

Wireless Climbing Robots for Industrial Inspection

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Abstract-- Climbing robots have proven their abilities and enormous potential for industrial inspection tasks. These automated systems can climb, work, perform different actions in hazardous environments, changing between different types of surfaces and navigating through narrow spaces with difficult accessibility. Recently advances in mechanical engineering design and materials such as composites, have resulted in components and structures with complex geometries that need to be inspected more rigorously with more robust devices and novel techniques.

The paper describes a survey on climbing robots for different environments along with adhesion techniques that operate in critical industrial environments, such as aerospace, transportation, pipelines, petro-chemical processing and power generation. The application for these robots are mainly for surveillance and inspection rather than executing none destructive tests.

Index Terms-- Climbing robot, industrial inspection, adhesion Techniques, none destructive tests

I. INTRODUCTION

Inspection on complex geometric spaces with accuracy and repeatability can be achieved through mobile robotic devices. Traditionally inspection tasks found in industrial scenarios were being performed by human technicians who encountered many difficulties when actions as climbing were involved; requiring physical, mental and cognitive skills for guaranteeing the objective was properly executed. These industrial structures are usually very large and/or located in remote and hazardous environments. In many cases e.g. in power plants, pipelines, aerospace, storage tanks in the petro-chemical and food processing industries, etc., the inspection has to be performed during an outage by shutting down a plant [1]. There is an enormous pressure to reduce the outage time by performing the inspections as efficiently and quickly as possible to provide a rapid turnaround.

Recent developments in industrial robots are mobile wall climbing robots, swimming and pipe crawling robots have provided the means to perform inspections on very large structures and remote test sites. These may be located in remote and hazardous environments, but also these are very expensive to access and require the erection of scaffolding and lengthy preparation before start [2]. The robots provide the possibility of carrying out inspections in-service thus preventing costly outages and safety for the human operator.

Current research is developing mobile none destructive testing robots that: navigate inside petro-chemical storage tanks (while full of product) to inspect floors for pitting and corrosion; climb on the hulls of steel ships to inspect hundreds of kilometres of weld; inspect the walls of petro-chemical storage tanks for corrosion and weld integrity; inspect nozzle welds inside nuclear pressure vessels; inspect structures such as dams and bridges for cracks; inspect overhead power cables; internally inspect buried pipelines that are currently not reachable by intelligent pigs; climb up off-shore wind turbine towers to inspect the blades and to climb on aircraft wings and fuselage to detect for cracks and loose rivets [3][4].

This paper describes some recent developments of climbing robots with wireless control, mobile communications and capability to perform industrial inspections with some challenges, like improving battery time life; time-running, actuators technology, speed inspection, real-time analysis and safely distance of perform. Nevertheless, there are some advantages which could make more affordable such developments that may result in small size, low weight, easy recovering after inspection, where the costs and effort of robot recovery would be eliminated.

II. MULTIPLE SURFACE ADHESION

Different techniques are possible to create a climbing robot, for multiple surfaces of adhesion the most recognizes are Van der waal's adhesion [5], a bio-inspired technique from geckos and electro-static adhesion [6] well known in the field of physics; but due to industrial conditions like dirt, rust, corrosion, shape discontinues, weld, obstacles, etc. these techniques still need to be improved. One usual technique named vortex creates a vacuum system by spinning air (often turbulent flow) in spiral motion with closed streamlines; it could be suitable for non-ferrous surfaces. A vortex can be seen in the spiralling motion of air or liquid around a centre of rotation. A good example of a vortex is the atmospheric phenomenon of a whirlwind or tornados.

Figure 1 shows a wall climbing wheeled robot using vortex technique adhesion. It is able to climb on most types of surfaces by creating a negative pressure by spinning an impeller at 20,000 rpm or higher to generate a vortex. Its dimensions are around of 14.8 cm by 21 cm and weighs 800gs with an additional payload of 200g excluding the camera system. The robot is suitable for

visual inspection of non-ferrous surfaces. It climbs reliably on brick, concrete and glass surfaces.



