A Robust Power Remote Manipulator for Use in Waste Sorting, Processing, and Packaging - 12158

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ABSTRACT

Disposition of radioactive waste is one of the Department of Energy's (DOE's) highest priorities. A critical component of the waste disposition strategy is shipment of Transuranic (TRU) waste from DOE's Oak Ridge Reservation to the Waste Isolation Plant Project (WIPP) in Carlsbad, New Mexico. This is the mission of the DOE TRU Waste Processing Center (TWPC). The remote-handled TRU waste at the Oak Ridge Reservation is currently in a mixed waste form that must be repackaged in to meet WIPP Waste Acceptance Criteria (WAC). Because this remote-handled legacy waste is very diverse, sorting, size reducing, and packaging will require equipment flexibility and strength that is not possible with standard master-slave manipulators.

To perform the wide range of tasks necessary with such diverse, highly contaminated material, TWPC worked with S.A. Technology (SAT) to modify SAT's Power Remote Manipulator (PRM) technology to provide the processing center with an added degree of dexterity and high load handling capability inside its shielded cells. TWPC and SAT incorporated innovative technologies into the PRM design to better suit the operations required at TWPC, and to increase the overall capability of the PRM system. Improving on an already proven PRM system will ensure that TWPC gains the capabilities necessary to efficiently complete its TRU waste disposition mission.

INTRODUCTION

The WIPP geological repository is responsible for the safe storage of TRU waste generated from DOE activities. In order to ensure that this waste is properly stored for generations to come, it is required that waste be packaged in accordance with recognized Waste Acceptance Criteria. A large amount of mixed waste is currently located at the Oak Ridge Reservation and requires shipment to WIPP for proper long-term storage. This combined waste form contains low level, mixed low level and TRU waste forms which must be sorted and repackaged in order to ensure that the Waste Acceptance Criteria is met prior to shipment.

The TRU waste processing center is a special facility equipped to handle a number of different types and classifications of wastes, and performs the sorting and repackaging of the Oak Ridge Reservation waste forms. Mixed waste forms which are classified as remote handled pose a significant task for TWPC operations due to the wide variety of items which are contained in the existing waste containers. Some of the most difficult tasks required to sort these materials include size reduction of large structural frames and use of power tools within the shielded cells.

EQUIPMENT OVERVIEW

For this project, TWPC and S.A. Technology worked together to provide shielded cell operators with a more robust, more flexible alternative to traditional master-slave manipulators. The intent behind the project was to expand shielded cell operational capabilities, allowing for applications that require higher payloads and an expanded range of motion while maintaining the ability to perform intricate tasks. This was accomplished through by including innovative technologies into SAT's existing Powered Remote Manipulator technology.

The SAT Powered Remote Manipulator is a modular and adaptable system which provides a reconfigurable design can be integrated with a variety of platforms, including: MSM ports, gantry/rail systems, bases, and other industrial equipment. The PRM's innovative hydraulic joint design and use of radiation-hardened carbon fiber result in a lightweight and robust system, capable of long reach and high payload operations.

Fig 1: Powered Remote Manipulator Mounted to Spider Crane

The PRM is a hydraulically powered, seven (7) degree-of-freedom design that is equipped with a quick-change connector for tool change-out, allowing a variety of custom tooling capabilities. The primary tool for the PRM is a parallel action gripper that opens up to six (6) inches, but the PRM is able to utilize a variety of different tools and attachments that include but are not limited to: shears, saws, torque wrenches, hydrolasing equipment, dry media blasting equipment, and water jet cutting equipment.

The control system for the base PRM is PLC-based and uses proportional joysticks along with proportional valves to control the individual joint motions and speeds. A speed range adjustment

is also incorporated into the system to allow the operator to move at full speed or limit the maximum speed of the arm to make precise movements.

