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Development and performance test of hollow-shaft type actuating module

Dong Il Park, Chanhun Park, Hyunmin Do, Doohyung Kim and Jinho Kyung
Department of Robotics and Mechatronics, Korea Institute of Machinery & Materials

***Abstract*— An industrial robot has been generally used to do simple and repetitive process on behalf of human beings in order to automate the production process. It could operate only in the separated environment with human in the past, because the robot safety is not sufficient. Nowadays, the interest in the human-robot cooperative industrial robot with physical interaction is increasing. Therefore, the lightweight robot mechanism and the compact actuating module become necessary as the technology to achieve the robot safety. In the paper, the hollow shaft actuating modules were designed to develop a lightweight robot. And the performance test of the manufactured modules was carried out and the performance of the module was proved.**

***Index Terms*—Actuating module, Lightweight robot, Hollow-shaft actuator, Performance test**

I. INTRODUCTION

An industrial robot has been generally used to do simple and repetitive process on behalf of human beings in order to automate the production process. It could operate only in the separated environment with human in the past, because the robot safety is not sufficient. Nowadays, the interest in the human-robot cooperative industrial robot with physical interaction is increasing. Therefore, the lightweight robot mechanism and the compact actuating module become necessary as the technology to achieve the robot safety.[1]-[6] We are developing the lightweight robot and dual arm robot for the defined task such as automatic assembly.[7]-[8] In the paper, the hollow shaft actuating modules were designed to develop a lightweight robot. And the performance test of the manufactured modules was carried out and the performance of the module was proved.

II. MODULE SPECIFICATION

The first step of the robot design is to decide the degree-of-freedom and the kinematic configuration of robot. We determined that the degree-of-freedom is 7 in consideration with redundancy and its configuration is similar with a general 7 DOF manipulator. And the length of each link was determined for the necessary workspace. The next step is to decide the specification of each actuating module. We repeated the dynamic simulation from the expected mass and inertia to the real parameters and measured the static torque and dynamic torque in the various conditions.

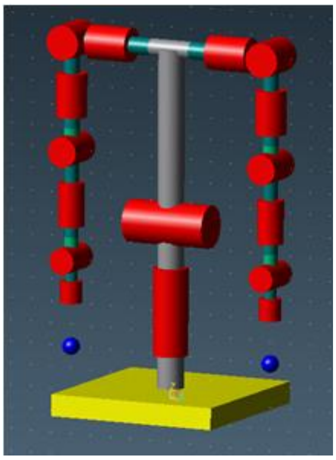

Fig. 1 Dynamic simulation of the robot

Figure 2 shows the result of dynamic simulation. We can obtain the required output torque and the required nominal output torque from various simulations for each joint as shown Table 1 approximately.

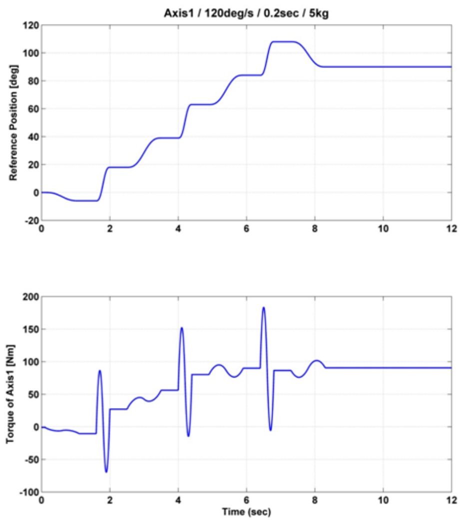

Fig. 2 The required torque of axis 1

Table I Required torque and speed

Joint #	Required maximum torque (Nm)	Required nominal torque (Nm)	Rotational speed (deg/s)
1	120	60	150
2	120	60	150

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3	70	30	150
4	70	30	150
5	35	15	240
6	35	15	240
7	25	10	240

III. DESIGN OF THE JOINT MODULE

A joint module is composed of a motor, an incremental encoder, a harmonic drive, a torque sensor and an additional absolute encoder. Figure 3 shows the concept design of the proposed actuating module with the hollow shaft type components.

