Remote Manipulators and Simulator for the PRIDE Facility Application

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1. Introduction

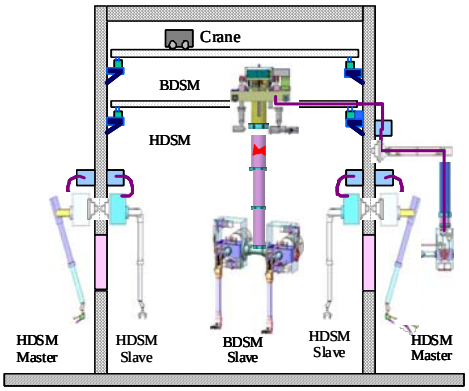
Pyroprocessing technology, which refines nuclear materials from spent nuclear fuels using an electrochemical method in a molten salt medium at high temperatures (500 – 700°C), is being developed at the Korea Atomic Energy Research Institute (KAERI). Various types of specially designed equipment for a Pyroprocessing technology development are under development, and their characteristics in terms of performance, remote operability and remote maintainability should to be tested by taking account of their design requirements in the Pyroprocessing mock-up facility, named PRIDE (PyRoprocess integrated Inactive DEmonstraion) facility, which is under the design development at KAERI. They then may require some modification or reconstruction if necessary. Conventional master-slave manipulators that are used in a hot-cell facility have limitations in terms of the workspace and payload due to their mechanical structures and power transmission. Thus, the remote operation and maintenance work of Pyroprocessing equipment can not be achieved by use of such conventional manipulators only and need a more efficient additional means.

The objective of this work is to design and develop remote manipulators and simulator that could be used for a Pyroprocessing technology development in the PRIDE facility at KAERI.

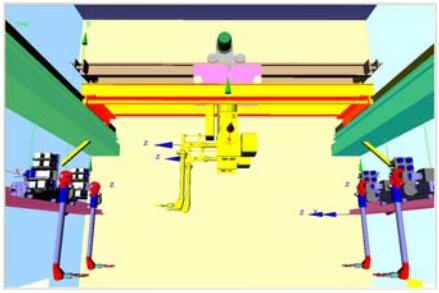
2. Remote Manipulators

The PRIDE facility is designed to have an argon-atmosphere cell for Pyroprocessing technology development. Two types of remote manipulators are designed to handle the process equipment or other devices in the argon cell. One is BDSM (Bridge transported Dual arm Servo-Manipulator) and another HDSM (Horizontally moving Dual arm Servo-Manipulator). BDSM is an electrically driven servo manipulator. It has dual arms of which each arm consists of a pair of master-slave manipulators. HDSM is also a similar servo manipulator to a BDSM with differences in its size and kinematics. Fig. 1 shows the conceptual layout of a BDSM and a HDSM to be installed in the argon cell of the PRIDE facility. The two slave manipulators of a BDSM that are mounted on a bridge transporter are installed inside a cell and travel the length of the ceiling and two master manipulators are installed outside a cell. Two HDSMs are installed on the wall of the cell - one on the front wall and another on the rear wall. The two slave manipulators of each HDSM are installed in-cell and travel the length of a wall, and its master manipulators are installed out-of-cell. On both a BDSM and a HDSM, an operator through out-of-cell controls the salve manipulators by simply moving the master manipulators.

In the design, the slave manipulators of a BDSM are mounted on a 4 dof bridge transporter with a handling capacity of 2 tons. The master and the slave manipulators of each arm of BDSM, respectively, are designed to have a configuration of a 6 dof serial link mechanism with all revolute joints, and power to each joint is transmitted through a wire from a corresponding motor mounted on a base frame [1]. The slave manipulator of each arm is designed to have a 25 kgf payload capacity to carry remote tools or parts of the process equipment. In the configuration, the master manipulator is a replica type with a kinematic similarity to the slave manipulator. Such a similarity in the kinematics is advantageous because the constraints on the workspace of the slave manipulator due to the arm joint limits and singularities can be faithfully and unambiguously reproduced at the master manipulator. The motions of the operator via the master manipulator are reproduced exactly at the slave manipulator located in-cell.



a) Schematic view



b) Graphical view

Fig. 1 Graphical conceptual layout of BDSM and HDSMs in the PRIDE facility.

