RESEARCH ON ASCS SYSTEM FAULT DIAGNOSIS OF AUTOMOBILE AUTOMATED MECHANICAL TRANSMISSION

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ABSTRACT: The safety and stability of the Automatic Mechanical Transmission (AMT) determine the quality and safety of the car. Thus, the fault diagnosis of the car AMT system is conducive to enhancing the quality of the car. Therefore, we study the fault diagnosis system with AMT as the object. Methods: Firstly, put forward a feasible fault diagnosis scheme according to the function introduction of the AMT in the Automatic Shift Control System (ASCS). Secondly, design a fault diagnosis instrument by using 16 m x 8 bit FLASH memory, which can store car traffic data when having serial communication with TCU of ASCS system. And export data to PC through a serial port communication with it, thereby having a dynamic analysis of the traffic data. Finally, test the designed equipment. The experiment platform is constructed to simulate drive gearbox running state. Results: It is verified that the diagnosis instrument with accurate feedback and judgment on the operation state of AMT, at the same time, the dynamic analysis of signal in PC can be obtained through the storage function of the data stream. Conclusion: The designed scheme of fault diagnosis can carry out the dynamic analysis of traffic data effectively.

KEY WORDS: Automated Mechanical Transmission; ASCS; Fault diagnosis; Portable diagnostic equipment.

1 INTRODUCTION

Along with the enhancing of the vehicle's automation, the improvement of automobile transmission technology has been an important research branch in enhancing the quality of vehicles. At present, there are following automated mechanical transmissions have been used on cars: AMT system, Automatic Transmission (AT) system, and Continuously Variable Transmission (CVT) [1-3]. Among them, AMT system is improved on the basis of traditional dry clutch, mechanical transmission principle of manual fixed axis gearbox transmission and automatic control [4]. Preserving the traditional transmission system structure, it has the advantages of low cost, small volume and high transmission efficiency [5]. AMT, meanwhile, also has the automatic transmission function with convenient operation. And it can precisely control over automobile gear shifting to ensure the best power performance [6, 7].

As the electronic control system [8] becomes more complex, it will bring deadly influence on the vehicle safety travel once the electronic components are broken down. ASCS is an important part of AMT [9, 10]. The stability and reliability of its control technology will directly affect the system performance of AMT [11]. Therefore, the study on ASCS fault diagnosis is of great importance to improve the reliability of automobile system and the motion of vehicle safety.

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2 LITERATURE REVIEW

At present, the development of electronic vehicle controller usually has fault self-diagnosis function. Through the judgment of the traffic data in the running process to conduct self-diagnosis and produce corresponding fault codes stored in the memory. And then output the fault code through the communication interface [12-14]. Therefore, many scholars continue to promote the online fault diagnosis of the AMT automatic transmission operating system and the key components of them. For example: to conduct qualitative and quantitative diagnosis of the fault components by controlling the analytic redundancy relations between the various components in the control system [15, 16], the fault diagnosis method based on AMT control system of the model [17], and the fault diagnosis method based on knowledge (such as fuzzy logic and expert system) [18, 19].

Chery developed AMT transmission in the car, the technology of which has improved the fuel consumption, exhaust emission and other aspect in different degree. AMT can accurately control the function of clutch and shift in different driving conditions [20, 21]. Therefore, this study will focus on the design of AMT fault diagnosis system to cars of Chery S model.

3 DESIGN SCHEME

3.1 The Overall Design Scheme of ASCS System Fault Diagnosis

AMT is a mechanical and electrical

hydraulic-pneumatic integrated product, which is formed by combining ASCS on the base of MT [22]. ASCS takes TCU (Transmission Control Unit) as the core, simulating the separation/ joint of the clutch and gear shifting via the hydraulic actuator and solenoid valve, so as to realize the automatic transmission of the drive system [23, 24]. The working principle of AMT is shown in Figure 1:

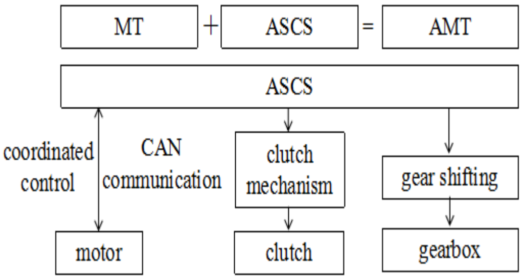

Figure 1 AMT Function Diagram of AMT

TCU is the electronic control unit of the ASCS fault diagnosis system. It can detect and diagnose the relevant data while controlling the start and shift of cars. If failure occurs, it will store the faults in the form of trouble code (DTC) in the EEPROM, and send them to the LCD screen through CAN bus fault code. Then the screen displays the happened failure.