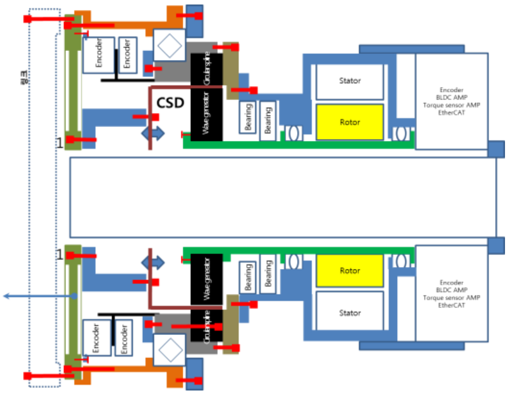


Fig. 3 Concept design of the proposed actuating module

The detailed design was derived from the specification of each component as show Fig. 4.

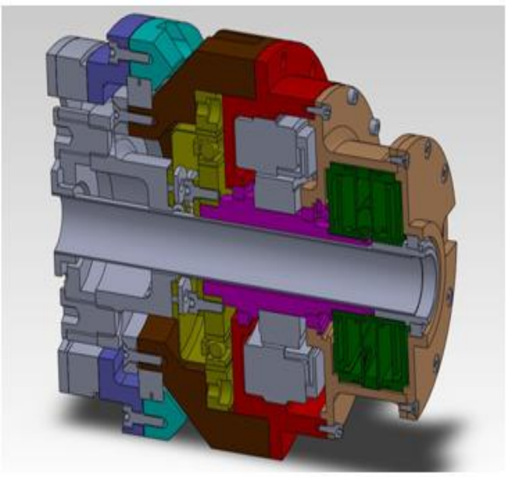
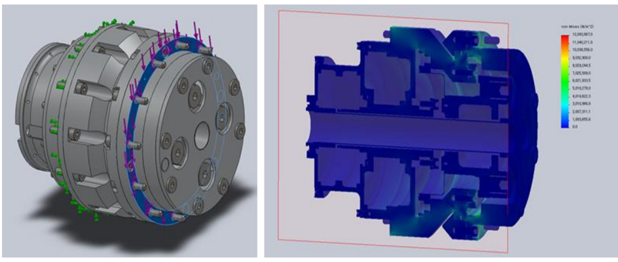
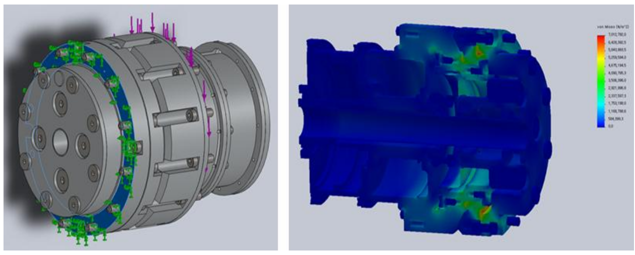


Fig. 4 The detailed design of the joint module (Module 1)

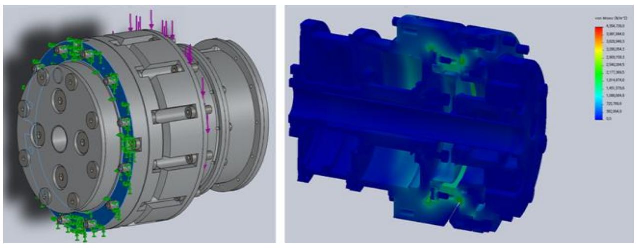
Then, the FEM analysis was carried out to investigate the stress and the strain. The analysis result is represented as Fig. 5. The maximum stress of the joint module is from 4.3Mpa to 12Mpa. The result indicates the structure of the joint module is adequate because the maximum stress is far less than the yield strength of Al.



(a) Module 1 (max 12Mpa)



(b) Module 2 (max 7Mpa)



(c) Module 3 (max 4.3Mpa)

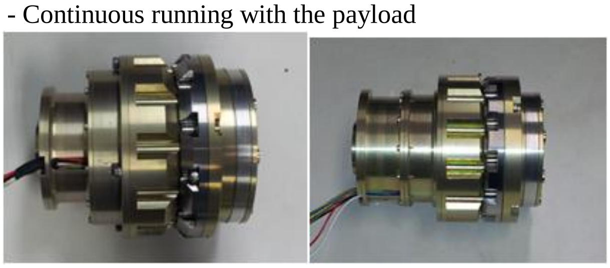
Fig. 5 FEM analysis of the joint module

IV. PERFORMANCE TEST OF THE JOINT MODULE

The proposed joint module was manufactured from the previous analysis and the detailed design. Figure 6 shows the manufacture joint module. Then, the performance test is carried out because the performance of the joint module is important.