BDSM is also designed to have a force reflecting ability such that an operator can feel the reaction force from the slave manipulator interacting with the process equipment or work environment inside a cell. As the slave manipulator interacts with process equipment and its environment inside a cell, force feedback is a source of information about the slave manipulator to be presented to the operator. Force reflection of a BDSM will provide significant improvements in the work rate and proficiency of the remote operation.

HDSM is also designed to have the similar functions to a BDSM in terms of the power transmission by means of wire and force reflection as compared to a single arm of a BDSM except for a link mechanism. The master and slave manipulators of a single arm of a HDSM are designed to have a prismatic joint at their elbow joints, respectively, and a kinematic similarity and force reflecting ability. The slave manipulator of a single arm of a HDSM is designed to have a 12 kgf payload capacity.

3. Simulator

The simulator in this work is a virtual facility of the PRIDE facility. Virtual in this paper denotes the representation and simulation in software of an object or environment. The simulator will provide an efficient means for simulating and verifying the conceptual design, design developments, arrangements, and rehearsal of the process equipment from a remote operation and maintenance viewpoint in a virtual process environment by use of various virtual functions in advance.

The simulator [2] from a model viewpoint mainly consists of a geometry that is the argon cell of the PRIDE facility, the apparatuses that are a BDSM, two HDSMs, one overhead cranes, and auxiliary devices or tools, and the process equipment that performs a specified task of each process. The geometry, apparatuses and process equipment are modeled in the software. Thus, the simulator includes all the virtual geometry, virtual apparatuses and virtual process equipment required to produce a functional virtual simulation system.

The simulator is constructed by using the Visual Studio 2005 and Open Haptics on the Window XP. The simulator consists of 3D models, graphics rendering API including the relevant GUI and various database, a haptic rendering API, various analysis algorithms, etc. The graphics rendering is a visualization of the 3D models on the PC. To enable a visual rendering on a PC, Open Inventor is used as a graphics rendering API because it is a scene graph based graphics rendering API that is useful for constructing a 3D model.

In the simulator, the 3D models of the geometry, apparatuses, and process equipment described above are imported into the VRML format and connected together to produce a virtual PRIDE facility. A user defined coordinate system is designed to enable an operator to move the virtual apparatuses and process equipment to a desired position inside a virtual geometry environment when needed.

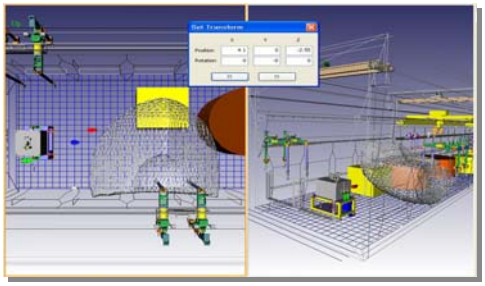


Fig. 2. Virtual PRIDE facility.

A case study has been done by building a prototype of a simulator that is composed of the virtual geometry of the PRIDE facility, virtual apparatuses of virtual BDSM and HDSM, and virtual process equipment of a voloxidizer, as shown in Fig. 2. This study was to confirm that an operator can deploy the virtual voxidizer and virtual slave manipulator in a virtual PRIDE facility. It has been found from the case study that the GUI used in this work has a time-saving advantage because it organizes the VRML files in the scene graph based on an object-oriented method. The simulation results showed that the virtual slave manipulator made contact with the overall surface of the virtual voloxidizer. It means that the forward kinematics and inverse kinematics of the virtual BDSM and HDSM were correctly analyzed to move the virtual slave manipulators to a desired position.

4. Conclusions

We described our ongoing research activities and progress made in developing the remote systems for use in the PRIDE facility. Work conducted so far has focused on the design developments of a BDSM, a HDSM, and a simulator. The detailed design of a BDSM has been completed, and it is under construction. A HDSM is under design development. A prototype of a simulator has been developed and tested to verify a remote accessibility of a virtual slave manipulator to process equipment in a virtual PRIDE facility. More efforts are being given to establish a more realistic and rich simulator for use in a Pyroprocessing technology development.

REFERENCES

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