Simulation and analysis of the joint module with passive compliance for rescue robot

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Abstract
On behalf of human, dual arm robot can perform the dangerous task such as search and rescue in the battle field and disaster field[1]-[2]. We are developing the dual arm robot which can be adapted on the mobile platform for rescue activity. It has to be designed to have the absolutely safe mechanism against the impact from the environment because it is operated under the circumstance of human robot interaction. There have been many kinds of researches about the safe mechanism of the robot system. One of them is about the active compliance mechanism and the active compliance control algorithm[3]. Another part of research is the passive compliance mechanism with the spring or the tendon[4]-[5]. Also, hybrid compliance mechanism with both passive and active compliance were studied[6]-[7]. We proposed the safe joint module with spring-damper material to absorb impact force and to overcome high impact force. It is composed of an actuator, a harmonic drive as the 1st reduction gear, a worm gear as the 2nd reduction gear and a spring-damper such as Figure 1. The spring-damper between the gears can absorb the impact force, but it occurs the vibration because of its flexibility. Therefore, it is important to identify the characteristics of the joint module to apply it to the dual arm robot.

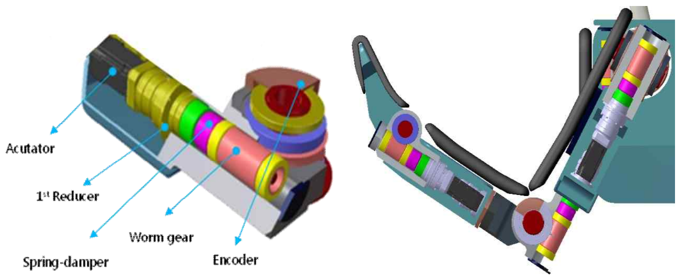

Figure 1: Example of a figure and its caption.

We analyzed the characteristic of the joint module through the dynamic simulation and the experiment. Concept design of dual arm robot is represented in the Figure 2 and joint modules are applied to each joint. Base excitation obtained from the mobile platform simulation was used in the simulation and joint torque and vibration were investigated.

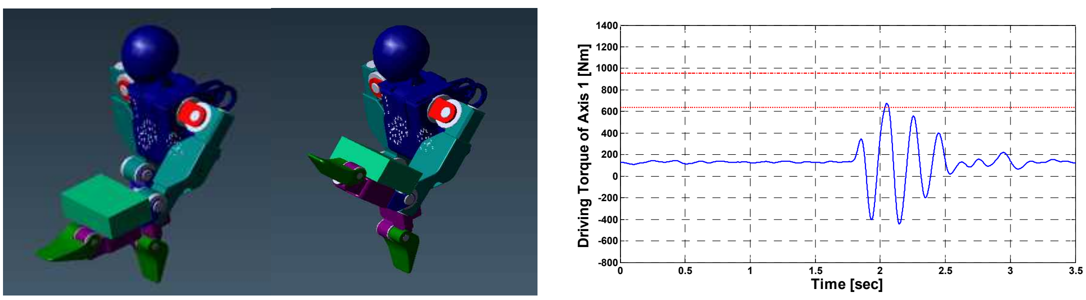

Figure 2: Dynamic simulation of the joint module

In addition, the characteristic such as the stiffness coefficient, the damping coefficient, the natural frequency and so on were investigated for each joint module. We also obtained its characteristics from the experiment and the results are represented as Table 1. There are a little variation of the results and the difference between the experiment and simulation because the spring-damper is non-linear and the joint stiffness on the dynamic condition is different.

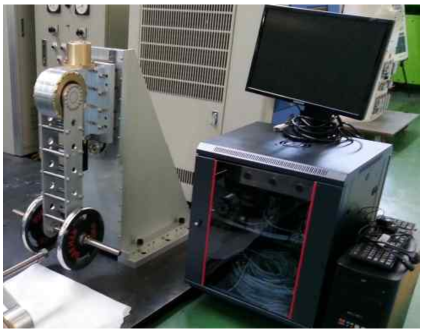

Figure 3: Experimental setup

Table 1: Characteristics of the joint modules

	Static Stiffness (Experiment) [Nm/rad]	Natural freq. (Experiment) [Hz]	Natural freq. (Simulation) [Hz]
Actuator 1	Avg. 13940	3.13~5.9	3.76~4.45
Actuator 2	Avg. 9888	8.8~11.4	7.57~8.49

The joint module will be applied to the robot arm and it is very important to control the robot with the flexible joint. Its characteristic obtained in the paper can be usefully applied in the flexible robot control in the future.

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