Pipe Robots for Internal Inspection, Non-Destructive Testing and Machining of Pipelines.

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Abstract. Inspector Systems is a specialist in manufacturing of tethered self-propelled pipe robots for internal inspection, non-destructive testing and machining of pipeline systems. Our industrial sectors, which originates from 30 year experience in the nuclear industry, are Gas & Oil (On-/Offshore, Refineries), Chemical, Petrochemical, Water etc. The pipe robots are able to get inserted through poor access points (e.g. valves) and to pass in bi-directional travelling vertical sections and numerous bends with small arc radius. The paper describes the system concept and performance of the pipe robot technology. A modular construction allows to equip the robots with different operational elements for the respective application.

1. Introduction

Technical installations that are subject to stringent requirements should always be kept on the best possible level of operational safety. This applies particularly to installations with their innumerable piping systems that require a high degree of reliability, comfort and safeness. Keeping individual pipeline sections in perfect condition is a crucial prerequisite for the trouble-free operation of the entire system. The pipeline systems therefore have to undergo strict and regular tests of various types which ensures that any damage to the pipes as a result of wear, corrosion, erosion and cracking etc. is detected, respectively prevented at an early stage. Subsequently it can occur that a detected damage is not accessible from the outside and a repair by appropriate means must take place from the inside. All this requires bendable and flexible pipe robots with the possibility to equip with modules for the respective application to carry out the maintenance- and inspection work from inside.

Fig. 1. Robot with drive units connected via folding bellows and video/laser-inspection head

More info about this article: http://ndt.net/?id=19552
2. System concept

Main Components:

- drive units (anodized aluminum) with its special rubber coated wheels
- flexible folding bellows (stainless steel)
- inspection/-testing- or machining module
- electrical housings
- abrasion proofed special cable
- control system (operating unit, monitor, HDD-recorder etc.)

The basic structure of the self-propelled and remote-controlled pipe robots consists of several drive units with its special rubber coated friction rollers as well as inspection-/-, non-destructive testing-/- or machining modules who are flexible connected to each other via folding bellows. This ensures a high degree of bendability and allows an insertion into the pipe system even when small amount of space is available e.g. open armatures, flanges etc. By means of an adjustable initial tension the friction rollers gets pneumatically pressed against the inner pipe wall and are stabilizing and centralizing the robot inside the pipe. As a result, the robot can pass in bi-directional travelling numerous bends with small arc radius ≥ 1.5D, vertical sections ±90°, diameter reductions and branches. A special cable connection to the control system outside the pipe system provides the energy supply, data transmission as well as to control the adapted inspection/-/ machining modules and ensures an additional safety pull back functionality.

Fig. 2. Drive unit retracted

Fig. 3. Drive unit extended

Fig. 4. Special cable with robust plug

Fig. 5. Control system e.g. ultrasonic
The robots are defined according to the following pipe diameter breakdown as standard, specific to the application and on request, different dimensions and customizations are possible.

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Fig. 6. Standard dimensions – diameter range robots

3. Basic performance pipe robots

- Self-propelled
  - no external drive medium needed,
  - stop at any time

- High degree of bendability and flexibility
  - insertion through poor access points (dismantled valves, flanges etc.)
  - crossing numerous bends $\geq 1.5D$
  - crossing welded seams, T-branches and diameter reductions

- Bi-directional travel
  - access only from one side necessary

- Horizontal and vertical travel
  - vertical inclined uphill (up to 90°) and downhill directions

- Online results / monitoring
  - live survey

- Long travel distance (more than 500 m possible)
4. Inspection- and non-destructive testing modules

Depending on the requested application, the robots can be equipped with different modules, the following describes a variety of the most frequently used ones.

4.1 Video/Laser module for visual inspection

For ordinary visual inspections of inner surfaces or to demonstrate the integrity of specific components, usually a video/laser-module will be used. It includes a tiltable CCD high-resolution color camera with picture resolution >460 TVL, 10x optical zoom, automatic-manual focusing and a powerful adjustable light source (ring of LEDs) for particularly illumination. The module is also fitted with a point laser who is integrated into the 360° rotating unit to verify anomalies like cracks, holes or pitted corrosion areas. At any point on the inner circumference of the pipe it is possible to do spot-measurements with an accuracy of 0.2 mm, also when the surface is intense shiny, wet or very uneven. By the laser, it is also capable to prove/check inner pipe profile/ovality (2D plot). All values (turn- and tilt angle, laser, etc.) are displayed on the laptop and illustrated by means of a title generator on the monitor, these values are then stored along with the camera image and comments on HDD / DVD.

