Measuring Metal Loss

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Newly developed "feeler snake pig" can help offshore pipeline operators detect and size internal corrosion.

Offshore pipeline inspection traditionally employs the same technologies used for onshore pipelines. One such technology is the instrumented pig, which usually runs under the same parameters and procedures as those used for onshore inspections. However, it is very common to find submarine pipelines with special characteristics such as varying diameters and small radius bends that may prevent the use of conventional instrumented pigs. Other equally relevant factors that make the inspection difficult are the increased pipeline wall thickness, which significantly limits the use of magnetic instrumented pigs.

An alternative currently available to inspect these pipelines is the use of ultrasonic pigs. Nevertheless, this method has its own limitations, most notably the need for a homogeneous liquid, with good acoustic properties, to serve as couplant. On crude oil pipelines, this couplant is not always available, since these lines often carry multi-phase fluids.

Focusing in this context, a new method was developed to detect and size up loss of wall thickness associated to internal corrosion. A special pig was designed to bear large variation in diameter, with no practical limit of thickness to be inspected, and be able to navigate through curves and geometric accessories with small bend radius. The pig was called "feeler pig" because it consists of several feeler-type sensors that measure internal corrosion.

The system was tested in the field, and its performance was compared to a standard ultrasonic instrumented pig. Excellent defect correlation was observed between the ultrasonic and feeler pig data, both in geometry and deepness of internal corrosion. With this high confidence, other prototypes of feeler pigs were developed. A new design, named the "feeler snake pig," was developed. On this device, the feeler-type sensors were mounted over a flexible support, yielding a tool with ultra-high tolerance to geometric restrictions. The excellent results of the prototype and its robustness against line geometric restrictions immediately open a wide range of opportunities for field applications.

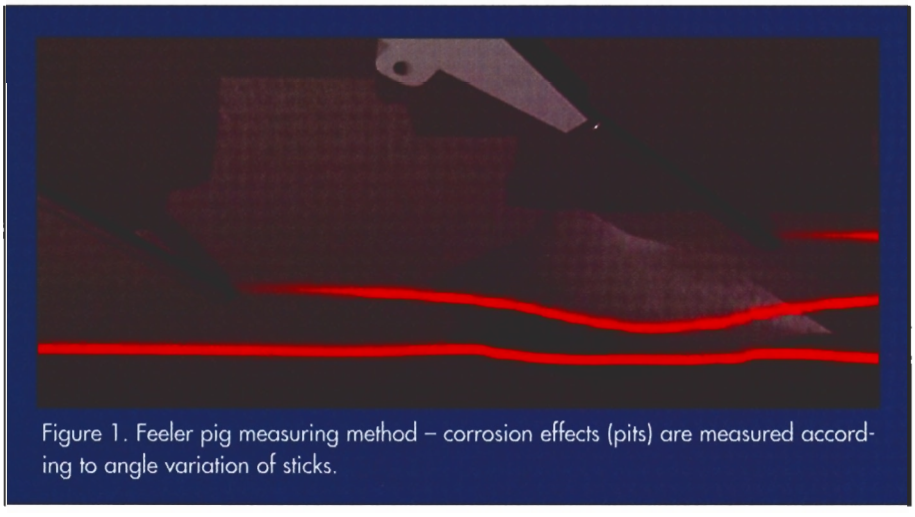


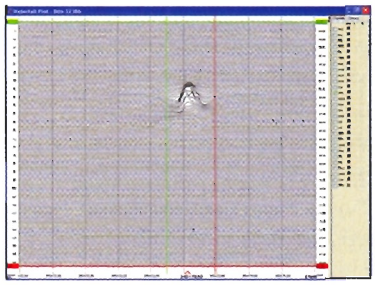
Figure 1. Feeler pig measuring method – corrosion effects (pits) are measured according to angle variation of sticks.

Inspecting offshore pipelines

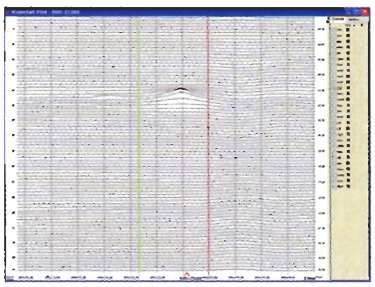
As noted, offshore pipeline inspection traditionally employs the same technologies used for onshore systems. There are, however, some particularities on these inspection procedures that must be considered. Onshore pipelines are usually easy to access, and that allows for excavation for field verifications and correlations, thus allowing inspection quality measurement. The same is not true for offshore pipelines, in which a correlation of instrumented pig indicated results implies very high costs; or, in some cases, it is not technologically available. During the 1980s and 1990s, a significant amount of funding was directed towards onshore pipelines in Brazil, to facilitate instrumented pig inspections. These efforts included removing small radius bends; installing launchers and receivers; unifying diameters; and removing obstacles. Some submarine pipelines received the same treatment, but those adaptations were not extended to the whole network. It is still very common to find submarine pipelines with multiple diameters and small radius bends (among other obstacles) that prevent the use of conventional instrumented pigs.

