УДК 629.5:811.111

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Welding Manipulators in Shipbuilding

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A manipulator is a device used to manipulate materials without direct contact. Its applications were originally for dealing with radioactive or biohazardous materials, using robotic arms, or they were used in inaccessible places. In more recent developments they have been used in diverse range of applications including welding automation, robotically-assisted surgery and in space. A manipulator is an arm-like mechanism that consists of a series of segments, usually sliding or jointed called cross-slides, which grasp and move objects with a number of degrees of freedom [1].

Manipulators are designed, constructed and developed by the science, called *Mechatronics* that is the synergistic integration of mechanical, electrical and computer systems. With the help of *Robotics* (the application of mechatronics to create robots which are often used in industry to perform tasks), manipulators can do different work much better than human operatives [2].

In industrial ergonomics a manipulator is a lift assist device used to help workers lift, maneuver and place articles in process that are too heavy, too hot, too large or otherwise too difficult for a single worker to manually handle. As opposed to simply vertical lift assists (cranes, hoists, etc.) manipulators have the ability to reach in to tight spaces and remove workpieces. A good example would be removing large stamped parts from a press and placing them in a rack or similar dunnage. In welding, a column boom manipulator is used to increase deposition rates, reduce human error and other costs in a manufacturing setting.

Additionally, manipulator tooling gives the lift assist the ability to pitch, roll, or spin the part for appropriate placement. An example would be removing a part from a press in the horizontal and then pitching it up for vertical placement in a rack or rolling a part over for exposing the back of the part [1].

A welding manipulator can be either open arc or submerged arc. A welding manipulator can be used to weld horizontally and vertically and is ideal for job shops as they are robust, have high production volume capacity and a greater degree of flexibility in product engineering. Welding manipulators are commonly used in pipe and vessel fabrication [3] but can be also used in a cladding procedure with the aid of a proper welding fixture.

Ship building automatic welding. In today's demanding and competitive ship building and repair industry, new technology is very much needed and automation plays a key role in improving the productivity and quality of shipyards. Welding is a fundamental task in shipyards and marine/offshore companies. Robotic welding is very attractive because of its robustness and manipulability and has been recognized as the next step in technological advancement of shipyards. There are many commercially available robotic welding systems that have been applied to shipyards, the robotic system of Odense Steel Shipyard Ltd in Denmark being one of the most notable. This robotic welding system is integrated into a CAD system and robots are programmed offline. Offline programming systems require the availability of CAD data describing the workpieces to be welded. A model of the robot and the welding process is then simulated in the computer together with a CAD model of the workpieces and environment. With a simulation environment, the robot program can be developed offline and tested before it is downloaded or implemented in the actual robot. However, such system has got a number of disadvantages. Offline robot programming systems require an accurate description of the workpieces and layout of the environment. Robotic welding systems are very complicated to use, they require a robot programmer and/or application engineer which shipyards do not normally have. Also, CAD data of plates, webs, stiffeners are not available. Part geometries are only available in manual drawings and this makes off-line programming technique for robot teaching not applicable. Another problem is the workpieces are very large. The robotic system SWERS (Ship Welding Robotic System) developed by the National University of Singapore is based on a completely new approach to robotics [4]. SWERS includes a special teaching procedure that allows the human user to teach the robot welding paths at a much easier and faster pace [4]. A 6-axis force-torque sensor is mounted on the welding torch through a custom-built walk-through teaching (WTT) handle. The operator grasps the WTT handle and moves the welding torch naturally to position it in the required welding positions. The sensor senses the force and moments exerted by the operator's hand. The controller then commands the robot to move in response to the sensed forces. To achieve this, it is important to be able to control the dynamic behavior of the robotic manipulator, or to control the *impedance* of the manipulators. The biggest advantage of SWERS is the easier and faster operation compared to a conventional robotic system. With the implementation of the new Walk-Through Teach method, robot can now be used for the panel line for a faster welding time as shown in the welding tests. For a specific welding length of 1m, the total operation time including robot teaching time of SWERS is 5% faster than manual welding. It will be even faster if the workpiece have repeated patterns because the *Teach-Weld-Weld* mode can be used.

As the SWERS is so easy to operate, the training time required to use the system is much shorter than for a conventional robotic system. Apart from the improvement of welding cycle time, the welding quality of the robotics system is better than manual arc welding due to the implementation of optimized welding parameters on the system and non-stop welding lines. Besides, the precise motion of the robot in addition to the arc sensing for search and tracking the seams has also contributed for better welds. Since the actual welding is handled by the robot, the operator can now stay away from the fumes and heat generated by the welding. A less hazardous and better working condition for human is another advantage of using this robotic system. By incorporating a force-torque sensor together with powerful algorithms, a new way of robot teaching method is implemented and proved useful for the automated welding in shipyards. The custom design man-machine interface is crucial for the operation of the robotic system for the complicated welding operation [4].

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