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Laser-Guided Underwater Mobile Robot for Reactor Vessel Inspection

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ABSTRACT: The footprint of Robotics in nuclear power plant is not surprising. Handling heavy radioactive loads, carrying out tricky maintenance and repair operations in contaminated zones, etc., In the nuclear industry, these high-risk activities have always had to be performed by robots immune to radioactivity. Over the years, these technologies have made considerable headway. The Introduction of robots with nanowire sensors, laser guided mobile robots can accomplish all the cumbersome tasks where human cannot move in. These upcoming technologies could help the department of atomic energy to get in to the next generation methodologies. Running a nuclear power plant is very risky until provided with proper maintenance. In the nuclear power plant robots can be used for underwater cleaning, underwater inspection and surveillance, Remote operation and maintenance, Surface decontamination, improved monitoring of heath physics tasks, General operation and maintenance tasks, preprogrammed inspection of controlled inspection areas, cooling tower basin sediment cleaning. Technologically, it may be close to the fully autonomous, intelligent robot that would represent the ultimate marriage between machine automation and the developing field of artificial intelligence Its ability to maneuver around or over obstacles under the guidance of a remote operator approaches the level of computer control integration that will be needed if a robot is to be capable of autonomously responding to a programmed set of directions by referencing a self-contained data base for its location, destination, route, and tasks. The acceptance of robots as tools for power plant missions will increase dramatically in the future with the co-design of robot and power plant.

KEYWORDS: Nuclear Power Plant, Robotics, Laser Positioning Unit, Reactor Vessel Inspection System, Multifunctional Sensors, Magnetic Wheeled Laser-Guided Mobile Robot, Underwater Operations, Nanowired Sensors

INTRODUCTION:

A nuclear and radiation accident is defined by the International Atomic Energy Agency as "an event that has led to significant consequences to people, the environment or the facility." Examples include lethal effects to individuals, large radioactivity release to the environment, or reactor core melt. The prime example of a "major nuclear accident" is one in which a reactor core is damaged and significant amounts of radioactivity are released, such as in the Chernobyl disaster in 1986. The impact of nuclear accidents has been a topic of debate practically since the first nuclear reactors were constructed in 1954. It has also been a key factor in public concern about nuclear facilities. Some technical measures to reduce the risk of accidents or to minimize the amount of radioactivity released to the environment have been adopted. Despite the use of such measures, human error remains, and "there have been many accidents with varying impacts as well near misses and incidents". The technological improvement can be somehow used to minimize the rate of occurring accidents. However with large new innovations hopefully sooner these nuclear accidents can be eradicated. The nuclear power plant has several cylindrical vessels such as a reactor vessel and pressurizer. The vessels are usually constructed by welding large rolled plates or nozzle pipes together. To ensure the integrity of the vessel, their welds should be periodically inspected using sensors such as ultrasonic transducers or visual cameras. To inspect these welds effectively, we developed an underwater mobile robot, which is guided by a laser pointer. The robotic system was devised to reduce the inspection time and schedule during mandatory code inspections compared to a conventional inspection machine with a large structure. The system mainly consists of an underwater mobile robot, a laser positioning unit, and a main control station. The underwater mobile robot is guided by a laser positioning unit with a precise resolution of 0.05◦. The mobile robot moves on the reactor vessel wall with four magnetic wheels. This paper presents the design and implementation of the underwater mobile robot. The laser guidance control of the mobile robot is also described along with the experimental results. After many improvements in its design and engineering, the system is expected to dramatically reduce the critical path of the reactor vessel inspection, if the system is used practically.

MOBILE ROBOT :

