

## Development and control of a shifting performance test bench equipped with AC servo drive shifting manipulator

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Shifting performance of Manual Transmission is very important for users and manufactures of Manual Transmission. Traditionally, shifting performances were tested on test bench equipped with pneumatic shift manipulator, which was low efficiency, low control accuracy and noisy. In order to improve test efficiency and accuracy, a shifting performance test bench equipped with AC servo drive was built. Two AC servo drive motors were used as the actuating device of shifting manipulator. Control methodology of these two AC servo drive motors was established to meet the needs of shifting performance testing with high efficiency and accuracy. Test results indicated that the shifting process ran smoothly and shifting performance of Manual Transmission can be tested with high efficiency and high accuracy on this test bench.

*Keywords:* Shifting performance test bench, Shifting manipulator, AC Servo Drive.

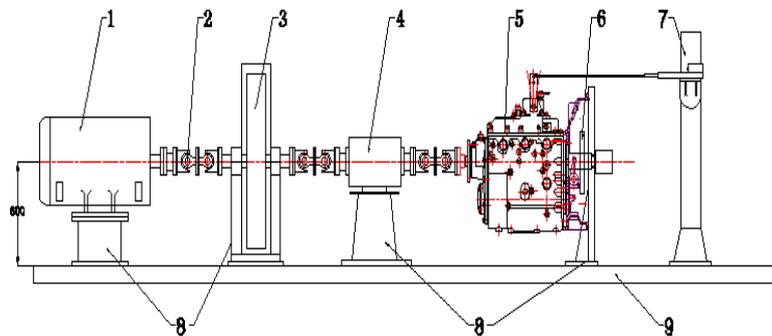
### 1. Introduction

Shifting performances of manual transmission in different speed have significant influence on driving performance. Traditionally, shifting performances were tested on test bench equipped with pneumatic shift manipulator, which was low efficiency, low control accuracy and noisy[1]. AC servo drive motors were widely used nowadays, they can be controlled more accurately than pneumatic cylinder. AC servo drive motors also have much quicker control response than pneumatic cylinder which means higher test efficiency[2]. In consider with all these advantages, a shifting performance test bench equipped with AC servo drive shifting manipulator was built In order to improve test efficiency and accuracy. Measurement and control system of the AC servo drive shifting manipulator was designed based on PLC controller. Control methodology of these two AC servo drive motors was established to meet the needs of shifting performance testing with high efficiency and accuracy. The system was built and tested, test results indicated that the shifting process ran smoothly and shifting

performance of Manual Transmission can be tested with high efficiency and high accuracy on this test bench.

## 2. Working Principle of the Test Bench

Structure of shifting performance test bench was shown in Figure1. A Frequency conversion motor was used as driving motor to provide the test bench with power so the whole test bench can rotate. An inertial flywheel was connect with the drive motor by a twin universal joint coupling, which was use to simulate driving inertia of vehicle. Other side of inertial flywheel was connected with the output side of testing gearbox, a torque and speed sensor was set between inertial flywheel and output side of gearbox to measure torque and rotate speed. Input side of the gearbox was connected with nothing, because engine and gearbox were disengaged during shifting. Shifting manipulator using AC servo drive motors was used to change gears of the gearbox[3-4]. Structure of shifting manipulator using AC servo drive motors was shown in fig. 2. There are two AC servo drive motors in the shifting manipulator, one is used as gear selector, and the other is used shift gear. With these settings, shifting process of test gearbox can be simulated just as in real cars, and shifting performance of the test gearbox can be tested in this test bench.



