Powered Remote Manipulator (PRM) System
Designing a Generic Manipulator for Decommissioning - 11312

Matt Cole
S.A. Technology Inc.: 3985 S. Lincoln Ave. Ste 100, Loveland, CO 80537

ABSTRACT

S.A.Technology has recently completed the development of our Powered Remote Manipulator (PRM) system that provides a customizable, off-the-shelf, designed manipulator solution for the decommissioning industry. Throughout the industry, hot cells are used to perform critical operations and processes. One of the key interfaces that operators have with the components and materials within the hot cells are Master-Slave Manipulators (MSM) style manipulators. The MSMs are valuable tools that have served the industry well for over 50 years, providing the trained operator with a tool that is able to perform lightweight, sensitive tasks with direct tactile feedback.

The problem that S.A. Technology has discussed with many hot-cell production managers, supervisors, and operators around the world is the limited payload capacity of MSM systems. Many times, hot cells that are used to process waste, are undergoing decommissioning, or are operating cells that require off-normal operations require a tool that can lift high capacities farther away from the operator window. This problem is what inspired the PRM solution.

INTRODUCTION

S.A.Technology has designed, manufactured, tested, and deployed a variety of manipulators and components intended for customized applications. The company has a great understanding of how to leverage previous designs and assemblies and apply them in unique and technically difficult projects. Competitors that specialize in production manipulators and components, often, are not able to adapt and implement existing technologies to meet customized requirements.

The baseline PRM technology is designed to pass through a standard 10" MSM port to perform heavy-duty operations that the MSMs are not capable of. The PRM design provides a modular and adaptable system that can be used in variety of industries that involve technical challenges and offers a huge leap forward in power, strength, functionality, range of motion, and reliability through a customizable product. The PRM design increases the operator's ability to do difficult, high-force, remote tasks while decreasing the amount of strain and other ergonomic issues.

The S.A.Technology Powered Remote Manipulator (PRM) provides a blend of these two approaches by offering a customizable, off-the-shelf, designed solution to its customers.

Fig. 1. Powered Remote Manipulator (PRM)

PRM DESIGN

The PRM has a modular, reconfigurable design that is lightweight and can be integrated with a variety of platforms, including MSM ports, gantry/rail systems, bases, and other industrial equipment.

The PRM is fabricated using radiation-hardened carbon fiber tubes. The carbon fiber construction is used to cut down on weight and material costs while maintaining the strength needed for lifting heavier objects. The use of this material allows the PRM to fit within tight deployment constraints without having to make significant modifications to the facility or structure. Carbon fiber is one of the enabling technologies that make this problem solvable.

The base PRM is a seven-degree-of-freedom design with a combination of hydraulic and electric drives. The system includes a 360-degree shoulder roll, 180-degree shoulder pitch joint, two (2) 180-degree elbow pitch joints, 180-degree wrist pitch joint, and a 360-degree tool roll. At full reach, measuring 13 feet from the shoulder, the PRM has a minimum load capacity of approximately 115 pounds. Higher load capacities are possible when the arm is not at full reach.

Because the orientation of the PRM can be so varied, it was important to design a joint with uniform torque throughout its range of motion. This allows the arm to have a consistent load capacity regardless of its orientation. S.A. Technology has been perfecting this joint design for the past 6 years. The PRM design utilizes the 5th revision of this design. This joint has undergone numerous functional, loading, and cycle tests to prove its reliability for deployment.

The PRM is equipped with a quick-change connector for tool change-out, lending itself to a variety of custom tooling capabilities. The primary tool for the PRM is a parallel action gripper that opens up to 6 inches. 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 technology, dry media blasting, and water jet cutting.

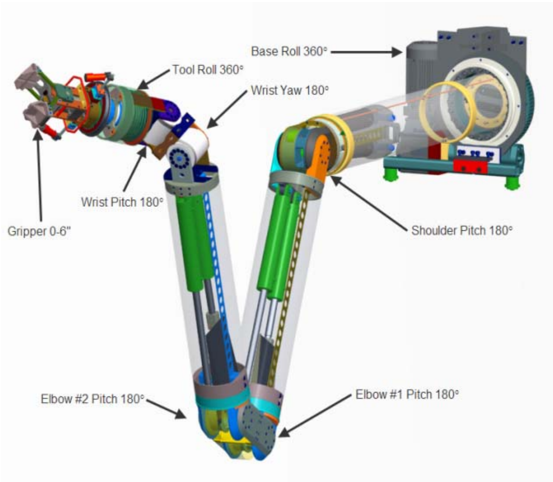

Fig. 2. Powered Remote Manipulator degrees of freedom joint diagram.

