CONF-940406--10

DUAL-ARM MANIPULATION MODULE FOR USE IN DECONTAMINATION AND DECOMMISSIONING OPERATIONS*

W. R. Hamel, D. C. Haley, and W. E. Dixon
Oak Ridge National Laboratory
Robotics & Process Systems Division
Oak Ridge, Tennessee 37831-6304
615-574-5691

Presented at the
1994 International Decontamination
& Decommissioning Symposium
Knoxville, Tennessee

April 24-29, 1994

*Research sponsored by the Office of Technology Development, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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Introduction

A dual-arm manipulation module is under development for application in decontamination and decommissioning (D&D) tasks. The development is led by Oak Ridge National Laboratory with support from Sandia National Laboratories, and with university and industry participation. The project is part of the Robotics Technology Development Program funded by the U.S. Department of Energy, Environmental Restoration and Waste Management, Office of Technology Development. The dual-arm module is designed to provide dexterous manipulation capability for remote characterization, decontamination, and dismantlement operations, and the module is reconfigurable to meet various deployment requirements. Remote manipulation capability can benefit D&D activities through reduced worker exposure to both contaminant and industrial hazards. When tasks conditions permit, increased use of robotic features can reduce costs by increased efficiency of operation.

Design Features

A wide range of facility size and complexity will be encountered within the D&D activities. D&D is required for facilities ranging from hot cells and reactors to massive chemical and process plants. The design of the dual-arm manipulation system was driven by the desire to provide maximum system versatility in deployment options and orientation relative to specific task performance. Figure 1 presents the design of the dual-arm manipulation module. The system consists of two commercially available hydraulic manipulators mounted on a positioning module, an electronics module, and a hydraulics module. Hydraulic manipulators were selected to provide the payload capacity required for anticipated tooling and material handling needs. The positioning module provides five degrees of freedom (DOFs) to allow positioning of the two manipulators in the most advantageous configuration for a given task.

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These added DOFs are used to configure the system prior to task execution, or to reconfigure the system, if needed, but are not active DOFs during operation of the two manipulators. The capability to roll each manipulator from an elbows-up through an elbows-out to an elbows-down configuration is provided by rotational hydraulic actuators upon which the standard six DOF manipulators are mounted. An elbows-up configuration is advantageous for operation from above on horizontally configured equipment. An elbows-down configuration is advantageous for working on vertically stacked equipment. The elbows-out positions allow the manipulators to reach around obstacles, if required. The relative distance between the two manipulators can also be varied

