Development of Smart Actuator and Its Application

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Abstract. This study is dealing with an industrial robot with smart actuators for applying an industrial manufacturing process. A smart actuator is defined as the integrated actuator of all components such as motor, controller, sensors, and communication unit. The robot which is linked to a smart actuator can be assembled or disassembled and reconfigured. Therefore, there are increasing demands from industries for a smart actuator. We develop a smart actuator and an industrial robot with the developed smart actuator. We also introduce a robot control simulator for operating and monitoring the robot. Finally, trajectory tracking control is performed in experiment for evaluating a performance.

Keywords: Smart Actuator, Industrial Manufacturing Process, Integrated Actuator, Robot Control Simulator.

1 Introduction

Recently, a robotic system has been needed in various fields. However, the role of a robot is different according to a task. And, it is needed a lot of time to develop a robot. Therefore, there are increasing demands from industries for a smart actuator for easily developing a robot. A smart actuator is composed of a motor, gears, amplifier, servo controller, and communication module. It can be operated to plug-in and assemble. The robot which is linked to a smart actuator is also easily able to assemble/disassemble and reconfigure it. Due to these advantages, the studies on a smart actuator are very much on-going and have been reported [1-3]. In the previous studies, we developed the hollow shaft servo assembly and the dual arm robot with the servo assembly [4]. And a human-robot cooperative robot with smart actuator was presented [5].

The goal of this study is to develop an industrial robot with a smart actuator for applying an industrial manufacturing process. Firstly, a smart actuator for applying to the robot is described. Secondly, the monitoring software of the robot is developed. Finally, the 7-axis industrial robot with smart actuators is developed and the performance of trajectory control is evaluated.

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2 Development of Smart Actuator

A smart actuator consists of a servo motor, a motor drive, gears, a brake, an encoder, a servo controller and a communication board as shown in Fig. 1 [1]. The specifications of the smart actuator are shown in Table 1. Fig. 2 shows manufacturing processes of servo motor assembly.

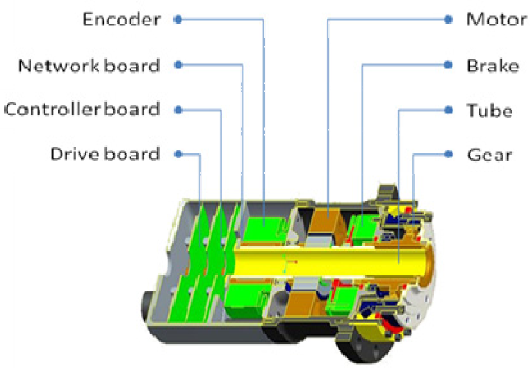


Fig. 1. Configuration of a smart actuator

Table 1. Specifications of the developed smart actuator

Item	Specification
Component	Motor/Drive/Brake/Encoder
Power of Motor(W)	200/400/750
Input Voltage (V)	DC 300V
Rated torque (Nm)	0.64 (200W) / 1.27 (400W) / 2.38 (750W)
CPU of controller	Drive : TMS320F2811 Slave : TMS320F2808
Sensors	Encoder : 17bit (Tamagawa) Current sensor : ACS712 Voltage sensor : HCPL788J Temperature sensor : ASM121
Communication	EtherCAT(Master - Slave) SPI (Slave - Drive)
Brake	DC24V (Autopower Co.)
Gear	Harmonic Drive

Material of The cores of stator and rotor is the Si-steel S18 and S30 respectively. And material of magnets is Nd-Fe-B and N-35SH. After assembling all sub components, encoder and brake are mounted at a servo motor. The controller generates PWM (pulse width modulation) signals. The signals are sent to the IPM (intelligent power module) for driving the smart actuator. Position/Velocity/Torque control functions are implemented by using PID control in the controller. The controller has two different type communication methods such as EtherCAT and CAN. The synchronous communications in EtherCAT is 100 Mbps between the master (main controller) and slave. And it is connected to SPI (14Mbps) between the slave and the drive.

Fig. 3 shows the developed controller. It can be mounted at the end of servo motor assembly. The smart actuator is developed as integrating a servo motor assembly and a controller as shown in Fig. 4.