1 Driving motor; 2 Twin-universal joint coupling; 3 Inertial flywheel; 4 Torque and speed sensor; 5 Test gearbox; 6 Inertial plate; 7 Shifting manipulator; 8 Mounting bracket; 9 Cast iron platform  
Figure 1. Structure of shifting performance test bench

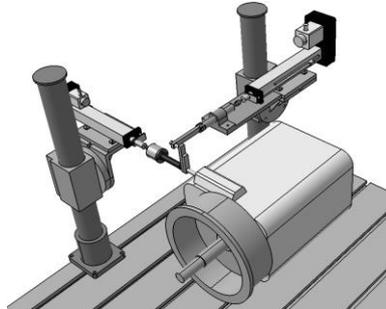


Figure 2. Shifting manipulator using AC servo drive motors

### 3. Measurement and Control System of AC Servo Drive Shifting Manipulator

The measurement and control system of shifting manipulator was shown in figure 3. The system was built up with three parts, including control system, actuating system and data collection system. The control system contains an Industrial Personal Computer (IPC) and a PLC, the IPC was connected with PLC by Ethernet cables. IPC used to store data collected by data collecting system, and sending control command to PLC. PLC send control signals to actuator of servo motors, which control servo motors to rotate. Actuating system is consisting of two servo motors and their actuators, and two screw rods. Actuators receive control signals from PLC and controls serve motors to rotate, screw rods change the rotating into linear motion, so as to shift the gearbox. Data collection system collect displacement of the two screw rods and push force of the screw rods, these data were transmitted to the Control system.

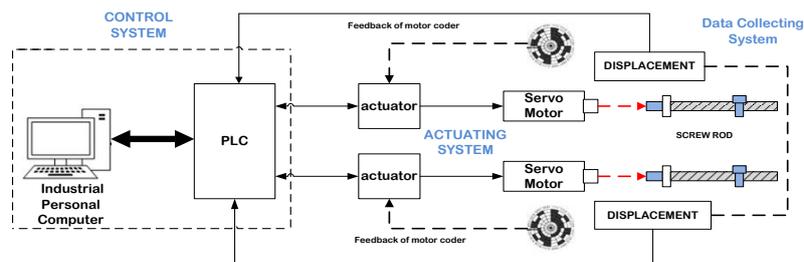


Figure 3. Measurement and control system for AC servo drive shifting manipulator

### 4. Measurement and Control System of the Test Bench

Measurement and control system of the test bench was shown in figure 4. An IPC was used to control the whole system and collecting data. A data collection card was used to collect rotation speed of the servo motors and force in the



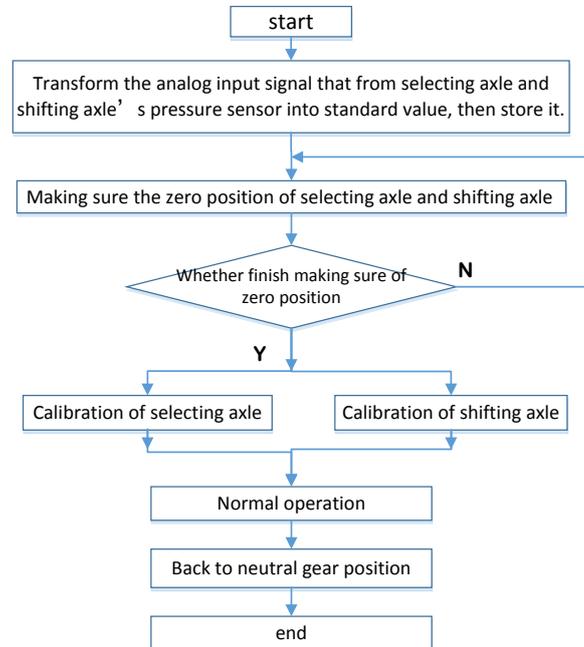


Figure 5. Control logic of PLC

### 5.2 Measurement and control software based on LabVIEW in IPC

There are five parts in measurement and control program, including test setting, gear calibration, test control (control of shifting manipulator, control of driving motor), state monitoring, and data processing. The control logic of measurement and control program is shown in figure 6.

Test setting module include test process setting and test parameters setting, test process setting include test date setting, selection of working condition, shift times and etc. Test parameters setting include up limit of gear select and shift force, velocity limits of gear select and shift screw rod. Under calibration mode, we can move gear select and shift servo motor by hand operation, we operation several buttons to move the servo motors to change the shift lever to different gear position. Coordinate of each gear was remembered by the software, these positions was latter used in test control mode to decide move direction and distance of each screw rod under different shift conditions. Under test control module, the program controls the system automatically to procedure the test process. State monitoring module was used to

collect and display different parameters of the system, so the operator knows the working condition of the system. Data processing module used to handle the tested data, so we can get more information about shifting performance of the test gearbox.

