Design of a High Power Robotic Manipulator for Emergency Response to the Nuclear Accidents

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1. Introduction

An accident in a nuclear facility causes a great social cost. To prevent an unexpected nuclear accident from spreading to the catastrophic disaster, emergency response action in early stage is required. However, high radiation environment has been proved as a challenging obstacle for human workers to access to the accident site and take an action in previous accident cases. Therefore, emergency response robotic technology to be used in a nuclear accident site instead of human workers are actively conducted in domestically and internationally.

Robots in an accident situation are required to carry out a variety of tasks depend on the types and patterns of accidents. An emergency response usually includes removing of debris, make an access road to a certain place and handling valves. These tasks normally involve high payload handling. However existing human-sized robotic manipulators are not appropriate to deal with heavy duty tasks due to the limit of payloads. Thus, a small sized high power robotic manipulator can be an appropriate candidate to deal with a wide spectrum of tasks in an emergency situation.

In this paper, we discuss about the design of a high power robotic manipulator, which is capable of handling high payloads for an initial response action to the nuclear facility accident.

2. Manipulator actuator

Various types of actuators are used for robotic manipulator. Most commonly used actuators are electric motors, hydraulic motors, pneumatic cylinders and hydraulic cylinders.

Electric motors are widely used thanks to high accuracy and easy control, but they are worse at torque and require high ratio gear reduction. Pneumatic cylinders are good candidates to power fast moving systems with a relatively low payload. Therefore, electric motors and pneumatic cylinders are not appropriate for a high power robotic manipulator.

Whereas, hydraulic actuators are generally used for handling high power system such as construction equipment. Especially a hydraulic cylinder is a good candidate for high power robotic manipulator thanks to its high power-to-weight ratio, diversity of design and simplicity [1]. We chose a hydraulic cylinder as the type of actuator for a high power robotic manipulator. Considering handling payload and workspace, stroke, inner diameter, push force and pull force of each hydraulic cylinder are shown in Table 1.

Table 1. Specification of hydraulic cylinders

Actuator	1	2	3	4
Stroke (mm)	80	35	55	65
Inner diameter (mm)	40	30	30	40
Push force (kgf)	1758	989	989	1758
Pull force (kgf)	1318	741	741	1318

3. Mechanical structure

The design of manipulator is inspired by human arm structure. Each joint is actuated by a linear actuator and consists a four bar linkage structure. Schematic design of the robotic manipulator is presented in Fig. 1. Base serves as a stable platform to support the whole manipulator. Hydraulic servo valves are contained therein. The robotic manipulator consists of four serial links (link 1, link 2, link 3 and link 4). Link 1 and base are connected by joint 1, which generates pitch motion of shoulder and actuated by hydraulic cylinder 1.

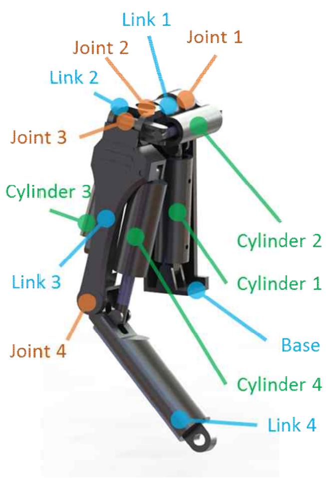

Fig. 1. Schematic design of the robotic manipulator

Link 2 rotates around joint 2. Joint 2 makes yaw motion of the manipulator and actuated by hydraulic cylinder 2. Joint 3 connects link 2 and link 3 and is powered by cylinder 3 for roll rotation. Link 3 and link 4 are combined at joint 4, which works as the elbow joint. Angle ranges of each joint are 100, 25, 90 and 95 respectively. Joint movement and workspaces are shown in Fig. 2.

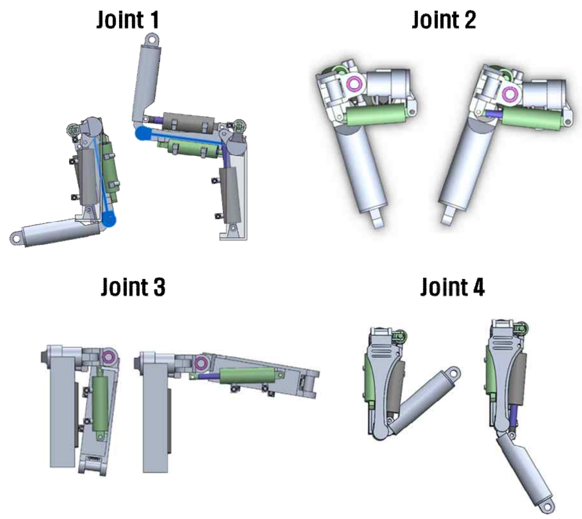

Fig. 2. Joint movement

The whole robotic manipulator is four degrees of freedom system and weighs approximately 10 kg. Overall length of the manipulator is 0.7 m and expected moving speed of the tip and payload are 0.3 m/s and 50~100 kg respectively.

4. Conclusion

In this paper, we presented a small sized high power robotic manipulator design. Actuator types of manipulator was selected and mechanical structure was discussed. In the future, the servo valve and hydraulic pump systems will be determined. Furthermore, control algorithms and test bed experiments will be also conducted.

REFERENCES

[1] Jongwon Park, Chang-Hoi Kim, Kyung-min Jeong, Byung-Seon Choi, Jeikwon Moon, Evaluation methodology of a manipulator actuator for the dismantling process during nuclear decommissioning, Annals of Nuclear Energy, Volume 91, May 2016, Pages 22-24

ACKNOWLEDGMENT

This paper was supported by the Ministry of Science, ICT & Future Planning.