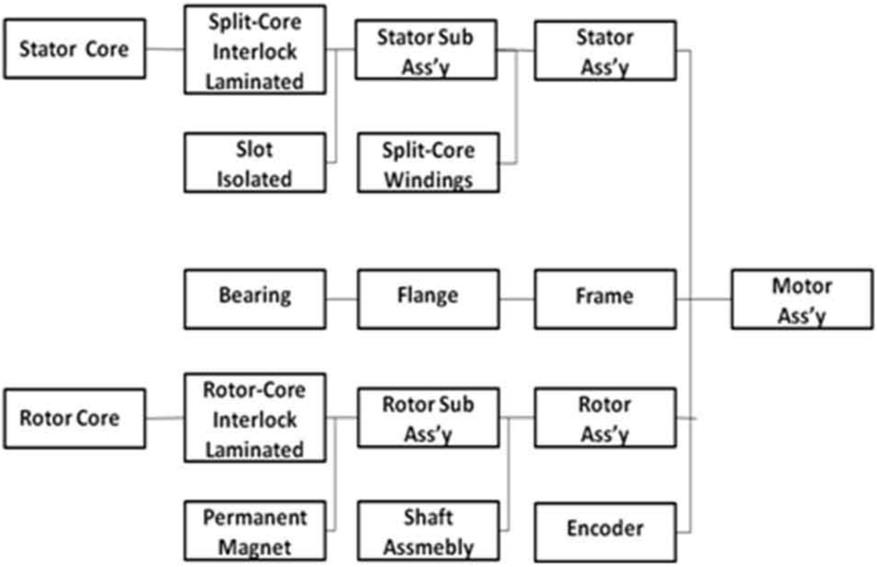


Fig. 2. Manufacturing process of servo motor assembly

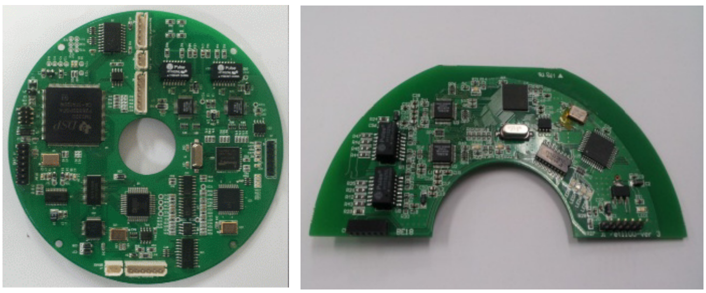


Fig. 3. The controller with drive and communication module

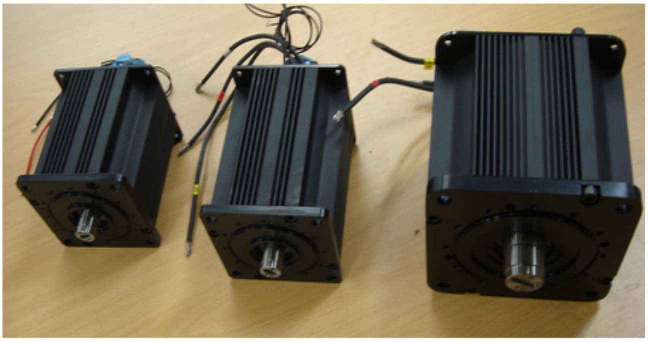
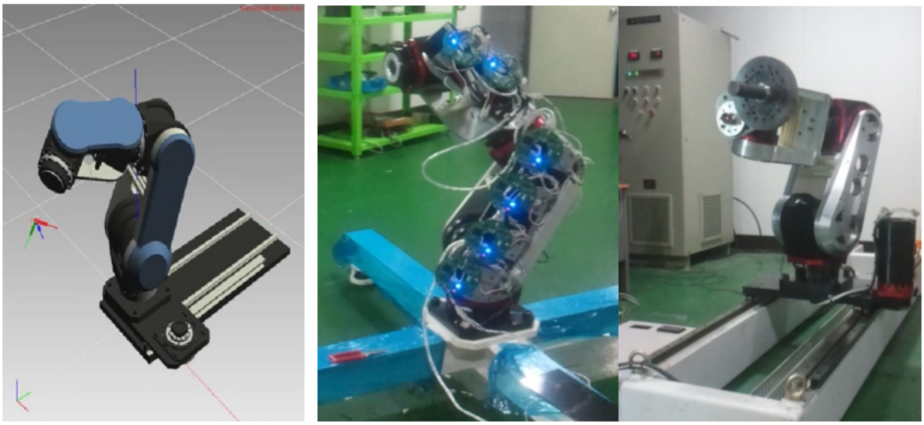


Fig. 4. The developed smart actuator

3 Industrial Robot with Smart Actuator

3.1 7-Axis Industrial Robot

The 7-axis industrial robot has been developed by using the developed smart actuators. The robot has a 6-axis articulated robot and a 1-axis linear driving unit for applying an industrial manufacturing process. Fig. 5 shows the virtual robot on a specific CAD interface and the fabricated the industrial robot.



(a) Virtual robot (b) Fabrication of robot

Fig. 5. 7-axis industrial robot with smart actuators

3.2 Robot Control Simulator

Fig. 6 shows the overall scheme of a robot control simulator. It contains a dynamic analysis module, a real-time control module, and a communication module between computer and the developed smart actuators. 'S/W MMC' of Fig. 6 is a module based on GUI. It can generate a command for trajectory control and monitor a tracking performance and a robot status.