Fig. 1. Multiple surface adhesion robot for visual inspection.

The body structure of the robot was designed with perforated aluminium to reduce its weight, and support the electronic devices for control and wireless communications. The wheels are driven by four servo motors with 360 degrees of rotation. Each pair of wheels is driven simultaneously to obtain rotation in any direction moving forward and backward. The motors and angle camera are controlled by a radio control system.

III. FERRO-MAGNETIC ADHESION

Magnetic adhesion is the most common industrial technique for climbing robots and NDT. This method depends dramatically on the position, direction and type of the magnetic field. The simplest form of magnetic adhesion uses permanent magnets to obtain constant forces. The force can be actively controlled by using electromagnets or combinations of permanent magnets and electrical coils. Magnetic adhesion is applicable to ferrous materials like steel, iron, nickel, cobalt, and gadolinium. The most important magnetic property, specifically for the attachment mechanism, is the magnet's power. The factors that determine magnet power are its material composition, magnet arrangement, environmental temperature, and its mechanical strength. Therefore this magnetic power can be increasing several number of times by using a especial arrange of concentrator behind the magnets, which basically focus the magnetic flux into the wall surface [7].

There are different types of permanent magnet materials with different properties and applications, the most commercially available are neodymium, made from sintered neodymium, iron and small amounts of boron; samarium-cobalt with excellent corrosion resistance and very useful in high temperatures; Alnico magnets, made with aluminium, nickel and cobalt and have higher temperature resistance, but not as strong as the previous two magnets; and some other like ceramic and plastic but at the moment not very useful in term of weak magnetic force by these are lightweight and waterproof.

The Neodymium and Samarium-Cobalt magnets have proved to be most useful in climbing robot applications,

these magnets in especial arrange and with flux concentrator have been performed in a 200 kg wall climbing robot [8][9].

Figure 2 shows a NDT inspection robot using adhesion with permanent magnets to perform long weld line inspection on new ship hulls and also repaired.



Fig. 2. Weld inspection robot with magnetic adhesion

The robot achieves smooth and continuous movement, as well as an excellent manoeuvrability, with a differential drive wheeled, its size is 600 mm x 375 mm x 340 mm and can work over large air gaps of 20 mm for working on curved surfaces and overcoming small obstacles such as studs and bolts. The payload of the NDT robot is approximately 20 kg. The robot has two sections connected by a hinge joint, with two wheels to drive the robot, and two omni-wheels, one in the front and one in the back, to support the robot. The two-section design enables motion through sharp angled corners presented in ship hulls with the back half maintaining strong holding force when the front half of magnet is lifted up. The robot has on-board controllers and can access the operator via wireless ethernet network.

The NDT robot is able to follow the welding robot by using infrared distance measuring sensors and by sensing the hot welding point with a thermal array sensor of eight thermopiles arranged in a row. It can measure the temperature of eight adjacent points simultaneously. The sensor reads infra-red in the 2 μ m to 22 μ m range, which is the radiant heat wavelength [8].

The NDT robot performs real time inspection of long weld lines with 100% volume coverage, simultaneously with the welding process. Ultrasound phased array NDT with an Omniscan carried by the robot sends data wirelessly to a laptop for analysis [9].

IV. FRICTION OR GRIPPER ADHESION

Multiplex alternatives can be achieved to make a climbing robot adhering with its own weight on wall. Many researches have developed several alternatives with gripping, needles, centrifuge or centripetal force around a pipe or pole [10]. Many of the force applies goes directly to the surface or been activated by gravity [5].

In heavy industry scenarios the main distribution element for oil and gas transportations are their pipelines. Frequently the inspection is carried-out to monitor aging, corrosion, cracks, and mechanical damages from third parties [2]. Continuous activities for inspection, maintenance and repair are strongly demanded; however, those activities required enormous budgets that may not be easily handled by several industries. For these reasons, the application of maintenance robots of the pipelines appears to be one of the most viable solutions to be implemented [11].

