Remote Operation and Maintenance of Crane System for Use in ACPF Argon Cell

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1. Introduction

The Advanced spent fuel Conditioning Process Facility (ACPF) at the Korea Atomic Energy Research Institute (KAERI) has recently been successfully renovated to demonstrate lab-scale electrolytic reduction process using the spent fuel. One of the highlights of this renovation project was the installation of a small argon compartment within the atmospheric hot cell of the facility [1, 2]. A special crane system for use inside the compartment was also developed and tested under the renovation project. In this paper, we describe the remote operation and maintenance of the crane system.

2. Remote crane system

2.1 Key features of the design

In general, the electric drive unit of a bridge crane is connected directly to the mechanical drive unit at high elevation. However, this configuration is not proper for the argon cell crane considered in this study because of the limited space reserved for the crane as well as the reach limitation of the MSM. We devised a remote actuation mechanism where the mechanical and electrical parts of the crane system are separated, located far from each other, and connected through power transmission shafts and bevel gears. The electrical parts consisting of servomotors, position sensors, and limit switches were lowered in place inside the workspace of the MSM. They transmit power to the mechanical parts installed near the ceiling. Even though this configuration does not provide an optimal solution, as the mechanical parts are placed outside the workspace of the MSM, it can become a widely used practical solution because it makes it easier to enhance the durability of the mechanical parts to minimize or eliminate the possibility of mechanical failure within the expected lifetime of the crane.

In addition to the use of a remote actuation mechanism, the use of a linear drive mechanisms for precise motion, modular design of electrical components for easy maintenance, and the use of appropriately dimensioned, commercially proven components to ensure durability are implemented to design a smaller crane that is easily maintainable by the MSM. Furthermore, the cable tray is shifted from a high location near the mechanical parts of the crane and installed on a wall near the electrical parts. Therefore, this maximizes the working volume of the crane. Fig. 1 shows a three-dimensional computer-aided design model of the crane system.

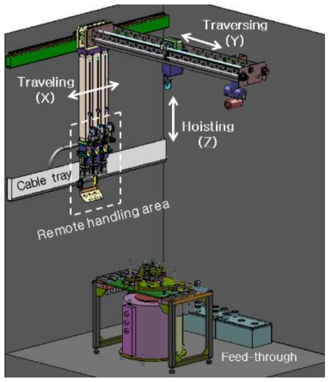

Fig. 1. 3D CAD model of the crane system.

Another key feature of the design is modular design for easy maintenance which is a major goal in the design of a remote handling system because it reduces service downtime and associated costs with quick troubleshooting. One common approach involves duplicating the same module for redundant use: for instance, the spare module is used in an emergency, whereas the damaged module is repaired in a maintenance area. Instead, an on-site replacement method is used that takes into consideration the limited space available for the crane. As shown in Fig. 2, two modular design concepts are introduced for a drive module and a sensor module, focusing particularly on their easy remote maintenance.

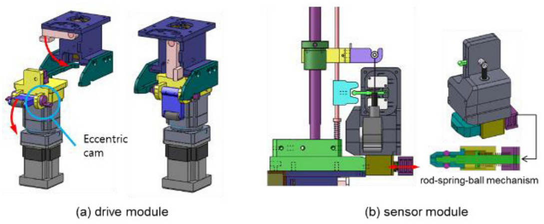

Fig. 2. Modular design for easy maintenance of drive module and sensor module.

2.2 Control system

An accurate servo-control system is also developed based on absolute positioning measurement to allow for the safer performance of perform through automatic operation. The motion controller integrates camera controller, therefore, the operator can operate the crane system by watching the camera monitor as well as looking through the lead-glass shield window. Several control modes, such as the jog mode, the absolute positioning mode, and the sequential operation mode, are prepared to be selectively assumed using the touch pendant in which several graphical pages are linked to each control mode.

2.3 Remote operation and maintenance

The crane system was tested and qualified at a full-scale evaluation mock-up facility prior to installation in the hot cell. After introducing the crane system to the hot cell, several mechanical and electrical tests were performed to check whether the crane system performed at the desired level. The maximum deflection of the girder frame at a load of 1.5 kN was measured at approximately 0.3 mm. The overall height of the trolley hoist including the load hook was 271 mm: this meant that the hook could be placed over the MSM, thereby achieving the design requirement for remote maintenance on it.

As shown in Fig. 3, several remote maintenance experiments were conducted to verify that the driving modules, sensor modules, and a hook of the crane can be replaced using an MSM only. For successful remote operation and easy maintenance, following design considerations were also considered in the design of the crane system,

- Alignment mark for visual guidance
- Proper guiding structure
- Modular design considering handling device
- Direction of the force applied from the remote system
- Initial pose of MSM
- Use of the camera to enhancement of work efficiency

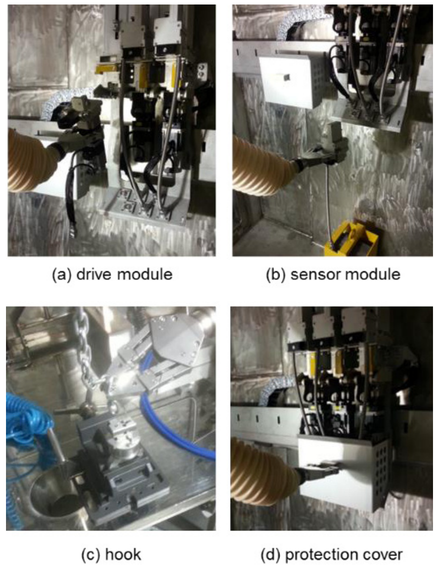

Fig. 3. Remote maintenance test of crane system modules.

3. Conclusion

Several operation and maintenance tests of the crane system showed that all design goals were achieved in general, especially remote maintainability. Based on the experimental results, the remote operation and maintenance procedures were established. The ACPF is right before hot operation, and further work is underway on the production of document for responding to normal and abnormal situation.

REFERENCES

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[2] Lee, J.K., Park, B.-S. Yu, S.-N., Kim, K., Cho, I.-J., “Crane system with remote actuation mechanism for use in argon compartment in ACPF hot cell”, Nuclear Engineering and Design, 307, 144-154 (2016).