Automation Testbed for Remote Basket Handling in a Hot Cell

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Abstract

Remote operation in most hot cells are manually done by using classical remote handling devices, such as mechanical master slave manipulators (MSM). The feasibility of automated operation in hot cell was explored in this research, adopting modern automation system. Pyroprocessing is one way to recycle the spent fuel, and various baskets are related in the process. The basket handling operations are complicated and repeated, and automation of basket handling and transporting is essential for the safety and the efficiency of pyroprocessing. This research integrates an automation testbed for remote basket handling, and an automation scenario to transport dummy basket from equipment to the other remote device was demonstrated.

1. Introduction

The nuclear technology contributed to reduce use of fossil fuel and to supply plentiful energy. However, it also brought the waste treatment issue. Various ways to reduce the toxic waste in nuclear spent fuel has been explored. Pyro-processing, one option for compressing down the waste by recycling 95 percent of Uranium from the spent fuel, has been extensively studied at the Korea Atomic Energy Research Institute (KAERI) [1]. For pyroprocessing experiment using simulated spent nuclear fuel (SIMFUEL, UO_2), PRIDE (PyRoprocessing Integrated inactive Demonstration facility) was constructed. A large argon processing cell (40.3m x 4.8m x 6.4) was built on the second floor to prevent the high reactivity and corrosiveness of using molten salt. The human operator, therefore, cannot be allowed to access inside the processing cell, and all processes were planned to be conducted by remote operation, as the same as a regular hot cell. Various remote handling systems, such as, mechanical MSMs (master slave manipulator), servo master slave system, crane, small and large transfer lock system, and etc., were installed in the processing cell [2]. For two year operation of the PRIDE processing cell, the manual remote operation strategy caused controversy, and automation in a hot cell was issued for economic feasibility of pyroprocessing. Preliminary automation concept for pyroprocessing was proposed at KAERI [3,4], and an automation testbed was integrated for evaluation of the proposed concept. In section 2, the concept is briefly reviewed, and section 3 describe the details of the integrated automation testbed. Then, section 4 shows experimental results.

2. Preliminary automation concept for hotcell operation

In advance to propose a preliminary automation concept for pyroprocessing, the basket flow was investigated [3]. The required baskets were listed up and the types of basket were defined [4]. The flow of each basket was proposed in logical domain, and the overall path and the related equipment passing through were examined. For developing a detailed transportation plan, the examined path was divided into the basic transportation element, that is only related to the origination/destination equipment. Finally, the detailed transportations in the overall flow was described for each basket, including how many stations in the flow exist, how many transportations are occurred, where the basket starts, and how to the empty basket returns

back after finishing the flow. The basket transporting plan was successfully evaluated in logical domain and also with the virtual 3D simulator, as shown in Fig. 1.

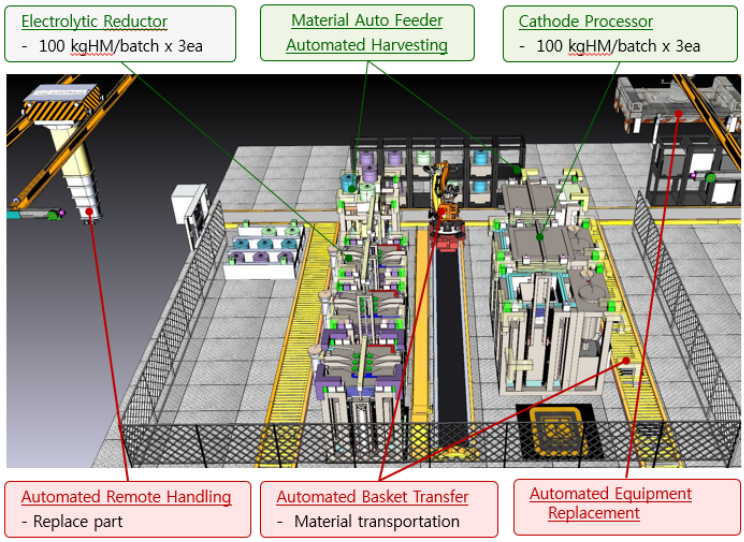

Figure 1. The virtual 3D simulation for evaluation of automation concept [6].

