Underwater Wall Climbing Robot for Nuclear Pressure Vessel Inspection

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ABSTRACT

This work has developed an underwater teleoperated wall climbing robot that can carry another pipe crawler robot to nozzle openings inside a nuclear pressure vessel (PV). The wall climbing robot is positioned over each nozzle in the pressure vessel via teleoperation using visual feedback. The pipe crawler robot is transferred into the nozzle where it non-destructively tests circumferential welds located at a distance of 700mm from the inside walls of pressure vessel [1, 2].

These welds are currently inspected in maintenance periods by using very large robot arms that sit on the floor inside the PV at a depth of around 20 m. The arms are transported into the containment area in a disassembled state and re-assembled over a lengthy period in a radiation environment. A preferred solution to replace the time consuming transportation and setup of a large robot with attendant exposure to radiation is to develop a light weight and compact robot system that can be carried into the containment area by two operators maximum and inserted into a pressure vessel using an overhead crane. The robot must be able to climb on the walls of the PV, operate underwater, resist radiation damage and accomplish the weld inspection task in all the pipe nozzles located in the pressure vessel.

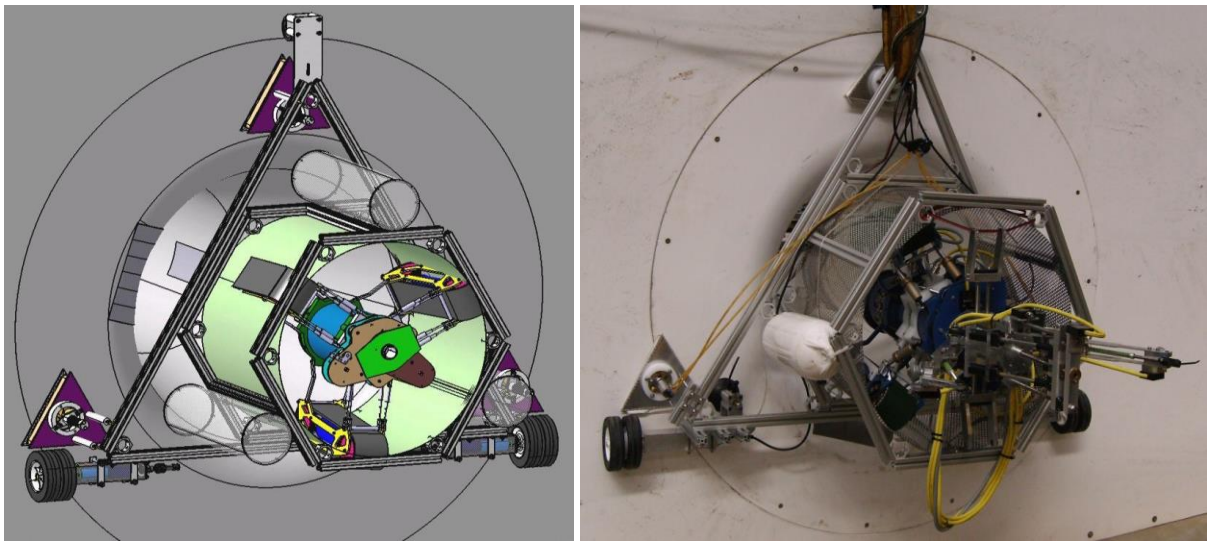

Figure 1: Prototype Underwater Wall Climbing Robot

The underwater wall climbing robot, shown in figure 1, achieves these aims. It uses hydraulic vacuum cups to create a negative pressure over the wall surface to adhere and climb on the internal walls of a pressure vessel. Robot motion is controlled by teleoperation. A triangular configuration of three omni wheels and three motors enables straight line motion in any direction thereby easing the positioning of the robot over a nozzle that is 760mm diameter at its opening but tapers down to 540mm. The wall climber carries another pipe crawling robot located centrally in the triangle shaped climber. The pipe crawler sits inside a 600 mm long tube with diameter 760 mm. After the wall climber is positioned accurately over a nozzle, the pipe crawler makes a transition into the nozzle and travels to find the weld located 700 mm from the inside surface of the pressure vessel. The pipe crawler robot adapts itself to the size of the tapering pipe during this motion. It then locates the circumferential weld and scans it using a number of Non-Destructive Testing techniques that include standard ultrasonics, phased arrays, and eddy currents.

The climber design is modular and symmetrical so that any of the identical robot links and brackets that make up the body of the robot are interchangeable. In addition, all three motors, three suction cups, and three pumps are identical and interchangeable so that the robot can be assembled/disassembled very quickly to enable its transportation from site to site. A major consideration in the design is the radiation hardening of motors, sensors and umbilical cable as well as the selection of materials to prevent chemical interaction with the water in the vessel and its possible contamination by the inspection system. Another important consideration is the assured retrieval of the robot in case of breakdown.

Conclusion

The results of trials with the robot in a mock-up of the PV will be presented. The paper will describe the performance of the final underwater wall climbing robot prototype, with emphasis on the performance of a special design of suction cups that have a low coefficient of friction and the precision of motion in cylindrical pressure vessels.

References:

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