ASCS has many components, most of which can be diagnosed by fault self-diagnosis system. However, it is difficult to determine the precise location and the degree of the fault diagnosis [25]. Therefore, this problem need to be settled with the aid of portable fault diagnosis instrument, which can conduct fault diagnostic tests on maintenance level. To read fault codes from serial communication by using fault diagnostic instrument, and to do precise analysis and judgment through collecting the interface data changes [26, 27]. When receiving traffic data from the serial port, fault diagnosis instrument will store the data in the FLASH. Therefore maintenance personnel can export the data from the FLASH to the computer, and realize accurate analysis of the fault reasons and fault degree by installing data collection and analysis software on the computer.

3.2 The Design of the Fault Diagnosis of Automobile Automated Mechanical Transmission

The fault diagnosis instrument has four main functions.

Serial Communication: Through RS-232 interface, the fault diagnosis instrument communicates with computer and TCU, the electronic control unit [28, 29].

Liquid Crystal Display (LCD): the fault diagnosis instrument receives the travel data from TCU, displaying the working state of TCU on the LCD screen in the text mode. Besides, the LCD screen can also display the data in EEPROM of TCU and the progress of storage or export of the 16 M FLASH memory. Table 1 shows the marking description of the LCD.

Table 1 Screen Logo Description of Fault Diagnosis Instrument

Screen Logo		Description
Magnetic Valve	EV0,EV1,EV2 ,EV3,EV4	Display operational status of all magnetic valve.
		Power on when displaying ON; Power off when displaying OFF.
Switching Signal	BK,HB,AM,E S	BK: brake signal, HB: hand break, the switch signals are “ON” or “OFF”.
		AM: manual shift / automatic mode, the switching signals display “A” or “M”; ES: power mode, the signals are “E” or “S”.
Sensor Signal	CP,GP,SP,OP, NE,N1,N2	Showing the signal value of all sensors.
EEPROM	ROM	Read the data of EEPROM, and display the results on the LCD
Flash Memory	SAVE,READ	SAVE: FLASH storage data, READ: FLASH reading data.
the Time of Three-Phase Start Clutch Engagement	Time1-Time3	Calculate the time of the Three-Phase Clutch Engagement when the cat starts.

Save or export data: Fault diagnosis instrument can save the serial data to FLASH memory, with the ability to export data into the computer from the FLASH memory. Then it draw an important offline data curve with the help of data collection and analysis software written by VC. This is conducive to fault diagnosis.

Implement the corresponding function by operating keyboard: ASCS master software enclosed with a part of the subroutine, which have certain functions when they are used alone (The corresponding function keys are “F1”~“F6”) [30, 31]. The keyboards of diagnostic instruments are able to invoke these subroutines through the diagnostic instrument and the serial communication between TCU [32, 33]. After finishing the subroutine call, FLASH erase/read operation (“F7” or “F8”) is needed.

3.2.1 Hardware Design

This research adopts XC164CS chip micro-controller as a fault diagnostic instrument. XC164CS has two asynchronous/synchronous serial channels and double CAN module, 14 A/D conversion module, etc. [34, 35]. Besides, it also has strong peripheral subsystem and integrated on-chip memory. The fault diagnostic instrument hardware system in this study is mainly composed of clock circuit, power supply module circuit, serial communication module circuit, liquid crystal display, keyboard, and FLASH memory module, etc. Clock circuit introduces 8 MHZ external crystals into XC164CS, and increases the frequency to 20 MHZ, serving as the internal clock in XC164CS [36]. Power supply module circuit needs two kinds of voltage as 3.3 V and 5 V, so the study chooses SN74LVCC3245A chips being able to shift between 3.3 V and 5 V. Because XC164CS has serial interface module [37, 38], RS232 interface adopts MAX232E chip to conduct serial communication with external module [39]. Liquid crystal display using HYW320240P (320 × 240), a kind of graphic dot matrix liquid crystal display module, which displays TCU working state in the form of text. Keyboard adopts common determinant keyboard, the key value is10 (2 × 5), taking16 M x 8 bit K9F2808U0C NAND FLASH memory, which saves the data from the serial port. In addition, there are some other hardware devices, such as the external power source, and reserve CAN communication interface, etc. The interface circuit of XC164Cs and FLASH tube feet is shown in Figure 2.