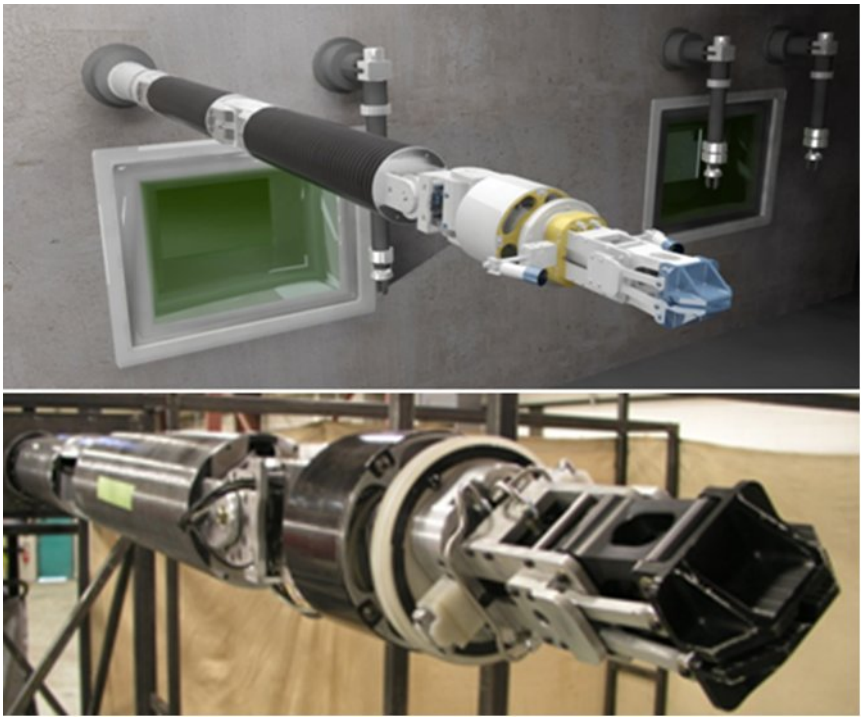

Fig 2: Concept Rendering of PRM (top), PRM in Testing (bottom)

SAT has previously delivered Powered Remote Manipulators for use in shielded cell processing environments, but the collaborative effort between TWPC and SAT has resulted in the inclusion of innovative technologies including:

- Force protection measures
- Hydraulic contamination control measures
- Size, speed and port size optimization

FORCE PROTECTION MEASURES

The TWPC PRMs are the first generation of PRMs to implement force protection measures. This feature enables the PRMs to alert the operator when the arm is performing an operation which could result in the application of excessive force; ensuring that damage is not imparted on the surrounding equipment or incurred by the PRM itself.

The need for this type of protection stems from a common problem with all manipulator systems with multiple degrees of freedom. In these systems, the joints near the tip of the manipulator must be reduced in size and weight when compared to those joints near the base in order to maintain reasonable joint loads through the manipulator. With reduced size and weight, these smaller joints are also not as robust. However in some arm configurations, these smaller joints can be subjected to the same loads as their larger counterparts resulting in potential damage.

The TWPC PRM system includes a custom controls loop that constantly monitors the position and payload of the manipulator during operations, and uses the retrieved data to determine the anticipated joint loads at each of the PRMs seven (7) joints. The PRM system then compares this data to the actual hydraulic pressure and mechanical torque values for each joint. When the PRM system detects that the actual pressure/torque values exceed the calculated values, it prompts the operator with an error message to alert them of the condition. In this manner, the system is able to prevent potential issues before they occur.

HYDRAULIC CONTAMINATION CONTROL MEASURES

As mitigation for the large amount of alpha contamination present in the TWPC shielded cells, the TWPC PRM system includes increased contamination control measures for its hydraulic system. One area of the PRM design that is more susceptible to the ingress of alpha contamination is the hydraulic components associated with the PRM gripper. The majority of the PRM is contained in a boot to limit contamination ingress, but the gripper must be located externally to this boot to allow operators to interact with in-cell objects.

The gripper being exposed to the in-cell environment provides the potential for contamination ingress via the gripper hydraulic cylinder rod seal. Additionally, the PRM system provides a quick-change tool connect device which is susceptible to contamination ingress during tool changes. In most standard manipulator hydraulic systems, a common hydraulic system is used, so ingress of contamination through one of these seals would represent the potential contamination of the entire hydraulic system.

For the TWPC PRM system, the hydraulic system for the gripper has been separated from the main hydraulic system to limit the potential for contamination ingress. The gripper hydraulic system is a smaller, closed hydraulic system consisting only of a master cylinder and small hydraulic reservoir. A drive cylinder on the main hydraulic system is mechanically linked to the master cylinder on the gripper hydraulic system to eliminate the possibility of contamination transfer. With this design approach, if contamination of the gripper hydraulic system should occur, the potential volume of contaminated material is limited to 1400mL (as opposed to 75L of potential volume in the main hydraulic system)

