Diagnostics of ABS and ESP systems

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Abstract. The purpose of the tests is to register signals that have a direct impact on the ABS system when braking and accelerating the vehicle. The purpose of the simulation tests was to analyse the influence of signals from the velocity sensors of individual wheels and the moment of recognition of the fault signalled by the ABS diagnostic lamp lighting up. The ESP system simulation was carried out on a specially designed and made test stand equipped with the ESP 5.3 system.

1. Introduction

The latest cars use control devices that affect safety and ride comfort. The devices affecting safety include ABS, ASR, ESP and SRS systems, whereas those improving driving comfort and environmental protection can be: air conditioning, automatic transmission and the start-stop system[1,2,7,8].

During sudden braking in a classic braking system there is a danger of the wheels blocking and the vehicle slipping. The ABS system solves this problem by regulating the braking pressure so that on all types of surfaces it is impossible to effectively block the wheels and ensure control of the vehicle. The correctness of driving must be maintained not only on dry asphalt, but also during black ice and in all other conditions.

The ABS controller [3,4,6,9] receives input information from the wheel speed sensors needed to regulate the braking process. In order to prevent blockage of the wheel, the pressure in the braking system is maintained at the previously reached level and does not increase (the pressure maintenance phase). If the rotational speed of the wheel continues to decrease, the braking pressure is reduced (the pressure reduction phase) and the wheel is braked less. As a result, the wheel speed increases again and the vehicle remains under control. During all control phases (maintaining, decreasing or increasing the pressure), the control device activates one or more solenoid valves grouped in the modulator.

ESP Stability Control enables safe driving in critical situations regardless of whether the accelerator or brake pedal is depressed or not. The starting point is the ABS anti-lock system, designed to prevent the wheels from locking when braking, and anti-skid system of ASR drive wheels, preventing wheel slip during acceleration. Statistics show that about one-sixth of all road accidents are caused by the vehicle slipping, especially when the tires have little grip on the surface (ice, snow, rain). The regulation of the stabilisation of the course takes place mainly during violent maneuvers and reactions of the driver, showing the tendency to understeer or oversteer by the vehicle and changes in the type of surface (adhesion). It involves individual braking of the wheels and interference in the engine control. ESP electronics with numerous sensors, similar to ABS and ASR systems, are more efficient and faster than the best driver. While the ABS and ASR systems change the parameters of vehicle motion dynamics along its longitudinal axis, the stabilisation of the vehicle's path stabilises the vehicle in a rotary motion around the vertical axis.
The control device via the CAN interface activates the warning lamp on the instrument panel. It illuminates continuously after a failure of the stabilisation system. In the same way, the control device, through the CAN interface and multifunction indicator, processes the signals from the sensors controlling the degree of wear of the friction pads and activates the warning lamps of the electronic traction system and ABS. Similarly to all systems described so far, this one also has the possibility of extensive self-diagnosis with storing error codes in the diagnostic memory, the contents of which can be read with the help of an appropriate tester. However, not all signals are recognised as faults in the form of error codes [5,10].

2. Road test of the ABS system

The purpose of the tests is to register signals that have a direct impact on the ABS system when braking and accelerating the vehicle. The test object was the Honda Accord 2.0 KAT 2003 car. The following signals were read and recorded using the KTS 540 device (Fig. 1), having direct and indirect connection with the rotational speed and its measurement:

- wheel speed (right front, left front, right rear, left rear),
- ABS pump motor and solenoid valves,
- pump motor voltage.

The operation of the ABS system while the vehicle was braking was visualised by signals showing the moment of activation and deactivation of the brake fluid pump. The "pump motor" signal is zero-one and only indicates the pump operation status, while the "pump motor voltage" signal is the voltage value at the brake fluid pump terminals.

The test results are presented in the form of time courses of selected physical quantities related to the measurement of rotational speed. Figure 2 shows the speed courses of individual wheels of the tested vehicle during braking and acceleration. Differences between them can be caused by driving along a road bend. Variable speed values for individual wheels illustrate the operation of the braking system. Figure 3 shows the moment of switching on the electrical pump during braking and starting the ABS system. The ABS pump works with the system’s solenoid valves and switches on when one of the valves cuts off the brake fluid supply to the blocked wheel and the other opens to drain the fluid. The fluid is drained via the ABS pump to the braking system. During the operation of the ABS system, the speed of individual wheels decreases when the solenoid valves and the ABS pump are switched on.