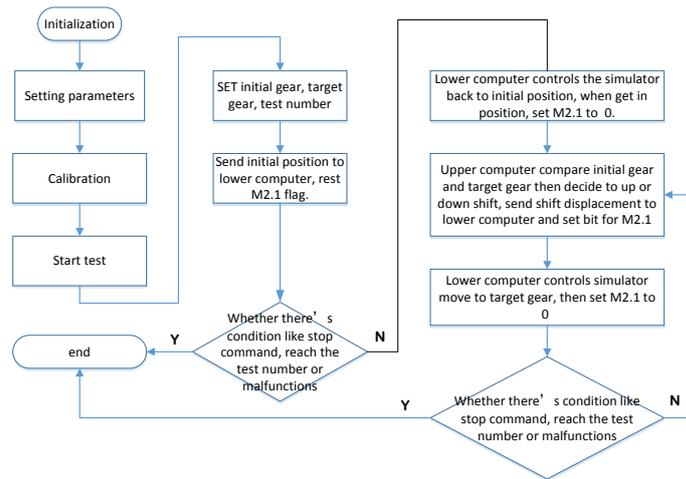


Figure 6. Control logic of upper computer

### 6. Analysis for Test Result

The test bench was built and tested, Pictures of the shifting performance test bench and measurement and control program are shown in figure 7. One of the tested curves of shifting force is shown in figure 8.

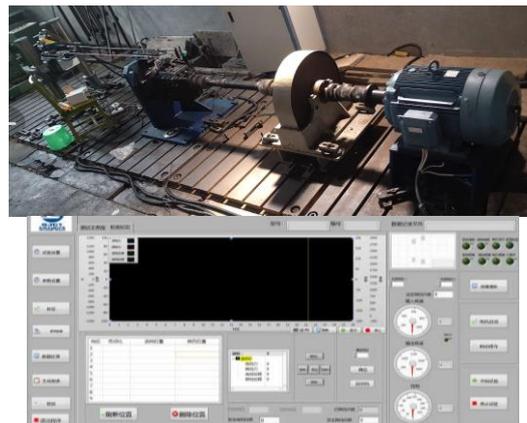


Figure 7. Pictures of the test bench and measurement and control program

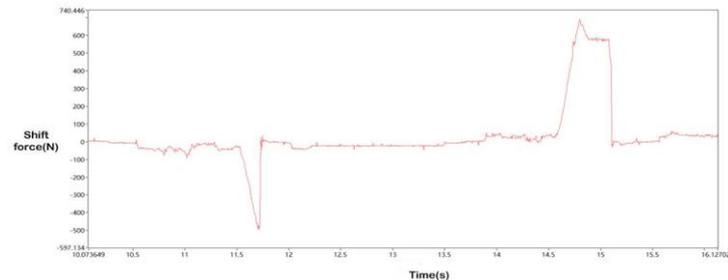


Figure 8. Curve of shifting force

Figure 8 shows the tested curve of shifting force in a test cycle in which gear changes between gear 2 and gear 3. According to Figure 8, direction of the force is opposite when gear 2 changes to gear 3 and gear 3 changes to gear 2. From 11.5s to 12s, the shifting process is gear 2 changes to gear 3, we can see from the shifting force that the synchronization process is not obvious. During the time of 14s to 16s, the gear changes from 3 to 2, the force changes dramatically, and the synchronization process is very clear.

## 7. Summary

A shifting performance test bench equipped with AC servo drive shifting manipulator was designed and built, a PLC is used in the system to control the two servo drive motor and driving motor, a IPC is used in the system to run measurement and control program based on Labview. Two AC servo drive motors were used as the actuating device of shifting manipulator. Control methodology of these two AC servo drive motors was established to meet the needs of shifting performance testing with high efficiency and accuracy. Test results indicated that the shifting process ran smoothly and shifting performance of Manual Transmission can be tested with high efficiency and high accuracy on this test bench.

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