PETROBRAS’ DEVELOPMENTS in UNDERWATER INSPECTION

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Abstract

Over the years PETROBRAS has installed an expressive number of subsea equipments and underwater pipelines at up 3000m deep. In many cases it is impossible to inspect them with intrusive techniques, and the need of advanced underwater in-service inspection tools and self monitored equipments has become imperative. The PETROBRAS Research Center – CENPES – is focused on advancing inspection and monitoring technologies to face these challenges, leading a project which main goal is provide reliable and practical solutions applied to SURF components inspection (subsea structures, Xmas trees, umbilicals, control systems and subsea piping). This article will present some tools which are already developed and ready for use, as well the new prototypes and concepts.

Keywords: Subsea inspection, inspection and conditions monitoring

1. Introduction

PETROBRAS Research Center – CENPES – has developed solutions destined to underwater inspection for many years, but its initial focus was on activities performed by divers. The first tools made available were the ultrasound scanner, the underwater gammagraphy system and the feeler pig; this last one, of course, not operated by divers, but an autonomous system for in-line inspection [1, 2, 3]. In a second time, to meet new demands for the deepwater applications ROV-operated tools have been developed and are being tested under field conditions, like the UT crab tool and the Ø8-10” gammagraphy grab [4, 5].

This article aims to briefly describe the advanced underwater in-service inspection tools and self monitored equipments which represent the ongoing research project conducted by CENPES.

2. Developed Tools

2.1 UT Scanner Operated by Divers
Coordinator: Carla Marinho

This tool is based on an ultrasound multi channel system and was designed to provide an accurate solution for instrumented pigs’ results correlation. It contains 64 UT immersion transducers symmetrically arranged along a flat support, which is connected to four magnetic wheels in order to be able to move around the pipe without loose contact. These transducers
communicate to an electronic multiplexed system hermetically kept inside a metallic container, and the whole inspection is remotely controlled by a software, at the surface. Once the diver starts a scan the results are real time displayed as a B, C and D-scan image. Figure 1 shows the tool, an image displayed during an inspection and a real operation [1].

![Figure 1](image)

**Figure 1** – (a) Two sides of the UT scanner; (b) Complete system schematically represented; (c) B, C and D-scan view of an inspected pipeline; (d) A diver performing a real operation in Campus Basin [1].

The UT scanner is a valuable tool for thickness measurement, saving time and costs related to underwater inspection, and can be used over a wide range of diameters (from Ø10”) and thickness (from 8 to 25mm, but this limits can be broadened).

### 2.2 Underwater Gammagraphy System Operated by Divers
Coordinator: Carla Marinho

Like the UT scanner, this system is a spot solution for instrumented pig’s results correlation, but the focus is crack detection (although it also can be used for wall loss measurements). The system is also a multi diameter tool and is very safe and easy to operate.
The system is composed by a mechanical dispositive, necessary to the positioning of detector and source, an Iridium (Ir-192) source, a encapsulated detector (industrial film or phosphor imaging plate) and a remote electronic controller. Before an exposure, the diver fixes the mechanical dispositive at the correct position, following the inspection team instructions, and then put the source and the detector at their respective positions. The source exposition is fully remote electronic controlled, and is based on an exposure time previously defined. During an exposition, the diver must be, at least, 1 meter away and once the shot was taken, he’ll move the set up to the next position. This operation is repeated around the tube until it reaches the full circumferential coverage. After each shot, he sends the detector to the surface and receives another one [2]. Figure 2 shows the system and a real operation in Campus Basin.

![Image](image1.png)

**Figure 2** – (a) Complete underwater gammagraphy system fixed on a sample; (b) Different positions for circumferential coverage; (c) Inspection of a flowline in Campus Basin [2].

### 2.3 Ø8-10” Gammagraphy Grab Operated by ROVs
Coordinator: Carla Marinho

This system uses the same source, detectors and electronic remote controller than the previous one, the difference between them is only the mechanical dispositive associated: a mechanical grab is employed to allow an operation conducted by a ROV. This grab is fixed at the desired position of the pipeline, already holding the source and the detector, and the system is only able to permit one shot per operation [4].