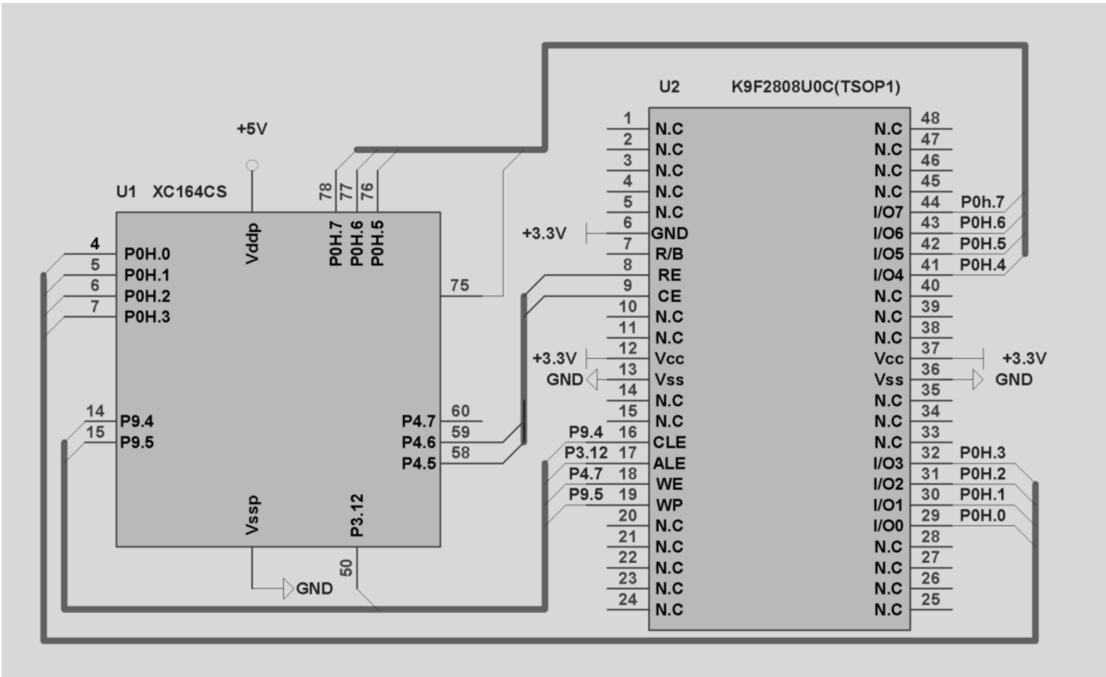

Figure 2 Interface Circuit between K9F2808U0C and XC164CS

(2) Software Design

This research adopts Keil uVision3.0 programming, and uses C language to write.

The main program flow chart of software is shown in Figure 3:

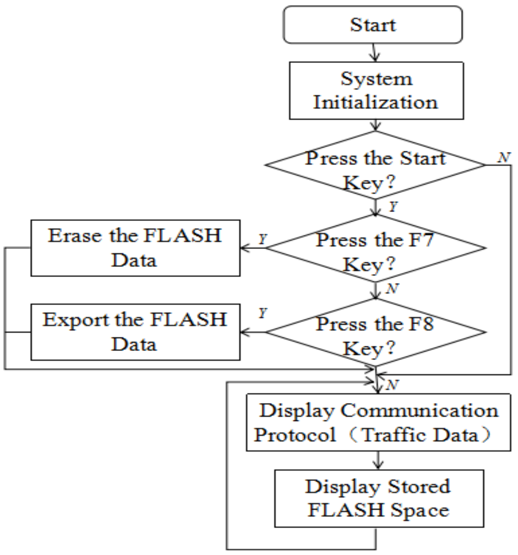

Figure 3 Flow Chart of the Main Program

We define the Diagnostic Trouble Code (DTC) referring to SAE protocols. DTC consist of five characters [40-42]. The first of which indicates that which system is fail: P=Power train、B=Body、C=Chassis、U=Network.