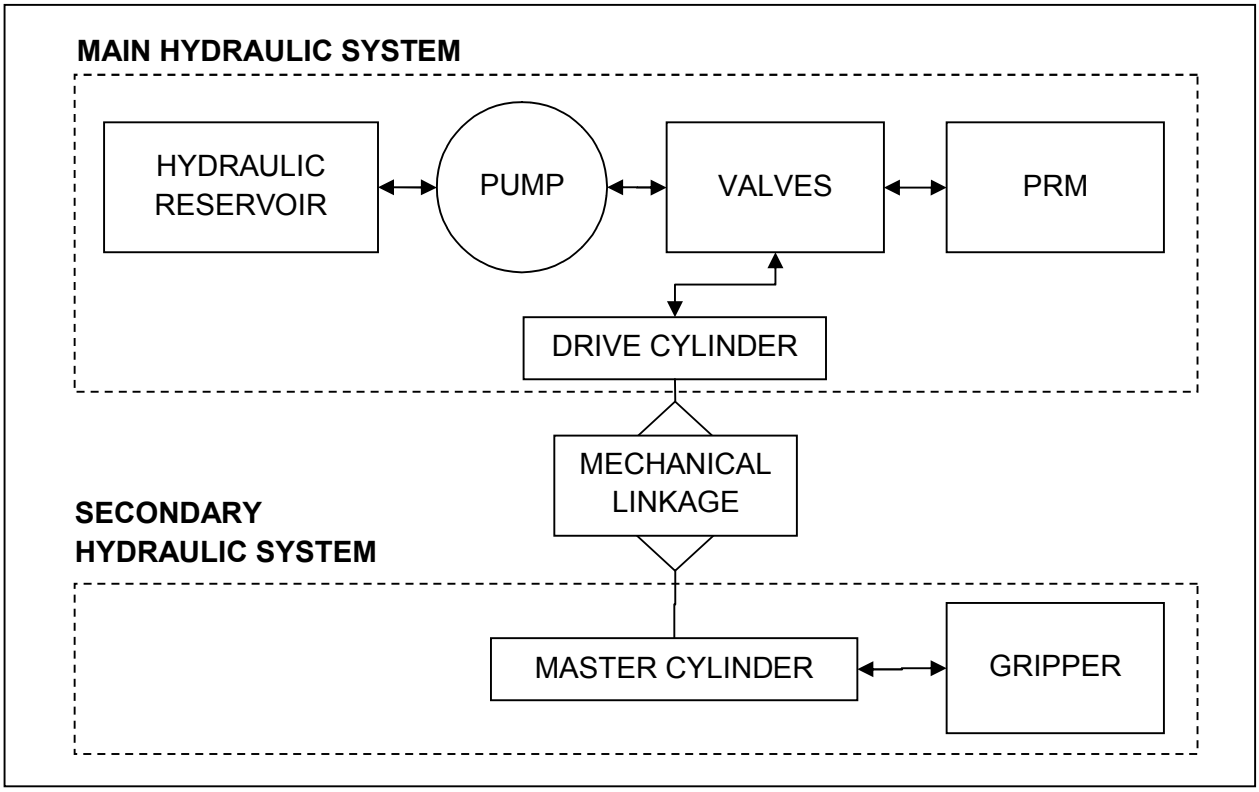

Fig 3: TWPC PRM Hydraulic Diagram (Simplified)

RANGE, SPEED AND PORT SIZE OPTIMIZATION

In an effort to optimize the PRM system for use at TWPC, numerous small refinements were made to the existing PRM design. Among these refinements, the most significant were optimizations to the PRMs range of motion, movement speed, and port size capability.

In previous PRM designs, the design of the shoulder pivot joint was limited to +90° -10°, which limited the ability of the PRM to transfer loads from very low to very high positions without completely changing the manipulator configuration. With the anticipation that these movements will regularly occur during TWPC operations, the TWPC PRMs have been developed with a revised hydraulic shoulder pivot joint that is capable of a full ±90° range of motion. This extra range of motion allows uninterrupted movement from the lowest PRM position, to the highest.

Improvements were also made to the overall PRM system speed. The PRM hydraulic valves were moved directly adjacent to the base of the PRM and a lighter weight hydraulic fluid was implemented. These changes resulted in an increase in maximum speed by approximately four (4) times when compared to the previous PRM models, as well as a reduced response time to operator inputs. The TWPC PRMs are capable of movement at speeds of up to 600 mm per second, however this speed can be reduced as required to meet operational requirements.

For the TWPC PRMs, the overall girth of the PRM was also reduced to accommodate the existing 250 mm MSM ports present at the TWPC facility. This dimensional change was

completed while maintaining the PRMs overall reach and maximum payload. Previous PRM designs were designed to be deployed through a 280 mm diameter MSM port (as found at most shielded cell facilities in the United Kingdom).

CONCLUSION

The collaborative effort between TWPC and S.A. Technology has yielded an extremely capable and robust solution to perform the wide range of tasks necessary to repackage TRU waste containers at TWPC. Incorporating innovative technologies into a proven manipulator system, these PRMs are expected to be an important addition to the capabilities available to shielded cell operators. The PRMs provide operators with the ability to reach anywhere in the cell, lift heavy objects, perform size reduction associated with the disposition of noncompliant waste.

Factory acceptance testing of the TWPC Powered Remote Manipulators has completed at SAT's Colorado facility, and on-site training at TWPC is scheduled to start in early 2012.

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