Combo Tool. More Info.

Theirs:



Is it really a Combo Tool? Really? MFL analysis results indicate a 10% metal loss feature; B31G PSafe values do not affect the MAOP.

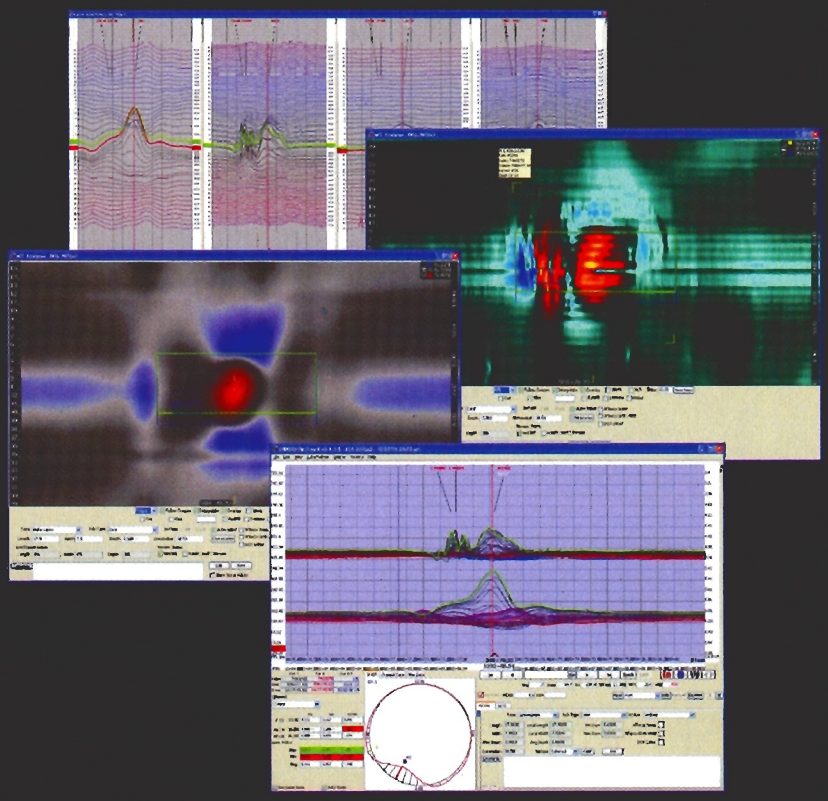


A tandem caliper survey of the same pipeline shows no deformation exceeding 2% of the pipe diameter.

Many companies offer pipeline surveys with tools that detect Metal Loss or run a tandem Deformation tool. Others imply that deformation exists at Metal Loss Indications and sizing of the deformation is not possible; a second survey is required to determine the extent of the deformation. The implied COMBO tools work much the same way; without "state of the art" analysis what do you really have?

Think Pigs!

Ours:



Enduro's DigiTel Flux Logger (DfL™) incorporates the ability to acquire data from several sources simultaneously in one pass, negating the need for performing independent surveys. Data sets for conducting metal loss, deformation, and inertial surveys, along with internal and external discrimination and residual field data are taken in one pass. Processing and analyzing the closely coupled data allows the software users/analysts to more readily recognize pipeline features and assess conditions. Any areas indicating geometry and/or metal loss features may now be simultaneously evaluated for deformation, strain, profile, and permeability variations. And because our tools all carry complete inertial navigation systems, GPS mapping is available at your request.

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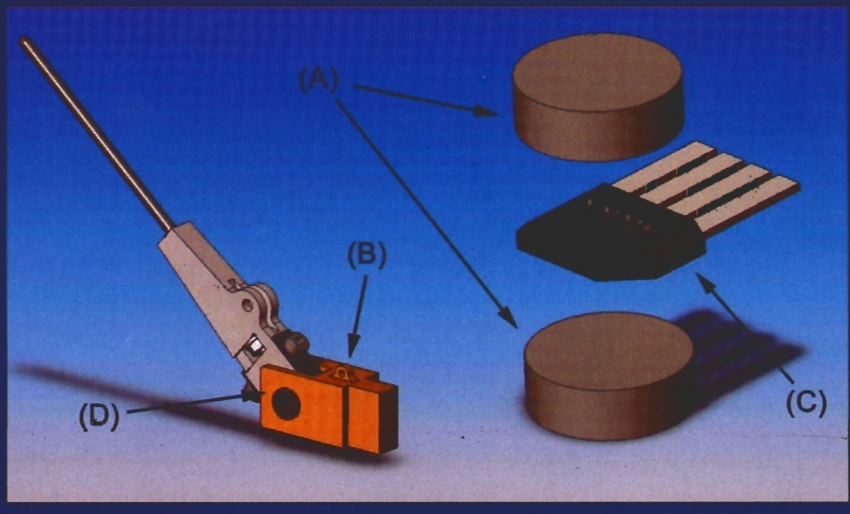

Figure 2. Feeler pig typical sensor – an two magnets (a) are fixed on the stick base (b); any movement produces a change in the magnetic field, which is detected by a Hall sensor (c) located inside the axis (d).