The second one represents the type of the fault. In group P, if the second character is 0, it means the fault code is a standard code. But if it is 1, it means the fault code is a custom one. The third one defines the subsystem that including the fault. If the second character is 7, 8 or 9, it means the subsystem is transmission. The final two represents concrete object and type of the fault. The relating fault codes are in Table 2:

Table 2 Fault Code List of AMT

Fault Code	Meaning	Fault Code	Meaning
P0710	Faulty Transmission Actuator	P0781	Gear Selecting Failure
P0715	Transmission Output Speed Sensor Signal Circuit	P0805	Clutch Position Sensor Failure
P0720	Transmission Output Speed Sensor Signal Malfunction	P0821	Gear shifting Travel Sensor Fail
P0750	Solenoid Valve EV0 Malfunction	P0822	Gear Selecting Travel Sensor Fail
P0755	Solenoid Valve EV1 Malfunction	P0875	Shift to Neutral Position Failure
P0760	Solenoid Valve EV2 Malfunction	P0890	Faulty Clutch Actuator
P0765	Solenoid Valve EV3 Malfunction	P0942	Oil Source System Malfunction
P0770	Solenoid Valve EV4 Malfunction	P1500	Clutch Disengagement Failure
P0775	Shift Malfunction	P1505	Shift Lever Malfunction

In programming, turning global variable DTC to the fault code variable when DTC equals to zero means the system is trouble-free. If the system fails, the corresponding code value is assigned to the DTC. It is known from the preceding analysis that the fault code is composed of five characters. The study omits P (the first character of all fault codes of this research are all Ps) in order to facilitate the storage and send of code, thus the fault code consists of four digits. For example: if handle failure, the number 1505 will be assigned to DTC. Whenever a failure occurs, the fault code is assigned the variable DTC, saving the latest fault code stored in the EEPROM. But, in a certain period of time when the same fault occurs repeatedly, it will frequently access to EEPROM, writing the same code to waste the resources of the TCU. In view of this, only the current fault code is different to the last one, this new code will be stored.

This study compares the values of clutch separation distance sensor CP, respectively file position sensor SP, shifting position sensor GP, transmission input shaft speed sensor N1 and transmission output speed sensor N2 to their corresponding maximum and minimum. If the value is beyond the normal range, the corresponding sensor is fail. If the same failure occurs continuously more than five times, then the corresponding fault code will be sent.

The research do not diagnose engine speed sensor at first, so the default value of the sensor is normal during detecting. Therefore, there are analytical redundancy relations among the engine speed (NE), N1 and N2 in the ASCS system. With clutch engaging, the transmission gear is neutral, there are the following analysis relations:

$$NE = N1 \cdot i_c \tag{1}$$

$$N1 = N2 \cdot i(Ga) \tag{2}$$

$$NE = N2 \cdot i_c \cdot i(Ga) \tag{3}$$

Among which, i_c indicates the speed ratio between the gear transmission boxes of engine and transmission; $i(Ga)$ is the speed ratio when the transmission is in the Ga position. According to the analytic expression (1)-(3), it is clear that there are abnormalities if they are not established at the same time. For example, if the expression (2) works, while (1) and (3) do not, it means the clutch actuator is abnormal.

There is no transmission box in the ASCS system in this study, which means $i_c = 1$. The relations in the fault diagnosis are shown in Table 3:

Table 3 Speed Resolution and Redundant Diagnosis Relation Sheet

Speed relations	$N1 = N2 \cdot i(Ga)$	$N1 \neq N2 \cdot i(Ga)$
$N1 = NE$	Trouble-free	$N2$ sensor fault or transmission actuator malfunction
$N1 \neq NE$	Clutch actuator malfunction	$N1$ sensor fault

4 EXPERIMENTS ON FAULT DIAGNOSIS SYSTEM AND RESULTS ANALYSIS

4.1 Experiment Scheme

The object of this research is the AMT system of Chery S, the normal working state of the AMT will be simulated by bench test, which is shown in the Figure 4.

In the experiment, it comes first to test the data communication between AMT control system and fault diagnosis instrument and detect the FLASH memory in the fault diagnosis instrument to ensure that it can store the data from TCU and that the stored data can be exported. With normal AMT system parameters, simulate the functions of vehicle as upshift, downshift, clutch joint and separation, and validate the feasibility of diagnosis by reading all parameters through the fault diagnostic instrument. Finally, according to the judgment condition of the diagnostic program, check whether the fault sends corresponding fault code timely and accurately and displays it on the LCD screen, and whether the fault code is stored in the EEPROM.