The conceptual baskets were visualized as 3D models, in the consideration of automated transportation. The 3D concepts for equipment was also designed with respect to remote maintenance. The equipment was modularized with three different types of handling standards, as shown in Fig. 2.

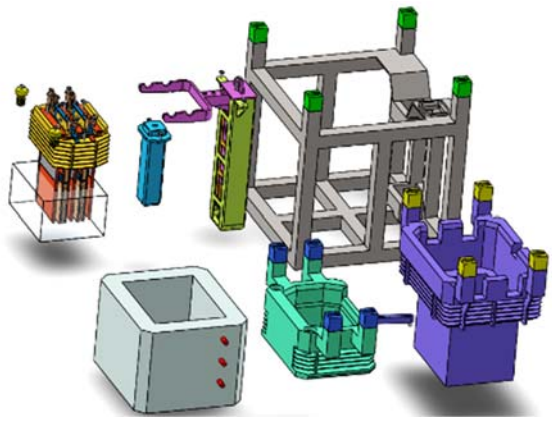

Figure 2. 3D CAD models for draft evaluation in a virtual environment.

The proposed basket handling methods and overall automation transportation plan was approximately evaluated with 3D CAD models in virtual space [5,6]. However, the results were not enough to guarantee the real transportation only with virtual simulation, and the physical feasibility were still questionable. While the handling device keep transporting, the possibility of sudden fails was negligible, but the failures during the moment handling over the basket is critical and needed to be examined thoroughly. Therefore, the needs to actual verification focused on the basket hand over with various situation were requested, and a physical testbed to verify automation feasibility of basket handling was integrated.

3. Automation testbed for basket handling

The automation testbed was proposed to use an overhead telescopic transporter system,

conveyors, and a dummy equipment. The target handling objects are dummy baskets and electrode, and there are slots to insert the baskets and electrode on top of the dummy equipment. The given task in the automation testbed is to deliver the basket from conveyor to the specified slot on the equipment and to replace the electrode from one slot to the other. The evaluation scenario is summarized as shown in Fig. 3.

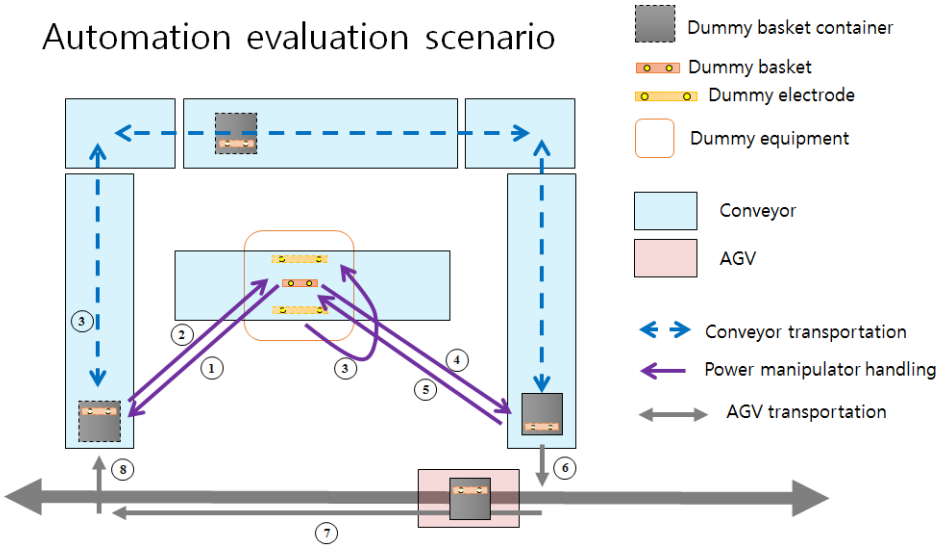

Figure 3. Evaluation scenario for pyroprocessing automation concept.