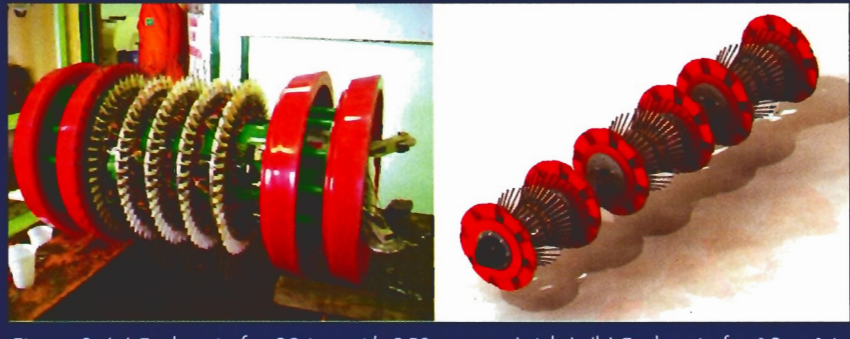

Figure 3. (a) Feeler pig for 22-in., with 250 sensors (sticks); (b) Feeler pig for 12 to 16-in., with 180 sensors (sticks).

There are other equally relevant factors which make submarine pipeline inspections difficult. These include submarine pipeline wall thickness, which significantly limits the use of magnetic instrumented pigs, including the magnetic flux leakage (MFL) inspection tools. As oil production heads for deeper waters, pipelines become thicker for structural reasons, and that implies loss of MFL measurement capacity. Those pigs present reduced sensitivity in pipes starting at 15 mm-thick wall, with a practical limit of 20 mm. The problem gets even worse in pipelines with diameters smaller than 14-in., which present large thickness and small internal volume. This makes magnetization very difficult, since the space available to place magnetizers is restricted.

With current technology, there are not enough compact and high-power magnetizers to be used for large thickness in such small space. Another particularity of submarine pipelines is that their external visual inspection is almost always possible, since those pipelines are accessible from outside using remotely operated vehicles (ROVs). Those vehicles are already periodically used to inspect the company's submarine pipelines to identify external damages, measure cathodic protection electrochemical potential, and identify spans. The external visual access is, compared to onshore pipelines, the greatest distinguishing feature regarding submarine pipelines inspection.

Another notable aspect regarding submarine pipelines is that the main cause of deterioration is internal corrosion, generally in lower generatrix, which occurs in the presence of produced water. External corrosion is easily prevented with cathodic protection, while damage caused by collisions or anchor action are, mostly, identified through ROV visual inspection. It is considered, therefore, that the main objective of oil and gas production submarine pipeline inspection is to detect and quantify internal corrosion and, to a smaller extent, external defects related to diverse actions.

An alternative currently available to inspect pipelines subject to internal corrosion is the use of pigs with ultrasound technology. Depending on its mechanical design, the ultrasonic pig may tolerate variations in diameter, and does not present inconveniences for measuring large thicknesses. A severe limitation to that method is the need of a homogeneous liquid, with good acoustic properties, to serve as couplant. That limitation makes it more difficult to inspect gas pipelines, requiring introduction of a diesel batch, but with strong operational impact. Also, the fluid is not homogeneous in production pipelines with "live" oil (oil + gas + water), making ultrasonic inspection practically impossible.

Feeler pig method

Given the known difficulties of inspecting submarine pipelines, a research and development project was launched to devise a new method to detect and size up loss of wall thickness associated with internal corrosion. A special pig was designed to bear large variation in diameter, with no practical limit of thickness to be inspected, and be able to navigate through curves and geometric accessories with small bend radius. The pig