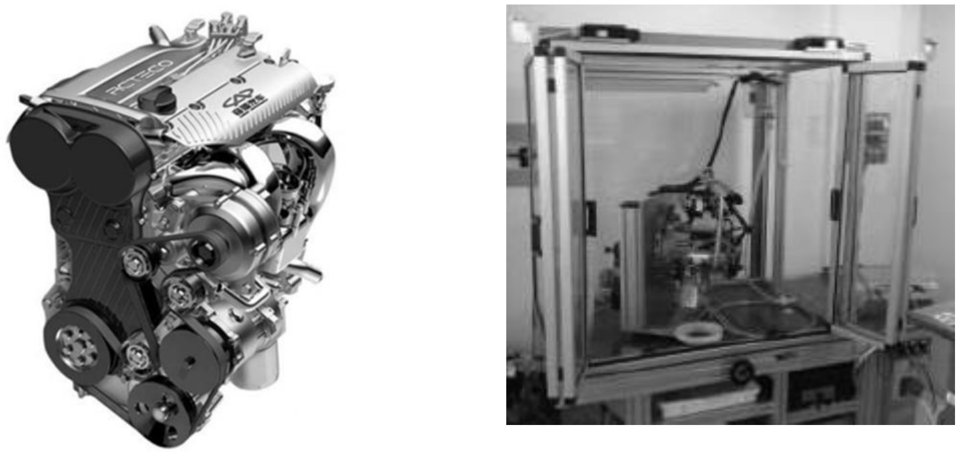

Figure 4 Test bench

4.2 Experimental results and analyses

(1) Stability experiment in free-trouble condition

Before the beginning of the experiment, the history data of FLASH should be erased firstly. Observe the diagnostic instrument in the stability and reliability of the system by simulating the vehicle starting gear and lifting block in a trouble-free condition. The figure 5 shows that DTC is zero, the system has no failure.

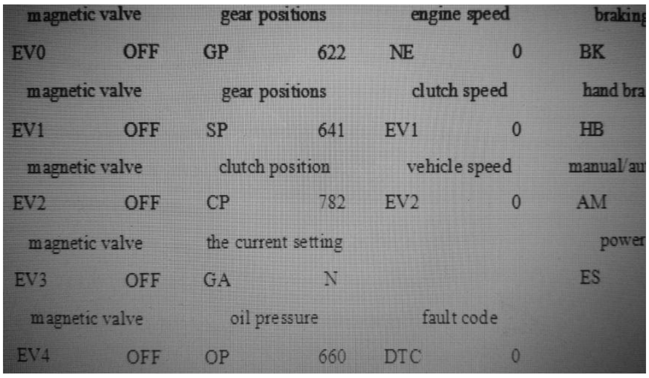

Figure 5 Trouble-free Display Data

(2) Debugging experiment on AMT system diagnostic program

Debugging experiment on clutch separation/joint fault diagnosis program: the research is tightly related to clutch position feedback, which requires the clutch feedback key should be “ON” all the time. Fault diagnosis instrument sends clutch separation command to AMT. Then it displays fault code as 1500 judging by the program. The result is shown in Figure 6:

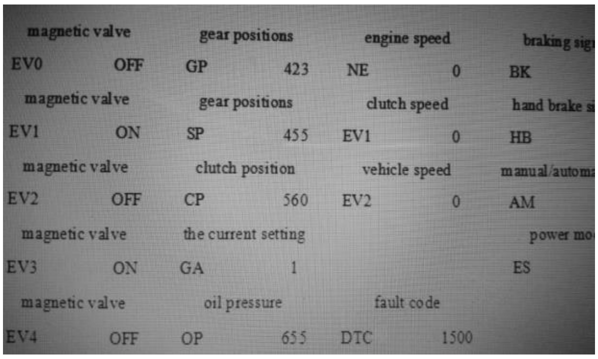

Figure 6 the Experimental Results of Disengagement Clutch Failure

Afterwards, TCU sends instruction to AMT system to make the system in first gear. Due to no input of N1 (which means zero), so |NE-N1|>100. Fault diagnosis instrument judges that the clutch is in discrete position all through, so it shows fault code as 890. The result is shown in Figure 7.

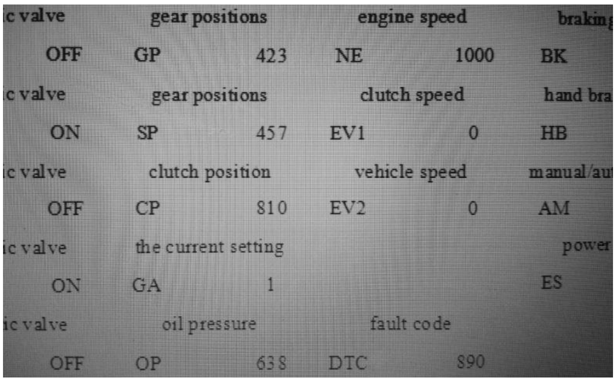

Figure 7 the Experimental Results of Joint Clutch Failure

Debugging experiment on the shifting / picking neutral fault diagnosis program is shown as follows. At first, keep the system in the neutral position (with signal feedback as 650). Put off the position sensor which corresponding to the gear position of SP, and turn it to neutral manually. TCU sends upshift command to AMT system by pressing F1 key on the fault diagnosis instrument. Afterwards, the instrument shows fault code as 1505, which is presented in Figure 8.