First we have to define the process of the performance test, because there is not the official process of the performance test.

(1) No load test
- Initial current (CW, CCW)
- running current at 500 rpm
- running current at 3000 rpm
(2) load test
- Continuous running with the payload



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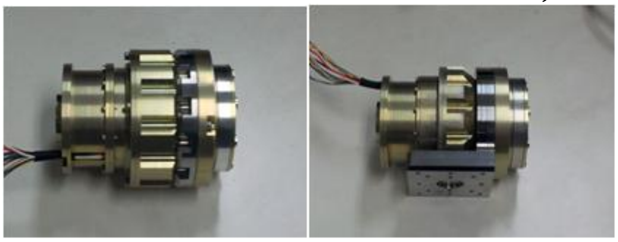

Fig. 6 (A)The manufactured joint modules

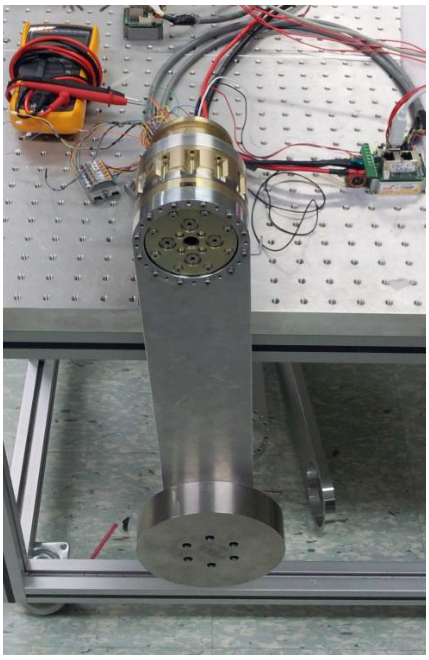

Fig. 6(B) The manufactured joint module

We compared the test result with the specification of the components. Especially, friction of harmonic drive is relatively much larger than the other components and the initial torque and the running torque of harmonic drives at the given condition were compared. Additionally, the performance test with the payload was carried out and the performance value was measured after the load test. The result of the performance test about the initial current and the running current is represented as Fig.8 and Fig. 9.

We can modify the assembly status of the joint module and fix its performance through the performance test.

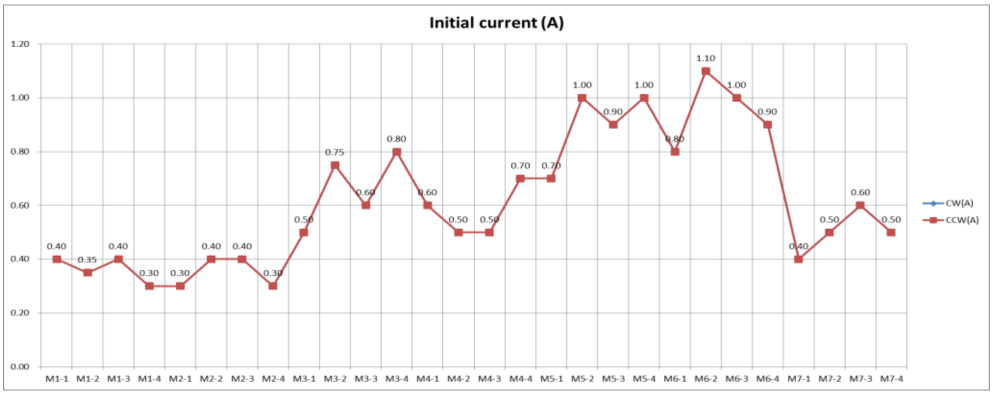

Fig. 7 The result of the performance test (initial current)