The simulator is developed by using the RTX Real-Time Operating System. It includes a EtherCAT master module. The EtherCAT master module can be communicated with 32-axis EtherCAT slave modules at 1 kHz speed. Robot control algorithm can be programmed by using the 'Plug-In of User-Define Control Algorithm' module. The window and functions of 'S/W MMC' is shown in Fig. 7 and Table 2.

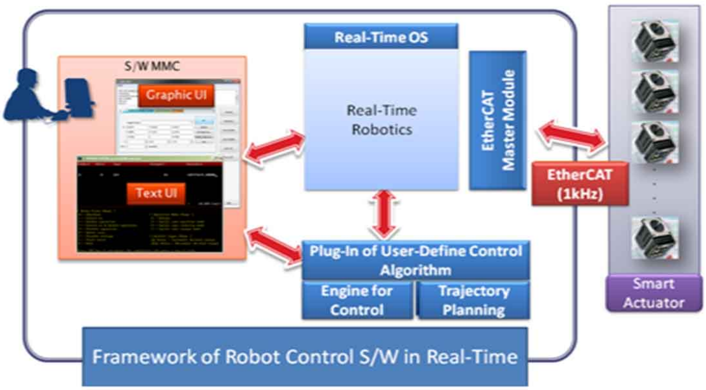


Fig. 6. Framework of robot control simulator

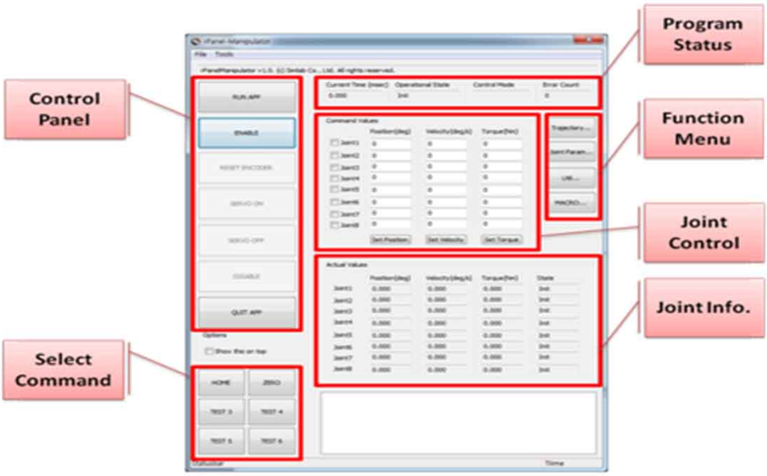


Fig. 7. Window of S/W MMC

Table 2. Functions of the S/W MMC

Item	Specification
Control Panel	Execute or terminate of S/W Enable or Disable of robot Servo On/Off Reset of encoder
Program Status	Current time Operational status Control mode Communication status
Select Command	Transfer robot command
Joint Control	Joint control (Position, Velocity, Torque mode)
Joint Info.	Monitoring of Position, Velocity, Torque and Status for all axes
Function Menu	Generate and modify of trajectory

3.3 Performance Evaluation of the Developed Robot System

A trajectory control experiment has been carried out for evaluating the performance of the robot. Fig. 8 shows the desired joint positions which are calculated by kinematics and a given reference trajectories in a task coordinate and the actual joint positions for each joint. The tracking position errors of joints are shown in Fig. 9.

As shown in Fig. 9, the maximum tracking position error is 0.002 rad and the steady-state error is 0.0001 rad. Fig. 10 shows the comparison between desired trajectories and actual trajectories in a task coordinate. The maximum trajectories tracking position error is 0.3 mm.

4 Conclusion

This study introduced a smart actuator which is integrated with a servo motor assembly and a controller. A smart actuator consists of a servo motor, a motor drive, gears, a brake, an encoder, a servo controller and a communication board. And then, 7-axis industrial robot with smart actuators and robot control simulator were developed. For verifying a robot performance, the trajectory tracking control was performed in experiment. The maximum trajectories tracking position error is 0.3 mm. In future work, the developed robot will be used in a mold and die manufacturing process.