The control system for the base PRM is PLC-based and uses proportional joysticks along with proportional valves and a variable frequency drive to control the individual joint motions and speeds. The gripper (or other attached tool) has a proportional pressure valve to allow the operator to limit the force of the gripper jaws. 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. A force sensor at the end of the arm is used to give the operator an audible tone indicating the amount of force being applied at the tool.

One of the major requirements for the PRM is the ability to retract it under a single-point failure. The control system and control valves are located outside of the arm to facilitate this emergency retraction. Worst-case scenarios were devised and fully tested to the satisfaction of the customer at S.A. Technology's test facility.

PRM OPERATING MODE

S.A.Technology has developed an advanced control system for the PRM that utilizes select operating modes to accomplish the precision deployment of tools. These operating modes included:

1. Joint-by-joint control
   The control system operated in conventional joint-by-joint mode, typically for maintenance and deployment operations. Each joint was displayed on the scada system in real time. Each joint was controlled by an axis of the joystick.
2. World mode
   The manipulator worked relative to the base or crane fitting. The first joystick adjusted the orientation, while second adjusted position.
3. 3. Tool mode
   The manipulator worked relative to the current position and orientation of the end effectors. The first joystick adjusted the orientation, while the second adjusted position.
4. 4. Locked axes mode
   The control system allowed for the locking of some axes during operations.
5. 5. Scaled movement mode
   The control system allowed for axes to be scaled, reducing the movement of the arm in proportion to the throw of the joystick.
6. 6. Limited travel mode
   The control system allowed for a configurable limited window of travel. This provided collision avoidance/slow down zones to prevent damage to the manipulator and environment.
7. 7. Path following mode
   Upon achieving a base position, the control system allowed the manipulator to follow a path and track a feature.
8. 8. Start up mode
   This allowed for out of range movement.

THE RIGHT SOLUTION FOR THE RIGHT PROJECT

The PRM was initially designed to meet various project requirements and to adequately address a wide range of customer needs. SAT first designed the PRM in 2008 as an R&D project. As a result, a prototype unit was built and tested significantly. The evolution of the SAT PRM has led to continued research and development efforts that have resulted in a more durable product with higher payloads.

Many lessons were learned while designing and manufacturing the original prototype unit. This has, ultimately, resulted in SAT's delivering the first production-unit PRM to the Dounreay nuclear decommissioning site in Scotland in early 2010. The picture below shows the first PRM being deployed through an existing hot-cell MSM port to decommission and decontaminate the cell interior.

The production unit delivered to Dounreay has been trialed and tested over the past year to prove functionality and reliability. The capability of the Dounreay PRM has received a significant amount of attention as a potential solution for other site project needs. The ongoing trialing at the Dounreay facility and the needs of other potential customers has caused S.A. Technology to look at various options that would add to the configurability of the product line. These include but are not limited to a greater range of motion in the shoulder pivot to improve the motion profile of the arm (now included in the base PRM); a yaw joint at the shoulder to improve the motion profile of the arm; compatibility with multiple hydraulic fluid types; and design modifications to allow for use underwater.

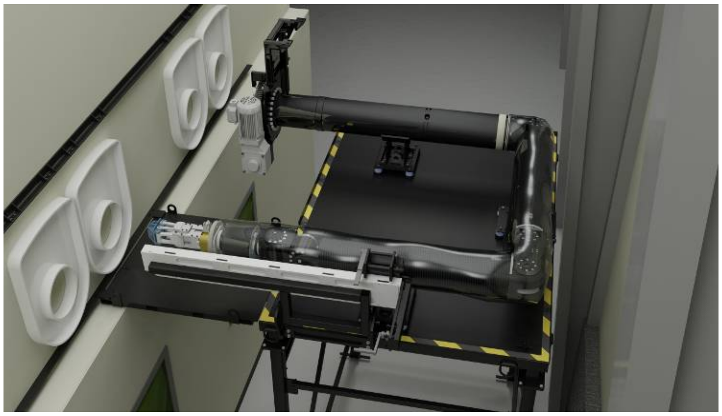

Fig. 3. Rendering of Dounreay PRM before being installed into an existing MSM port.

CONCLUSION

The PRM further proves that SAT is an industry leader in the development and construction of custom manipulators. The PRM's ability to be tailored to the customers' needs while maintaining its mobility and strength make it a highly versatile tool. The adaptable design and PRM's basic capabilities are an attractive solution for a variety of project needs now and in the future. S.A. Technology is confident that this new technology will become an effective solution that can solve many of the industry's most difficult remote problems and constraints.

REFERENCES

"*History of Telemanipulator Development*", Central Research Laboratories, Dover Company **http://www.centres.com/nuclear/manip/maniphis.htm ,** 10 Oct. 2010

B. Sony, Vivek Mahadev1, K. Jayarajan, and Manjit Singh, Research Centre (2006), "*Development of Sealed Three Piece Master Slave Manipulator*", Bhabha Atomic Division of Remote Handling and Robotics