4.2 Laser module for axial profile scanning and measurement of welding seams

Mainly used during the assembly of pipelines for nuclear power plants who are under construction, thereby this special axial laser scanning tool documents the quality of the ground welding seams of joined pipelines. E.g. for an actual project the angle of the grinded and polished ground welding seams resulting from the linear misalignment of two pipes must not exceed 7°. By using a point laser for measuring the ground welding seam, with the aid of two highly-precise centering units the laser is centered in the grinded welding seam region and travels over the welding seam propelled by an axial motor. Simultaneously a laser profile is recorded in the software and the condition of the welding seam can be examined by an additional high resolution CCD color camera. An integrated rotary unit between the two centering units allows to position the laser measurement point at the required location in the pipe and to take measurements at several points of the welding seam. Four or more axial scans are envisaged for measuring one welding seam, e.g. the first axial scan is carried out at 0°, the second at 90°, the third at 180° and the fourth at 270°, so that the welding seam can
be scanned all the way round. With the help of the software the individual recorded laser profiles can be called up and the angle of the ground welding seam with its automatically calculated value will be displayed directly in the laser profile by two cursors.

Fig. 10. Axial laser scanning module  
Fig. 11. Axial laser scanning profile

4.3 Ultrasonic module for wall thickness measurements and detection of pitted areas

In order to achieve a complete wall thickness measurement an ultrasonic inspection module can be used to detect pitted areas inside and outside of all echo capable materials. Fitted with a pivoting sensor arm, the module rotates continuously while travelling through the pipe. A gimbal suspension system allows the sensors to be guided orthogonally to the surface being inspected. To provide the echo couple medium a special feature is an independent continuous water supply to the ultrasonic sensor, i.e. it is not needed to fill the pipe with a liquid medium during inspection.

Fig. 12. Ultrasonic robot  
Fig. 13. Ultrasonic module  
Fig. 14. Ultrasonic monitoring unit

Centering mechanism  
Rotating mechanism (slip rings)  
Retainer mounted on pivoting sensor arm with water chamber and holder for UT-sensor (spring mounted)
4.4 Radiographic testing module (single-wall) for internal weld inspection

Film-based radiography is an effective NDT technique for locating and evaluating discontinuities that can adversely affect the integrity of an operating piping system. Characteristic discontinuities in welds are incomplete root penetration, burn-through in the root, root undercut etc. Open cracks can be detected, but tighter cracks, even though favorably oriented are detectable only by optimum practice, some cracks might not be revealed at all. The irradiation module carries out radiographic exposures on pipeline welds in single-wall technique from the center inside the pipe, instead of double-wall technique from the outside.

For the radiographic exposures an irradiation rod with a source guide tube of an external gamma irradiation system is adapted to the robot, whereas the radiation source, a low energy isotope (mainly Iridium-192), is housed in a source projector. By a hand crank, the low energy isotope gets propelled from the source projector through the source guide tube to the peak of the irradiation rod (exposure position) and back.

5. Machining modules

5.1 Grinding and polishing module

Particularly to be used to carry out any kind of work on the inner pipeline surface e.g. to renew strongly stressed points or to grind the various safety-relevant welding seams of the pipeline systems from inside during the assembly phase etc. By specific grinding of the internal weld roots the quality of the pipe joint will be increased (fatigue life), misalignment conditioned and inspection of the welding seams during recurring tests enormously facilitated. An accuracy of 0.1 mm makes it possible to produce local areas point by point according to precisely defined geometries. The grinding module comprises an electric-mechanical clamping/centering system, an on-board grinding camera, a powerful three-phase current motor with a grinding disc, a rotating unit with a rotating angle of 380° and a radial stroke for the grinding motor. A subsequent polishing with a buffing wheel allows a surface roughness better than Ra 3.2 μm.
5.2 Vacuum cleaning module

Based on the same principle as the grinding modules, the vacuum cleaning module cleans the pipeline e.g. after grinding. A suction unit with a suction tube is mounted on the rotating unit of the vacuum cleaning module. The suction tube is moved in the direction of the pipe wall via a stroke while the cleaning process is monitored by a suction camera, i.e. it is possible to specifically approach and provide suction at any point in the pipe.

5.3 Coating module

Internally coated pipes are required everywhere where aggressive or abrasive media can attack the pipe when in operation. Using the coating robot, a 1 mm coating can be applied evenly and in a controlled manner to pipe sections measuring up to 100 m. While travelling steadily in reverse, an epoxy coating is sprayed via a rotating spray nozzle to the inner wall of the pipe. The epoxy coating comprises a solvent-free dual-component mixture which is supplied from outside via a tempered hose.
6. Summary

The modular construction of the robots provides the platform for applications inside of all kind of pipe systems, in particular with strengths to travel through complex and/or unpiggable structures with difficult or non-external access. Many of the described modules were developed due to requests from different industry sectors, i.e. depending on individual specifications customized solutions are possible.