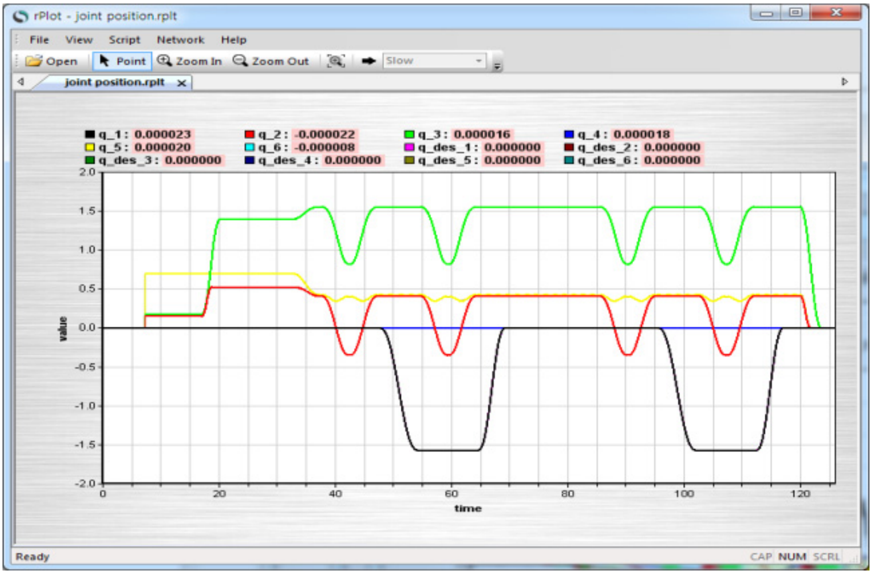


Fig. 8. Results of tracking control in each joint

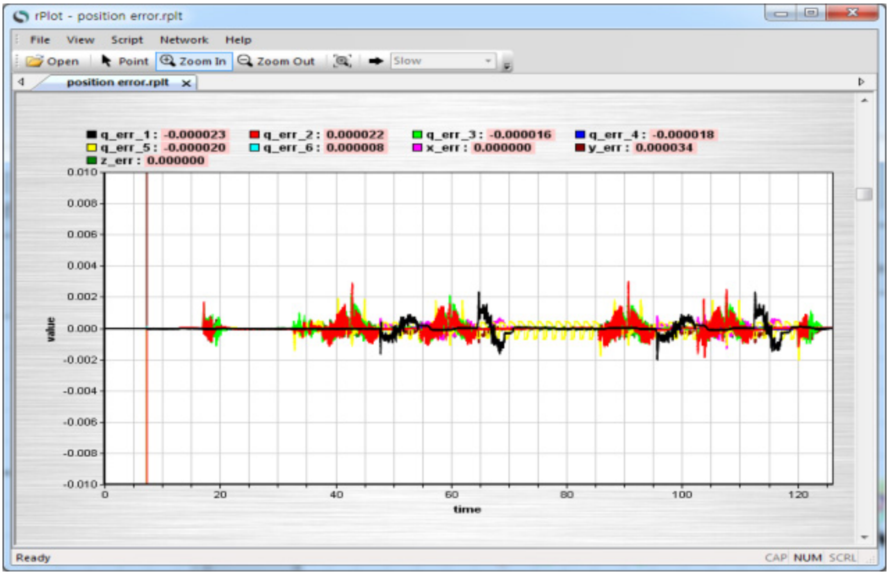


Fig. 9. Tracking errors of each joint

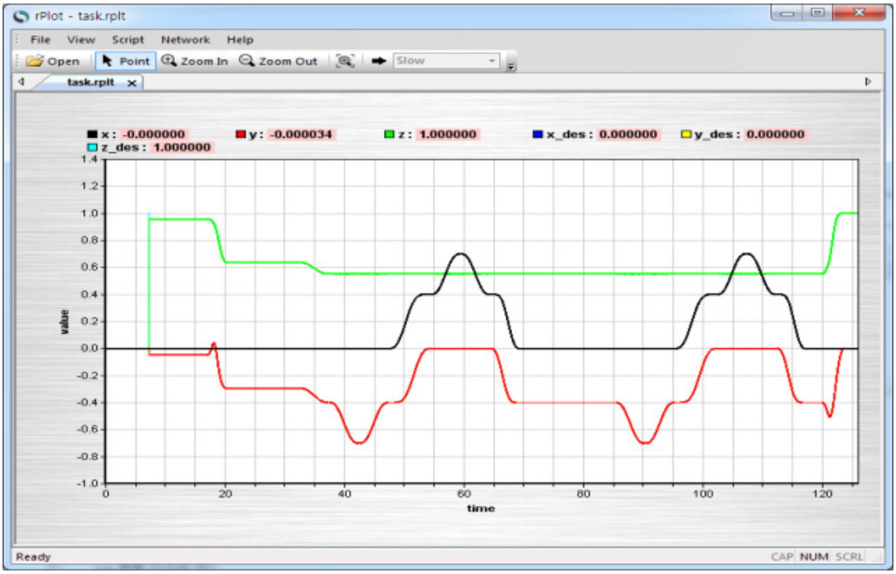


Fig. 10. Results of tracking control in a task coordinate

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