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DIRECTIONS FOR THE DEVELOPMENT OF PERIODIC TECHNICAL INSPECTION FOR MOTOR VEHICLES SAFETY SYSTEMS

KIERUNKI ROZWOJU OKRESOWYCH BADAŃ TECHNICZNYCH POJAZDÓW SAMOCHODOWYCH W ZAKRESIE BEZPIECZEŃSTWA

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Summary

The article presents the possibilities of extending the scope of periodic vehicle technical tests in the field of safety. The following mechatronic systems were analyzed: brake system with ABS / ESP together with sensors, brake assistant BAS and automatic braking system, power steering system (EPS), tire pressure monitoring system (TPMS), airbags, belts with pre-tensioners systems (SRS), system of adjusting the headlamp setting, assistant of the main beam and maintain the track.

Four levels of diagnosis have been proposed allowing, in turn, to determine more precisely the condition of the system under examination. The control tests at levels I, II and III consists in reading information from the signal lamp on the dashboard of the car and the data downloaded from the self-diagnosis program of the tested system through a diagnostic tester. Level IV consists in controlling the functioning of the entire system on the diagnostic stand. The operation of the tested system is triggered by a tester through the OBD socket in the car. The effect of the system is checked on the test stand. This allows to detect those mechatronic system failures that are not detected by on-board diagnostic systems. Such a method of diagnosis causes the need to synchronize the tester

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program (extortion signals) with the measurements on the stand.

Keywords: diagnostics, mechatronics systems, periodic technical inspection, bench testing of brakes

Streszczenie

W artykule przedstawiono możliwości rozszerzenia zakresu okresowych badań technicznych pojazdów w zakresie bezpieczeństwa. Przeanalizowano następujące układy mechatroniczne: układ hamulcowy z ABS/ESP wraz z czujnikami, asystent hamowania BAS i system automatycznego hamowania, układ wspomagania kierownicy (elektryczny EPS), system kontroli ciśnienia w ogumieniu (TPMS), układy zabezpieczający osoby w pojeździe (SRS), system regulacji ustawienia reflektorów i asystent świateł drogowych i utrzymania toru jazdy.
Zaproponowano cztery poziomy diagnozowania pozwalające kolejno, coraz dokładniej określać stan badanego układu. Kontrola na poziomie I, II i III polega na odczycie informacji z sygnalizatorów na desce rozdzielczej samochodu oraz danych pobranych z programu autodiagnostyki badanego układu poprzez tester diagnostyczny. Poziom IV polega na kontroli funkcjonowania całego układu na stanowisku diagnostycznym. Działanie badanego układu uruchamiane jest testerem poprzez gniazdo OBD w samochodzie. Efekt działania układu sprawdzany jest na stanowisku badawczym. Pozwala to wykrywać te niesprawności układu mechatronicznego, których nie wykrywają systemy diagnostyki pokładowej. Taki sposób diagnozowania powoduje konieczność synchronizacji programu testera (sygnałów wymuszeń) z pomiarami na stanowisku.

Słowa kluczowe: diagnostyka, układy mechatroniczne, stacja kontroli pojazdów, badania okresowe, badania stanowiskowe hamulców

1. Introduction

In the last few decades the motor vehicle has become a system of many mechatronic systems cooperating with each other and communicating via the CAN network. However, the methods of periodic inspections at the vehicle control station (PTI – Periodic technical inspection station), as part of mandatory technical tests, remained at the level of mechanical systems tests. The development of techniques and scope of diagnosis in the scope of periodical technical tests should take into account the fact of changes in vehicle construction, their electronicisation and computerization.

The first harbinger of a new approach to the methodology of mandatory vehicle technical tests is the use of OBDII testers to assess the implementation of diagnostic monitors related to the operation of the engine. For example, the execution of the catalytic converter control procedure by the OBD II on-board diagnostic system with a positive result, confirmed by the tester, may replace the exhaust gas analysis procedure for petrol engines performed at PTI station.

Mechatronic systems, whose main idea is to control the object through a programmable controller using signals from sensors, require a different approach to their diagnosis in relation to strictly mechanical systems. The self-diagnosis program built into the driver, should be used in control tests. For this purpose, it is necessary to use testers that allow to read out any error codes registered by the self-diagnosis system, as well as signals from the sensors and verify the correctness of their operation. The second purpose of using testers is the ability to force the actuators circuits through the electrical signals from the tester and obtaining answers (tests of actuators). The use of testers allows to speed up the process of diagnosing mechatronic systems, as well as to more widely use existing stands for vehicle control tests.

Research and development works carried out in foreign centers in the area of the development of vehicle inspection tests also include the use of computer testers for periodic tests in PTI stations [4, 8].

The principle of periodic control is to check the effects of the tested system and compare it with the requirements of the regulations. The effect of action can be observed on the screen of the test bench, while forcing the activation of the mechatronic system can take place through the signal from the tester to the controller of the tested system. Such a method of diagnosis causes the necessity of synchronization of excitations from the tester with measurements and registration of test results at the diagnostic station. This can be accomplished by integration the tester software with the controller and software of the test bench.