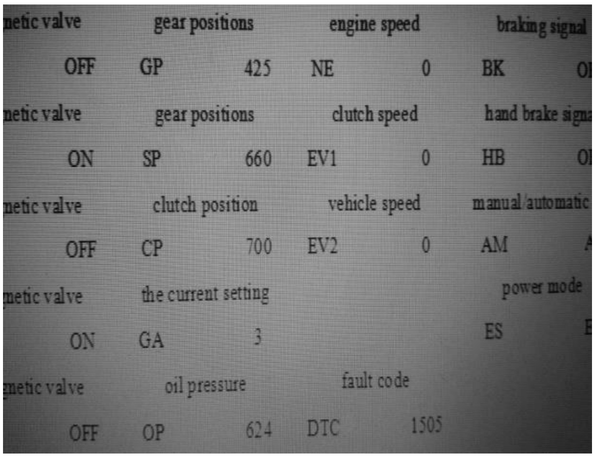

Figure 8 the Experimental Results of Selecting Failure

The same with the above operation, remain the system in neutral (feedback signal is 650). Put off the position sensor which corresponding to the GR gear position, and turn it to neutral manually. Fault diagnosis instrument shows fault code as 775, which can be seen in Figure 9.

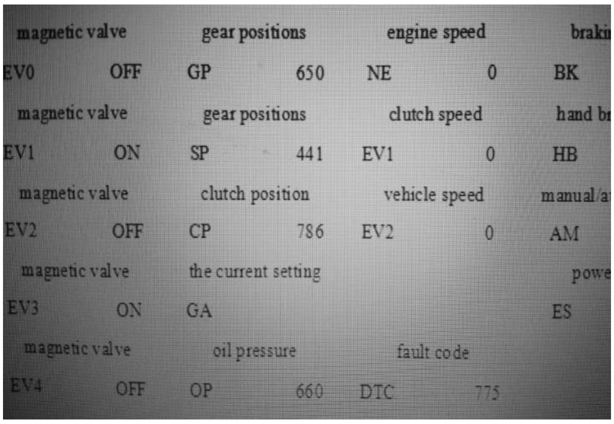

Figure 9 the Experimental Results of Gear Shifting Failure

Press the position sensor of gearshift, turn it to any position except neutral, and then send instruction of shifting to neutral to AMT system by pressing F3 key. The fault code on the fault diagnosis instrument is 875. The result is shown in Figure 10:

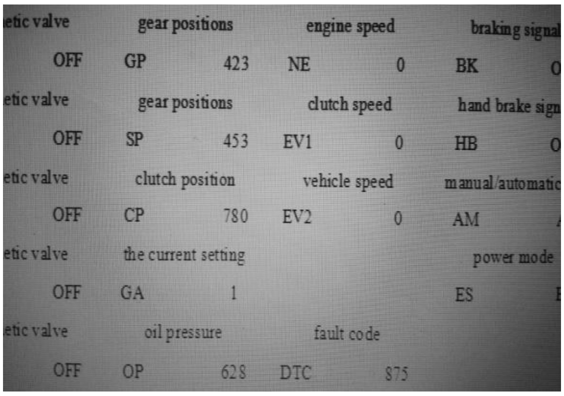

Figure 10 the Experimental Results of Shift to Neutral Position Failure

5 CONCLUSION

With the development of automobile industry, it is particularly important to guarantee its stability and safety. Therefore, fault diagnosis technology has become an important part in the field of automotive research. The main content of this study is shown below:

(1) Through the introduction of AMT system, a series of methods for diagnosis should be designed, combining the ASCS corresponding feedback signal.

(2) By shaping the hardware and software environment, we give an overall design on the fault diagnosis. By referring to the SAE agreement, we draw two kinds of online diagnosis methods: one is analysis based on signal detection and analytic redundancy, and the other one is defining the AMT system fault codes, providing reference for maintenance personnel to the diagnosis of system.

(3) Through the bench test, real-time monitoring of the input and output of the fault diagnosis instrument is made to verify the validity of the fault diagnosis instrument designed this time.

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