the three runs giving a high level of confidence in the findings. A summary of the measurements taken from the data from the three runs is given in the table below. Note that the length of the restriction is estimated from the time taken to traverse the feature multiplied by the average speed of the pig.

	Max Dent Depth (mm)	Maximum Bore Restriction (mm)	Estimated Length of Restriction (m)
Run 1	74	100	15.2
Run 2	63	86	13.4
Run 3	66	94	12.8
Average	**68**	**93**	**13.8**

A bi-di cleaning pig with a transmitter was then run through the line until it became stuck in the restriction and a diver with a receiver was deployed to locate the exact position of the transmitter on the sea bed.

The pipe section was excavated and it was confirmed that external damage to the pipe was present over a length of 15m. The damaged section of pipe was cut out and replaced with new pipe spools.

A re-run of the line was carried out with the Pathfinder on 16 April 2013 to check the installation of the new pipes. The pig was received undamaged and in good condition.

The new pipe spools were identified in the data and it could be seen that there were no restrictions in the new sections and no remaining damaged sections in the original pipework.

Figure 9: Bi-di Pig Stuck in Restriction

Summary

The Pathfinder foam caliper pig has been developed as a bore proving and debris mapping tool for oil and gas pipelines. The tool has met most of the original design objectives and it has been used in both onshore and offshore operational pipelines carrying a range of products including crude oil, diesel and natural gas:

- 12” x 3km water
- 12” x 12km crude oil
- 12” x 29km crude oil
- 16” x 11km diesel
- 14” x 23km natural gas
- 12”/14” crude oil

The applications have included measurement of wax deposits, bore proving in lines that have not been pigged and checking pipelines where bi-di pigs have failed to get through. Good quality data has been collected in each case and the reliability of the system has been good. Two jobs in particular demonstrate the capability of the tool:

1. The first operational project for the Pathfinder tool in Naples, Italy, proved to be very successful with the performance of the tool exceeding all expectations.

   Faced with a pipeline exhibiting severe pigging difficulties, the client was unable to progress with the use of any type of internal inspection tool to assess the integrity of the pipeline, until the extent of the problem had been identified.

   With the Pathfinder Foam Caliper tool, PIL were able to offer the client a unique solution to this problem. The tool was able to traverse the full length of the line and, despite suffering significant damage to the front of the pig body, the caliper system continued to operate and collect good quality data throughout the complete length of the line.

   Using the caliper data from the Pathfinder tool and by reference to the existing strip maps, it has been possible to identify and locate 144 internal anodes in the line. Knowledge of the number, location and distribution of the problematic internal anodes will now allow the Pipeline Engineers to make informed decisions on how to move the project forwards.

2. A bore proving run by the Pathfinder on a Subsea pipeline offshore Sicily, prior to running an MFL tool identified an unexpected severe restriction in the line. After carrying out repeat runs with the Pathfinder tool to confirm the findings, the location of the restriction was identified and the section of pipe was excavated. The damage to the pipe was confirmed and the damaged pipe spools cut out and replaced.

The Pathfinder is now an operational tool with a capability of running in pipelines fro 4” to 16” diameter and at operational pressures up to 20 bar. A new range of pressure vessels is being introduced which will be capable of operating at pressures up to 200bar and pig sizes in the range 18” to 24” are being developed. The design of the electronics system has now reached the stage where it will be possible to submit the design for ATEX certification.

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