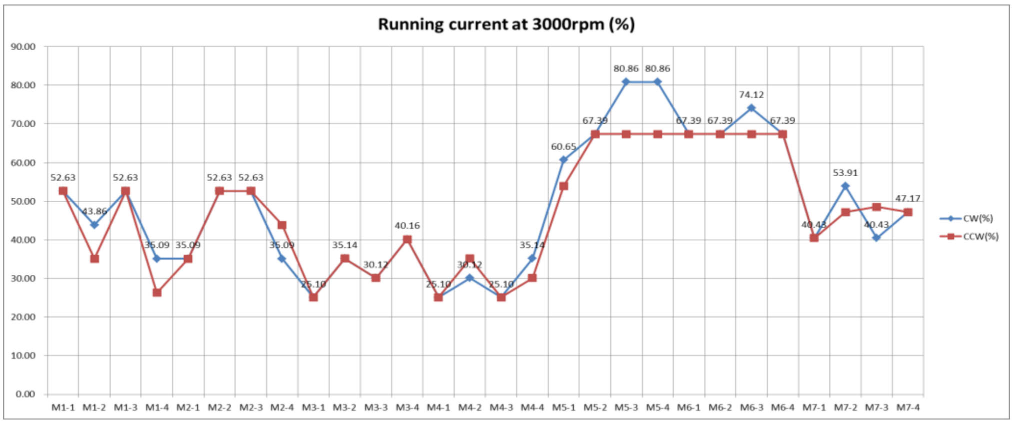

Fig. 8 The result of the performance test (running current)

V. CONCLUSION

We are developing the lightweight robot and dual arm robot for the defined task such as automatic assembly. In the paper, the hollow shaft actuating modules were designed to develop a lightweight robot. And the performance test of the manufactured modules was carried out and the performance of the module was proved. The developed modules with the hollow-shaft components will be applied to the compact robot manipulator.

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REFERENCES

[1] K. Kreutz-Delgado, M. Long, H. Seraji, "Kinematic analysis of 7 DOF anthropomorphic arms", IEEE International Conference on Robotics and Automation, pp.824-830, 1990.

[2] C.C. Nguyen, Z.-L. Zhou, G.E. Mosier, "Kinematic analysis and control of a 7-DOF redundant telerobot manipulator", Twenty-Second Southeastern Symposium on System Theory, pp.71-77, 1990.

[3] F. Shadpey, F. Ranjbaran, R.V. Patel, A.J. Robins, "Development and experimental evaluation of a robust contact force control strategy for a 7-DOF redundant manipulator", International Conference on Advanced Robotics, 1997, pp.393-400.

[4] M.V. Kircanski, T.M. Petrovic, "Inverse kinematic solution for a 7 DOF robot with minimal computational complexity and singularity avoidance", IEEE International Conference on Robotics and Automation, pp.2664-2669, 1991.

[5] Fan-Tien Cheng, Jeng-Shi Chen, Fan-Chu Kung, "Study and resolution of singularities for a 7-DOF redundant manipulator", IEEE transactions on industrial electronics : a publication of the IEEE Industrial Electronics Society, Vol.45, No.3, pp.469-480, 1998.

[6] D.P.T. anayakkara, K. Kiguchi, T. Murakami, K. Watanabe, K. Izumi, "Skillful adaptation of a 7-DOF manipulator to avoid moving obstacles in a teleoperated force control task", IEEE International Symposium on Industrial Electronics, Vol. 3, pp. 1982-1987, 2001.

[7] Dong Il Park, Chanhun Park, Hyunmin Do, Taeyong Choi and Jinho Kyung, "Design and analysis of dual arm robot using dynamic simulation", 10th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2013), October 31-November 2, Jeju, Korea, 2013.

[8] Dong Il Park, Chanhun Park, Hyunmin Do, Taeyong Choi, Doohyung Kim and Jinho Kyung, "Design and analysis of dual arm robot for automatic assembly," International Journal of Engineering and Innovative Technology (IJEIT), Volume 4, Issue 6, October 2014, pp68-70.

AUTHOR BIOGRAPHY

Dong Il Park received a BS degree in Mechanical Engineering from Korea Advanced Institute of Science and Technology (KAIST) in 2000, a MS degree in Mechanical Engineering from KAIST in 2002 and a PhD degree from KAIST in 2006. He has been researching the robotics in Korea Institute of Machinery and Materials (KIMM) since 2006. His research fields are the design, control and application of robot manipulators and mobile robots.