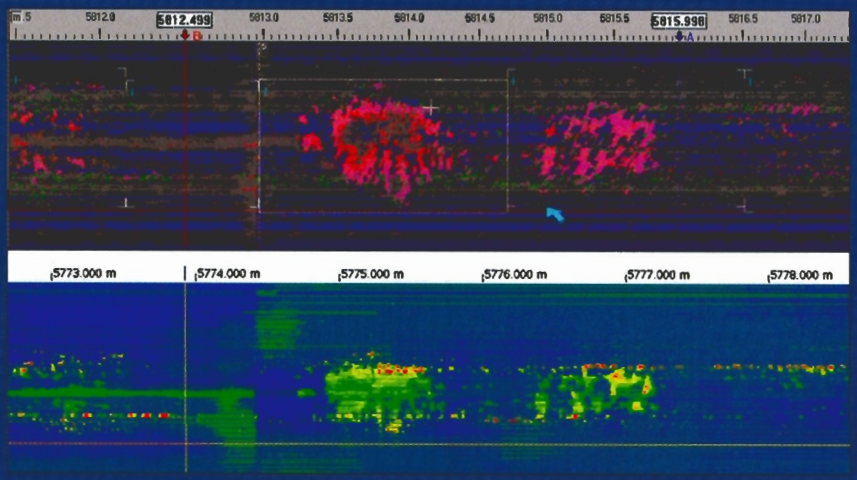

Figure 4. Two pictures (c-scan) extracted directly from data analysis software – (a) a corroded area detected by a commercial ultrasonic system; (b) the same corroded area detected by the 22-in. feeler pig.

Figure 5. Feeler snake pig – (a) general view of electronics and sensor modules; (b) equipment being received from offshore pipeline.

Figure 6. Calibration accessories – (a) calibration staircase; (b) tube with the staircase in place.

was called feeler pig, since it consists of several feeler-type sensors that measure internal corrosion (Figures 1 and 2).

The first special pig prototypes were developed to inspect small-diameter production pipelines, using just a few sensors. Later, thanks to the excellent results obtained in field tests, the concept was extended to large-diameter pipelines, in this case 22 inches. That tool carried out an inspection of a submarine pipeline, confirming its potential in real inspections. Figure 3 shows the pig assembled and ready to use. Results delivered by the pig's 250 sensors (sticks) were compared to the data collected by a previous inspection performed with a commercial ultrasound pig on the same pipeline. The new tool delivered results that were almost identical to those of the ultrasonic pig in terms of defect deepness and extension, confirming the technical viability of the new internal corrosion detection and quantification method (Figure 4).

Based on the aforementioned results, several inspections using that system were scheduled for 2007 and 2008, and these include oil and gas pipelines with or without diameter variation, in addition to short and long pipelines with a wide range of flow speed. In July 2006, an inspection was performed using a feeler snake pig, which is a fully innovative design using the abovementioned method. Figure 5 shows the new concept of instrumented pig, in which sensors (sticks) are mounted over a flexible base. That tool enabled a multi-size inspection, with small radius bends, a kind of inspection that tools commercially available cannot provide. As a result, 7.6 kilometers of a submarine pipeline were recovered.

Calibration

In order to achieve accuracy in deepness measurements, it is fundamental to employ a calibration procedure before launching the pig. Every sensor is individually programmed to meet the operational range of the project, considering the pipeline characteristics such as internal diameter and wall thickness. The sensor must be able to measure within its range, for example, a 100% thickness loss without saturation. Since there still may be some variability between sensors due to mechanical differences, magnets

positioning and strength, the tool is then calibrated with all sensors mounted over the main structure.

The calibration consists in passing the tool through a six-meter long plastic tube, with the same diameter as the nominal inspection target. The tube has an access window where a calibration staircase is inserted. Every step of the staircase is precisely known, providing calibration values to the entire range of the thicknesses which the tool is meant to measure. Figure 6 shows the staircase and the tube used for calibration of the pig. As the pig is moved within the tube, the signal for every sensor is acquired representing the staircase as seen by that particular sensor. Since the staircase does not cover the entire 360° span, the procedure is repeated until a valid signal is obtained for all sensors.

The known values of step heights provide a precise calibration reference to be later used in data analysis. The process is fully automated with individual polynomial fitting for every sensor. Once calibrated, the measurements taken by the pig are presented in millimeters to the operator.

Field testing results

In one of the field tests, the 16-in. feeler pig performed an inspection in a submarine pipeline. After the data analysis, no corrosion was found. All welds – circumferential or longitudinal – were detected. Also, as longitudinal welds reached the circumferential, it was possible to detect and size the internal grinding of longitudinal welds. Figure 8 shows the results obtained by the 8-in. snake feeler pig. Also in this 15 year-old pipeline, no internal corrosion was found.

Conclusion

As the feeler pig technology and the feeler snake pig concept are consolidated, Petrobras is changing its submarine pipeline inspection system, prioritizing this technology for internal corrosion control. The use of other pigs, such as MFL and ultrasound, will still occur whenever external corrosion is suspected. With the new system, Petrobras intends to inspect the great majority of its submarine pipelines, practically eliminating the expression "non-piggable line" from its offshore production fields. ■

Acknowledgment

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