The prototype is available for using in flowlines with 8 or 10” of diameter. Other adaptations can allow different diameters to be inspected. Figure 3 shows the prototype.
2.4 Feeler Pig
Coordinator: Claudio Camerini

The Feeler Pig was specifically designed to detect and quantify internal corrosion. Figure 4 shows the first prototype available, which performed an in line inspection in 2005. The results were compared with those from UT and MFL pigs and were used to validate the technology [3].

Main characteristics of the technology are presented below:

-Cross-sectional resolution: It is given by the ratio between the pipe inner perimeter and the total number of thickness gauges. The lowest observable defect is given by the gauge diameter (probe), because it must penetrate the defect. In the case of the first prototype, the value was 2 mm. Nowadays there are many tools designed to different diameters, including multisized configurations.
The largest defect that can be missed depends on the probability of it passing in between two
gauges. This gap can be reduced by increasing the number of sensors.

- Cross-sectional resolution: It is defined by the sampling rate and by the tool speed. Taking a speed of 1 m/s as an example, the 512Hz rate (used on the most prototypes) provides a cross-sectional resolution of 2 mm.

- Gauging: Each sensor was individually gauged in order to insert the true response curve of each sensor into the data acquisition software, thus correlating the angle of the thickness gauge to the tension generated by the angular sensor.

Figure 5 shows a compact and multisized configuration.

![Feeler pig: A compact and multisized configuration (from Ø4” to Ø7”).](image)

### 2.5 UT Crab Tool Operated by Divers
Coordinator: Rafael Wagner

Wet Xmas trees and PLEMs (Pipeline End Manifold) are mechanical devices that have bolts as key components. Due to the extremely aggressive deep water environment and the presence of hydrogen in oil, PETROBRAS has faced some problems with these bolts, which had failed because of cracks.

UT crab tool was developed to in-situ bolt inspection in order to detect cracks, even small, nucleated from the thread. Fourteen ultrasound transducers, seven per side, sequentially scan the bolt and the respective A-scan is real time displayed at the surface. Once a crack is detected is possible to localize its location and length [5].

The system is schematically showed in Figure 6: a ROV couples the UT crab firmly touching each face of the bolt and then the inspection is remote controlled from the surface [5]. A real operation can be seen in Figure 7.
3. The Ongoing Project

Figure 7 shows the project’s management strategy. Each technology, or phase, is under responsibility of a specialist and the team is composed by a multidisciplinary staff. This project has been conducted in partnership with Brazilian and foreign institutions and companies. All the phases run in parallel.

3.1 Mensageiro System
Coordinator: Claudio Camerini

It is a system to be designed and coupled to pipelines which are currently non monitored. The first prototype will perform thickness, temperature and vibration measurements, and will compare these values to those related to the normal conditions. From time to time the accumulated data can be acoustically transferred to an AUV.
In case of anomalous conditions, the system will uncouple and send a satellite signal to identify its origin. Figure 8 shows the prototype.

This phase is developed by PETROBRAS and the partnership PUC-ATIVA (The Catholic Brazilian University of Rio de Janeiro – PUC - and ATIVA, a Brazilian Inspection Service Company).

3.2 AUV Development
AUTONOMOUS UNMANNED VEHICLES
Coordinator: Luiz Mesquita
This phase aims to develop an AUV to perform extended missions in deepwater fields. The main activities will be visual inspection, cathodic protection measurement and sea bed evaluation.

A bidding, for the first use at Campus Basin, will occur this year, and the participants are Cybernetix, Subsea 7, Aker, Saab and Oceannering. After the results evaluation, it will be defined the goals of this line of work.