Mobile Robot is a submarine type mobile robot whose weight is approximately 40 kg in air and becomes zero in water by the aid of floats. Most of the reactor pressure vessel in a pressurized water reactor is composed of carbon steel and is clothed inside with austenitic stainless steel. To climb the vertical wall of the vessel, LAROB has four magnetic wheels. The ring-shaped magnet has N and S poles on each side of the magnet. Pure steel circular plates are attached on each side of the magnet to maximize the attraction force to the vertical wall. Smooth rubber is clothed around the magnet to prevent slippage on the vertical wall. Among four magnetic wheels, two are caster wheels and the other two are driven by dc servo motors so that the robot can move in any direction on the vertical inner wall of the reactor vessel. The robot can control the linear velocity and angular velocity by the sum and difference of the velocities of the leftand right driving wheels. Both the front and rear caster wheels are mounted on the parallelogram links with the robot body plate. It keeps the robot body parallel to the wall, even though the wall is cylindrical. The caster wheel frame can move only up and down, keeping the posture parallel to the robot body frame. Silver nanowires are used to develop wearable, multifunctional sensors that could be used in biomedical, military or athletic applications, including new prosthetics, robotic systems and flexible touch panels. These sensors could report the status of the mobile robot then and there. And also nanowire batteries could save the life of robot. the growth of single-crystalline WO_3 nanoneedles (NN) on sensor substrates using a horizontal aerosol assisted CVD cold wall reactor. The heating element of the sensors is used to keep the appropriate growth temperature. The morphology and the crystalline structure of the films were characterized by using scanning electron microscopy, X-ray diffraction and Raman spectroscopy, and the results proved the synthesis of thin layers of monoclinic WO_3 NN with preferred orientation in the [002] direction. The gas sensing properties of the films were also evaluated by exposing our sensors to different analytes: EtOH, H_2, and CO and we have compared their responses to those obtained from WO_3 sensors fabricated by a hot AA-CVD wall reactor. The new growth method is able to highly improve sensor stability and sensitivity in comparison to the conventional hot wall reactor. Additionally, it could be more easily adapted to rigid and flexible sensor substrates.

SENSOR MODULE :

Nanowire sensors have attracted much attention for two reasons. First, their large surface area to volume ratio promises high sensitivity. Second, the size of the nanostructures is similar to the size of species being sensed, thus the nanostructures make good candidate transducers for producing the signals that are then read and recorded by conventional instruments. The underlying phenomenon exploited in using nanowires is the field effect on which field effect transistors (FETs) are based. The wire acts as the channel from source to drain for the FET. If functional groups attached to the nanowire can act as a receptor to bind with a target species (particularly a biological entity that possesses a charge), then the charge on the surface of the nanowire changes. Since this can influence electronic behavior into the depth of the nanowire, a gating effect occurs that can be used in sensing. Figure provides a representation of a nanowire configured as an FET.

LASER POINTING DEVICE:

The robot is induced by the laser pointer, which is fixed in the middle of the crossbeam across the reactor upper flange. The laser pointer emits a laser beam to the next position for the robot to move. The robot, with the position sensitive detector on its back, detects the deviation of the laser beam spot from the center of the position sensitive detector, and moves in the appropriate direction to make this deviation zero. The laser pointing device is a kind of pan-tilt device upon which the diode laser is mounted. The device is accurately driven by dc servo motors with a resolution of 0.05◦. The laser pointer induces the robot to the next position by emitting a laser beam. The laser pointer is covered by a hemispherical-shaped plastic cap to prevent deflection of the laser beam and water penetration.

INSPECTION PROCEDURES:

To determine whether the weld has defects or not, we have conducted the well-known ultrasonic testing. After emitting an ultrasonic wave to the suspected welds, we monitor its reflected signal. Usually the reactor pressure vessel is manufactured by welding several parts together. The welds to be inspected in the vessel are largely classified as circumferential welds and nozzle welds. Circumferential welds include the flange to upper shell, upper shell tomiddle shell, middle shell to lower shell, and lower shell to bottom head welds, while nozzle welds include the nozzle to middle shell, and nozzle to nozzle pipe welds so-called safe end. In addition, the flange ligament should be inspected. In some reactor vessels, vertical welds of the reactor shell and welds of the safety injection nozzle are included as inspection items When inspecting each weld, we have to use various incident angles of an ultrasonic wave for a more accurate and strict inspection. For example, for a reactor shell weld inspection, we used incident angles of 0◦, 45◦, 60◦, and 50/70◦, respectively.In addition, for each incident angle, we have to scan the welds in four directions, upward, downward, clockwise, and counter clockwise directions, using ultrasonic probes with a specified incident angle.

CONCLUSION: This idea of nanowire sensors in robots could be applicable for various industries. Based on this approach future electronics era willl be benefited. Conventional methods can be replaced by nano scale which would improve efficiency, handling safety, examination reality, accuracy etc. Futuristic research can be studied upon with even more compact structure.

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