The overhead telescopic transporter (OTT) system was integrated with modifying the Power manipulator manufactured by Walischmiller, the well-known German remote equipment manufacturer. The bridge and the telescopic tube of the Power manipulator were position controlled by laser distance sensors. A new end effector was equipped to have a two-point gripping mechanism dedicated to the dummy basket so that the OTT system can move the dummy basket to the desired position.

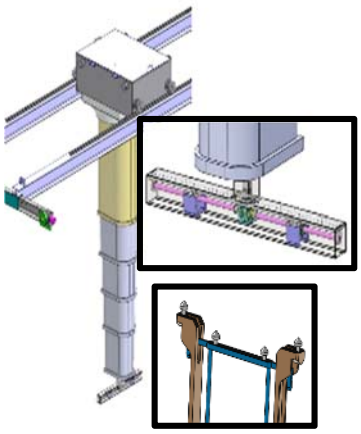

Figure 4. The proposed OTT system with T-shaped gripper for basket handling

The handling points were predefined in the layout as shown in Fig. 3. The OTT system automatically approaches, grips, transports, arrives, and release the dummy basket, if the origination and destination was assigned among the predefined points in the layout. When OTT moves, the z motion is separately and successively controlled. This means the horizontal motion was not allowed if the height is not enough to prevent collision. The x-y motion occurs first in the safe layer, and then go up or down to approach or release the basket.

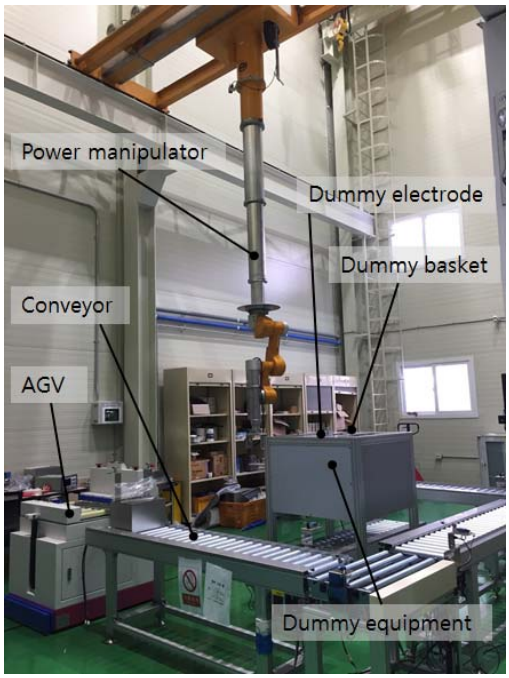

Figure 5. The integrated automation testbed

Figure 5 shows the actually integrated automation testbed. The detailed operation is explained in the next section.

4. Demonstration

The automated basket handling was demonstrated to show the feasibility of the handling system. Molten salt is used for pyroprocessing, and this affects the design of the related equipment. The equipment usually has a main vessel to contain the salt. A heater surrounds the vessel, and an upper cover seals the top of the vessel. Baskets and electrodes are immersed in the molten salt, so that the cover has holes to insert the basket and electrodes. The dummy equipment in Fig. 5 also has a holes on the top for the dummy basket and electrodes. The main goal in this research is to demonstrate a basket handling automation task. The dummy basket was handled by the integrated OTT system, as shown in Fig 6.

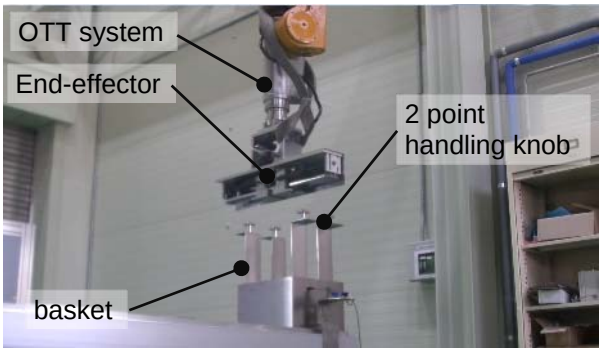

Figure 6. The integrated OTT system and its end effector for basket handling.