3.3 Autonomous Underwater Riser Inspector (AURI)
Coordinator: Claudio Camerini

This is an autonomous vehicle destined to external flexible riser inspection, avoiding the use of ROVs and, consequently, representing an expressive cost reduction. AURI will be able to perform visual inspection (through 4 cameras) along a predetermined deep, and then will return to surface. Its autonomy is about 1 hour and the maximum operating depth is around 1000 m. The final buoyancy is positive, and in case of emergency, it can be rescued by an ROV. The next steps will include insertion of two inspection tools: a multi channel ultrasound system and a multi sensor gamma profiler. Figure 9 shows the vehicle.

![Figure 9 – AURI: (a) croquis; (b) the first test under laboratory conditions.](image)

This phase is also a partnership between PETROBRAS and PUC, but the Brazilian Company involved is ENGEMOV.

3.4 SmartPipe
Coordinator: Sergio Morikawa.

SmartPipe is a self monitored pipeline on which thickness, vibration, strain and cathodic potential will be continuously monitored. The data transfer and some measurements will be done by fiber optics. Force Technology and Sintef are leading this technology in accordance with PETROBRAS. Figure 10 shows the concept.
3.5 Alternatives to Shallow Water Inspection
Coordinator: Sergio Damasceno.

This phase searches new inspection technologies for using in shallow water depth (up 50m), in order to guarantee a safety and productivity improvement, costs reduction and more reliability in shallow diving activities. The tools must provide real time transmission data and feasibility of inspection in the splash zone area.

PETROBRAS and HOIS (Harwell Offshore Inspection Services - a Joint Industry Project) concluded a process of identification of suitable technologies and partners. The next steps are: development of the selected technologies and execution of in-water demonstration of the new prototype tools.

3.6 Submarine Guided Waves Monitoring Sensors
Coordinator: Rafael Wagner.

On the scope of this phase, it will be designed and marinized an autonomous monitoring system for pipelines through guided waves. Firstly, tests to simulate the underwater operation will be conducted in order to investigate the overall performance. Other studies will analyze the interference of marine life growth, and the outer covering of the pipeline, in the coupling system and guided waves propagation as well the feasibility of employment in complex geometries such as manifolds and bifurcations.

This work is a partnership between PETROBRAS and Federal University of Rio Grande do Sul (UFRGS).

3.7 PROVUS – Non Intrusive Corrosion Coupon
Coordinators: Claudio Camerini and Carlos Patusco.

This coupon is based on ultrasound method and is completely non intrusive, differently from the other solutions available in the market. It is able to measure variations as slight as about dozens of microns. The technology is a result of a partnership between CENPES and University of São Paulo (USP). Figure 11 shows the prototype.
PROVUS was specially designed to underwater pipelines (risers and flowlines) and this installation is diver assisted. There is a prototype ready to use in Campus Basin. Is already under development a prototype which can be installed by ROV.

3.8 Underwater Real Time Radiography Operated by ROVs
Coordinator: Carla Marinho.

PETROBRAS has developed an underwater gamma ray system operated by divers [4] and it was employed in very relevant internal demands. There is another version, known as gammagraphy grab [2], which is ROV operated. Both systems can operate using industrial films or phosphor imaging plates and the latent image extraction is done at the surface. In order to provide the same effective solution applied to deep water, a flat panel detector and a high energy X-ray source will be marinized. Like the diver-operated system this tools is suitable for wall losses and crack detection, but the output is a real time image with high quality.

The partner is Federal University of Rio de Janeiro, and, later on, a Brazilian Inspection Company.

4. Conclusions

CENPES developed some inspection tools to fulfill PETROBRAS’ demands. In a first moment these tools were designed to be diver operated, but the expressive number of subsea equipments and underwater pipelines at up 3000m deep forced a necessary migration to ROV operated systems.
Eight different technologies have been developed by CENPES in partnership with Brazilian and foreign institutions and companies.

The technologies will allow a better control over pipelines and subsea equipments, avoiding unscheduled shutdown and leakages.

These new solutions will must be made available by suppliers or inspection service companies.

References


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