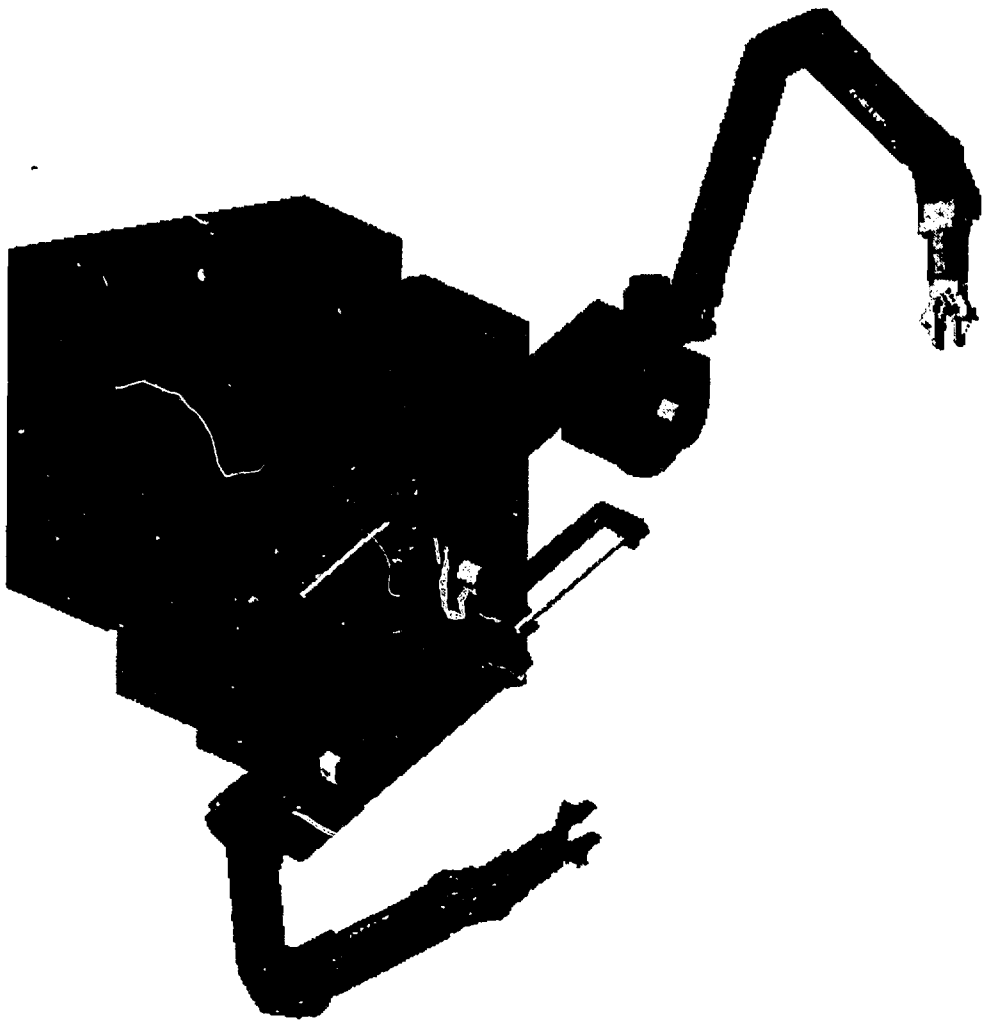
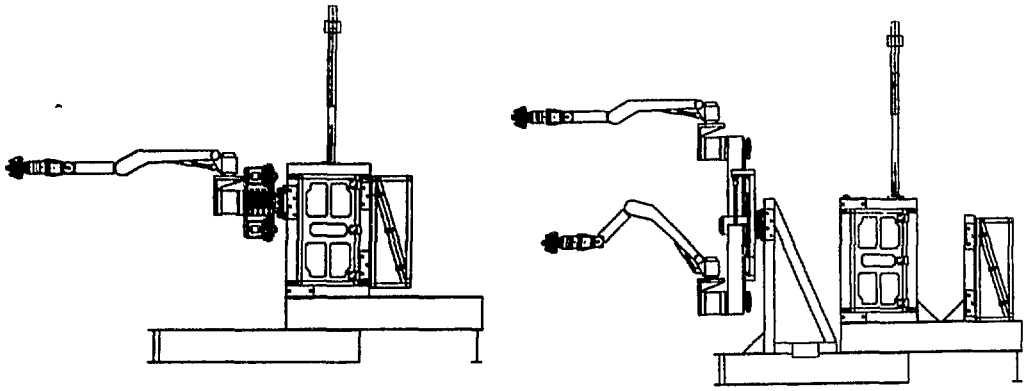


Fig. 1. Dual-arm manipulation module.

through the use of linear hydraulic actuators in the positioning module. Since deployment of the entire system may be constrained by access limitations, the capability to extend the area reachable by the two arms increases the task workspace while minimizing the need for system moves requiring repositioning by the mobility system. Finally, the entire positioning module can be rotated to reorient the centerline between the two manipulators. These positioning capabilities allow the manipulators to be configured to the best pose for performing tasks in the cluttered and constrained environments expected during D&D activities. The electronics and hydraulics modules are independent modules that allow maximum versatility in configuring the system for various deployment options. Figure 2 shows the dual-arm manipulation module on a test-stand configured as a single system (Fig. 2a) and as separate modules (Fig. 2b).



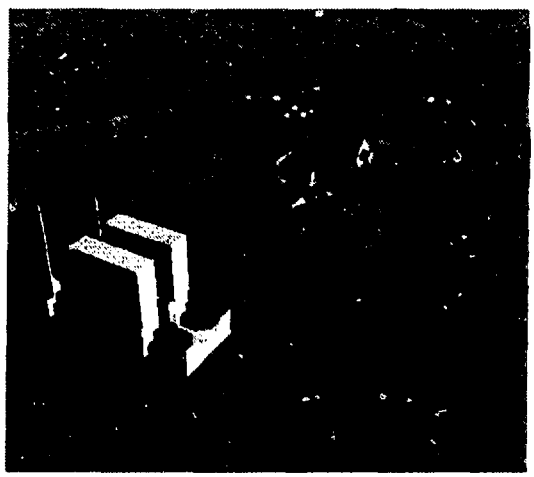
a. Single system configuration. **b. Separate modules configuration.**

Fig. 2. Dual-arm system modularity.