The analysis of the results confirms the effectiveness of the ABS system while driving at 40 km / h.
3. Simulation tests of the ABS system operation
The purpose of the simulation tests was to analyse the influence of signals from the velocity sensors of individual wheels and the moment of recognition of the fault signalled by the ABS diagnostic lamp lighting up.
As part of the tests carried out with the use of the BOSCH FSA 740 and KTS 540 specialist diagnostic equipment, the following measurements were carried out at the Kelsey Hayes EBC 430 ABS test stand (Fig. 4):
1. Registration of the wheel rotation speed sensor voltage for simulated speeds,
2. Readout of system error code memory,
3. Erasing the memory of system error codes,
4. Observation of real values,
5. Performing functional tests of subsystems.
The ESI tronic 2.0 program supporting the BOSCH FSA 740 diagnostic device includes the BOSCH KTS 540 interface.

Damage simulation was carried out by changing the rotational speed of individual wheels using potentiometers. The result of the simulation was to determine the error codes (Fig. 5) and to determine the speed at which the ABS diagnostic lamp will switch on.

Figures 6 and 7 have the following values registered:
– individual wheel speeds,
– operation of the electrovalve relay,
– power supply control,
– ABS pump motor operation,
– operation of the ABS lamp.
Figure 5. Reading ABS stand error codes

Figure 6. Actual values of rotational speed in the form of a graph
Figure 7. Actual values of rotational speed in the form of a graph

4. Studies of the ESP system response to vehicle slip in the event of a sudden wheel turn to the left and then to the right

The evasive action test (elk test) as a maneuver to bypass the obstacle according to the VDA standard is carried out to formulate conclusions about the dynamic properties of the vehicle such as stability, drivability, braking performance and behaviour in the conditions of loss of grip.

The simulation was carried out on a specially designed and made test stand equipped with the ESP 5.3 system (Fig. 8) from the Audi A6 2.5 TDI vehicle. The ESP system controller based on the transmitted signals about steering wheel rotation angle, engine load and selected vehicle motion parameters (e.g. speed) determines the required vehicle motion condition and assesses the actual traffic condition based on the lateral acceleration and angular velocity signals. Detected deviations from the required traffic condition are the basis for determining the necessary corrections for the microprocessor. Values that cannot be measured (e.g. the tyre-surface adhesion coefficient, longitudinal and lateral speed) are estimated by the microprocessor based on available data. The process of regulation, continuously controlled, is subject to corrections as a result of signals changing the road surface or the driver's new instructions.

Before starting the tests, it is necessary to adapt the steering angle sensor. Doing this involves the following stages: setting the steering wheel for driving straight ahead; turning the steering wheel to the left by 1.5 turn; resetting the steering wheel to straight ahead; turning the steering wheel to the right by 1.5 turns and returning to the straight-ahead setting, after which the ESP indicator light should go out.
Figure 8. Test stand for testing the ESP system

Side slip simulation was performed by turning the steering wheel to the left and then to the right by changing the position of the angular velocity sensor with the lateral acceleration sensor. During the test, a pressure change in the circumference of each wheel was observed using manometers. The tests were carried out without pressing the brake pedal and with simultaneous depression of the brake pedal. During the tests, the operation of the solenoid valve system and the ABS system pump were observed. Error codes inform about incorrect calibration. The purpose of the tests was to identify error codes for incorrectly performed calibration (Fig. 9). The second aim of the study was to analyse the elk test (Fig. 10, Fig. 11).

Figure 9. Reading ESP stand error codes
Figure 10. Signal value of steering wheel angle during elk test

Figure 11. Signal value of yaw sensor during elk test

5. Summary
Diagnostic devices connected to vehicle OBD sockets allow measurement and registration of individual physical quantities related to the rotational speed of individual wheels. This allows for an accurate analysis of the operation of control systems based on individual signals (Fig. 2).

The analysis of the recorded results during the braking and acceleration process, while recording the signals of the solenoid valves and the ABS pump, make it possible to interpret the effective operation of the ABS system (Fig. 3).

The correct operation of the ESP system is controlled while driving (ESP lamp). Damage and interference in the operation of the ESP system are recognised immediately, and the diagnostic system records all error codes in the controller's memory, which was confirmed during the simulation tests (Fig. 9).

The most common error code is the failure of the gap in the impulse sensor system and the impact of battery voltage on the ABS, ASR and ESP system.

The data stored in the ESP controller memory is retained even in the event of a power failure, e.g. during the battery replacement. These data can be removed from the controller's memory by means of a diagnostic device that allows the error memory to be cleared.
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