Figure 7, 8, and 9 shows the detailed operations. The transportation by OTT was composed of 3 sub motions, as like holding, moving, and releasing. Figure 7 shows the holing. In the safe layer, the OTT precisely positioned at the position on the horizontal layout. The OTT approaches down while fixing the x-y position. When the OTT detect the dummy basket, it stops moving and grips the basket. The holding operation is finished, when the OTT elevates

the basket up in the safe layer.

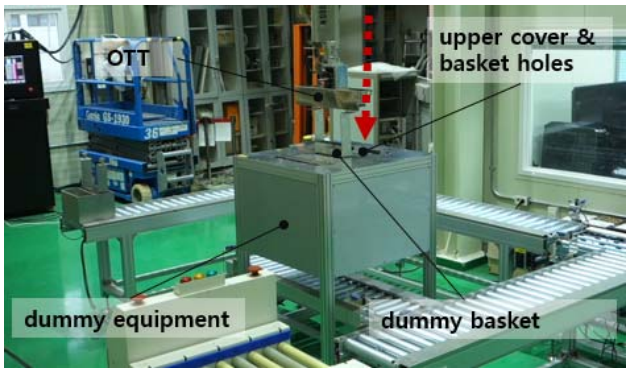

Figure 7. the holding operation

Figure 8 shows the moving operation. The OTT simply move in the safe layer, from the origination to the destination of predefined x-y position on the layout.

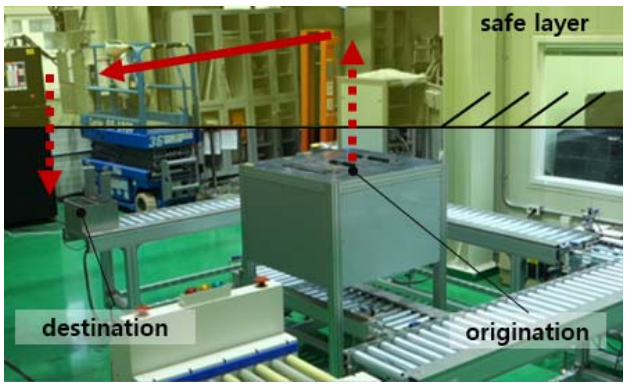

Figure 8. the moving operation

Figure 9 shows the final stage of transportation, the releasing operation. When it arrives at the x-y position of destination in safe layer, it starts to go down. It stop at the predefined height, and then releasing the basket

Figure 9. the releasing operation

Finally, the dummy basket was successfully demonstrated to move from the dummy equipment to the conveyer. The transported basket was fed back to the other end of the conveyor, laying on the basket container, as shown in Fig. 10.

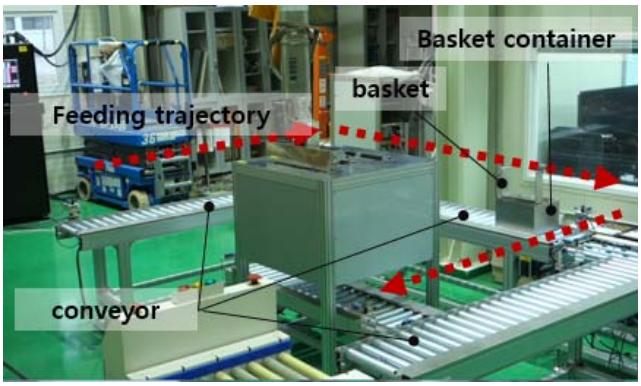

Figure 10. returning the basket

5. Conclusion

The automation testbed was proposed to enhance the evaluation results of the preliminary pyroprocessing automation concept, and the testbed for remote basket handling was actually integrated. The basket handling scenario in the testbed was planned to investigate the feasibility of the automation concept, and the given automation tasks were accomplished within the predefined accuracy and repeatability. The evaluation scenario was effectively demonstrated by the integrated automation testbed, and it contributed to substantively evaluate the proposed automation concept.

Acknowledgment

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