Deployment Options

To provide access to the task site, the dual-arm manipulation module must be deployed by an additional system that provides mobility within the facility undergoing D&D. Two primary deployment options have been identified: deployment by overhead bridge crane systems and deployment by a vehicle system. Many facilities included overhead-bridge crane systems for equipment installation and ongoing maintenance. Where available, these systems can be employed to deploy the dual-arm manipulation module. The initial overhead-bridge deployment option will be by a rigid mast system as shown in Fig. 3a. An additional option, under development in France, is deployment by an overhead crane hook using cables attached to various facility locations to provide stability. The bridge deployment options use the total system configuration depicted in Fig. 2a to minimize the support requirement provided by the deployment system. In facilities where overhead-bridge crane systems are not available, a

vehicle system will be used for deployment of the dual-arm manipulation module. Figure 3b represents the manipulators and positioning module deployed from a boom mounted on a vehicle. In this configuration, the dual-arm module electronics module is mounted on the vehicle and the dual-arm system uses existing vehicle hydraulics capability to provide hydraulic power. Use of a boom on the vehicle extends the workspace of the system in large facilities. For vehicle deployment without the boom, the manipulators and positioning module mount directly on the vehicle platform to provide the capability to perform tasks on floors, medium-height walls, and smaller equipment.



3a. Overhead bridge/mast. **3b. Vehicle/boom.**

Fig. 3. Deployment options.

Telerobotics Philosophy

The dual-arm manipulation module is designed for use in teleoperation, telerobotic, and robotic modes. Good teleoperation capability has been a primary design driver for this system. The wide variety of potential tasks and lack of good *a priori* models of the workspace limit extensive use of robotic operation except in facilities that consist of very repetitious equipment designs. Pure teleoperation, however, is operator intensive and less efficient. Therefore, the system has been designed to allow the addition of extensive operator aids to allow the use of many robotic capabilities to increase the operator effectiveness and increase the efficiency of the system. Such systems are referred to as telerobotic systems. An example of such capability added to the dual-arm manipulation system is the task space scene analysis capability developed by The University of Tennessee. This system uses a stereo camera system to capture images of the immediate workspace and uses image processing and interactive

operator input to allow the operator to quickly build a graphical model of the portion of the workspace that is the focus of the current task. This three-dimensional model is automatically registered to the manipulator systems since the camera system is attached to the dual-arm module at a known location. With this model, the operator can specify manipulator tasks such as grasp and cut functions, which can then be robotically performed by the dual-arm manipulator system. A capability to graphically preview the task is provided to allow the operator to verify the feasibility of the operation before allowing the system to proceed with the task. This graphical preview feature improves the safety of operations, especially in constrained or cluttered environments. Through the use of capabilities such as the task space scene analysis, the operator provides much of the cognitive capabilities required to plan tasks, whereas robotic system control features allow robotic execution to relieve the operator of much of the direct motion command activity required in pure teleoperation. For tasks that do not lend themselves to the use of these telerobotic capabilities, the operator performs the tasks under direct teleoperation control.

Testing, Evaluation, and Demonstration Plans

The dual-arm manipulation module under development provides an extensive range of possible deployment and control mode combinations. This wide range will allow testing of many remote D&D operation scenarios. One of the primary functions of the technology development task is to perform sufficient testing and demonstrations to allow evaluation of the capability of remote systems to perform realistic D&D tasks and to evaluate the added value of operator aids and robotic capabilities in increasing operator effectiveness and system efficiency. The initial hardware system will be available in the spring of 1994, with extensive testing and demonstration activities planned for the last half of FY 1994 and continuing into FY 1995.

Conclusions

The dual-arm manipulation module under development will provide a highly versatile remote manipulation capability with which to evaluate the applicability and effectiveness of remote manipulation in performing a wide variety of D&D tasks.