In-pipe robots can be classified into several elementary forms according to their locomotion mechanism such as, pig, wheeled, crawler, wall press, walking, inchworm and screw type [12][13]. The pig type is the most commercial, because it is passively driven by fluid pressure inside oil pipelines and is employ for inspection of pipelines with large diameters.

Figure 3 shows a wall press climbing robot for pipeline inspection using a single actuator to achieve mobility along the tube in 100mm diameters.

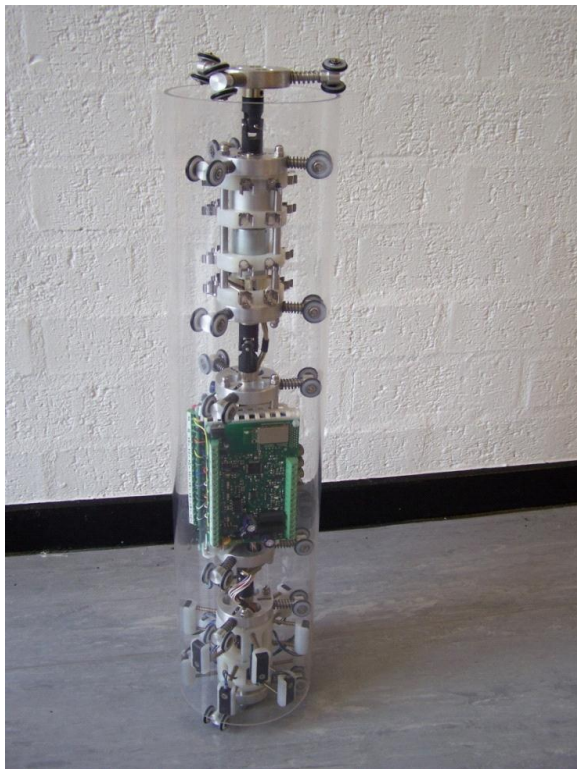


Fig. 3. Pipeline inspection robot by wall press locomotion.

The robot is 500 mm length and consists of three main parts, the drive module, the control module and the NDT module. The upper module shown in Figure 3 is the drive module; it is composed by one stator and rotor, these are connected by an active universal joint and powered by one dc motor with gearbox reduction. The control module is placed in the middle for cabling reasons and the bottom module is a NDT system simulated by digital sensors.

All three modules are designed as stators; these are equipped with a set of wheels which allow the motion parallel to the tube axis; however, the drive module has the rotor equipped with wheels tilted 10° which generates the axial motion with a small pitch with respect to the plane perpendicular to the tube axis, similar as a screw.

The stators are located straight along the pipe with the purpose of guaranteeing the overturning stability and certify a sufficient contact force between the robot and the pipe surface and also to be able to adjust small changes owing of non-homogenous pipe diameter or obstacles, and to allow travelling in curved pipes.

The robot is wirelessly control equipped with 12 batteries (AAA NiCd 1200 mAh) that last in one hour of continuous operation. These are distributed around the motor on the stator in the upper module. The NDT module is integrated by 16 inductive digital sensors placed around the pipe acting as NDT probes, inspecting the pipes for defects or cracks.

V. CONCLUSIONS

The wireless climbing robots presented here are a very brief review of several available in research and commercial applications, designed to provide access to inspection sites on very large structures and/or test sites located in hazardous environments. The robots can deploy sensors to implement an appropriate technique from the almost all NDT techniques to find defects such as cracks, inclusions, lamination debonding and the extent of corrosion on steel structures.

Robotic access both speeds up the inspection and reduce costs by eliminating the expensive and lengthy erection of scaffolding or the preparation of the site before humans can manually perform the inspection. Thus outage turnaround can be reduced or an outage prevented where the robotic inspection can be performed while the plant is in service.

Robotic deployment of NDT is the only means of performing testing where the test site is located in hazardous and dangerous environments.

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