The above problems are currently being undertaken by research centers in the European Union [3, 4, 5, 6, 7]. It is proposed to modify currently used diagnostic programs to standardize procedures, to facilitate access to subsequent drivers, to speed up the performance of diagnostic tests [3]. A range of mandatory control tests of active and passive safety systems and requirements in this area for diagnostic testers used in vehicle inspection stations are being developed [4, 5, 6].

2. Extending the scope of control tests of safety systems

The current regulations regarding periodic technical inspections include tests of electronically controlled safety systems in a very narrow range [1, 2]. The diagnostician uses only the information on the car instrument panel (check engine, ABS, ESP, air bag signal lamps). However, the control of mechatronic systems requires the use of diagnostic testers. This allows you to significantly extend the scope of diagnosis. It is proposed to directly use testers to read error codes and sensor values. Controlling actuators through the tester, with simultaneous recording of the entire system operation at the diagnostic stand, allows to detect failures that are not registered by the on-board diagnostic system.

The possibilities of modifying and expanding the scope of periodic tests of selected electronic safety systems (ECSS) are presented below: braking systems with ABS / ESP, brake assist (BAS), power steering (EPS), tire pressure monitoring system (TPMS), vehicle safety systems (SRS), headlights (automatic leveling, dynamic control functions). Next levels of control were proposed, indicating the scope of current research and their development.

2.1. Levels of diagnostic tests in the system of periodic technical inspection tests

In diagnosis of vehicle mechatronic systems, several levels can be distinguished – degrees, which allow to more and more accurately determine the state of the tested system.

Level I: Checking the status of signal lamps on the vehicle instrument panel

This level does not require the use of a diagnostic tester. It is currently used.

Level II: Identification of the system controller, reading error codes

It requires the use of a diagnostic tester and connection to the controller of the tested system. Currently, the OBD II tester is used in the field of engine diagnostics. It does not include safety systems.

The proposed scope of control:

- driver type (model) reading, verification with manufacturer's data,
- reading error codes

After developing specialized software with a set of data for SKP, it will be possible to check whether the tested system has a driver provided by the manufacturer.

Level III: Reading the data of the tested system

This level allows:

- reading of the sensors' indications under static conditions, or with a given dynamic forcing and recording of the results,
- control of the electrical efficiency of actuators through their activation by a signal from the tester

In order to speed up these checks, the tester should be programmed with a program dedicated to PTI station.

The implementation of level III is not necessary if the results of Level I and II controls are positive.

Level IV: Functional check of the system

This level includes checking the functioning of a given system by running it with a tester via the OBD port. This level of testing allows you to evaluate the operation of the system as a whole. The main purpose of its application is to detect disabilities that are not detected by on-board diagnostic systems and detection of manipulation of unauthorized persons, switching off safety systems or their signalling.

The current standards of communication of the diagnostic tester with the controllers and the range of possible tests are sufficient to implement the IV level. However, it is necessary to develop unified software so that the diagnostician has easier and uniform information access to controllers, to actuate actuators of individual systems and to read real values. A reference database is also required to evaluate the operation of the system being tested.

The development of a universal diagnostic tester and a method of obtaining data for the purposes of PTI station is a basic condition for extending diagnostics of the mechatronic systems as part of periodic technical tests. The second task is to develop a way of communicating of the tester with the diagnostic stand controller so that it is possible to simultaneously record the parameters measured with the tester and at the stand, eg brake system pressure and braking forces.

2.2. The scope of tests on selected safety systems

Below are proposals for the scope of control of mechatronic systems affecting the safety of car traffic.

Each system is subject to level 1 control, controller identification and error code reading (Level II). The implementation of Level III is not necessary if the results of Level I and II tests are positive. However, the implementation of the IV level depends on the possibility of integration of signals from the tester with the measurements at the PTI station.

Brake system check with ABS / ESP

Level I

Status of signaling devices on the instrument panel. This is the control currently being performed.

Level II

Driver identification, reading error codes. This range is possible with the current tester software.

Level III

Control of the operation of the STOP switch, hydraulic pressure sensor, accelerator position sensor, brake pedal position sensor (in EHB, SBC, EBS systems).

Reading the values of signals with a tester. Verification of results based on reference data.

The tester software should contain the data provided by the vehicle manufacturer.

Level IV

Functional tests on a roller stand:

- control of operation and indication of wheel speed sensors – reading results with a tester,
- measuring the braking forces of the front and rear axle wheels on the stand with the simultaneous measurement of the pressure in the brake's hydraulic system with the tester and transfer of pressure data to the roller station controller program,
- assessment of the braking performance, the inequalities of forces between the wheels of the tested axle and assessment the distribution of braking forces between the front and rear axles,
- control of the pump and valves of the ABS / ESP electrohydraulic modulator, actuation of the pump and valves with the tester, evaluation based on the measurement of the variation of braking forces,
- control of zeroing the steering angle sensor,

- control of the operation of yaw rate sensors ω_z and lateral acceleration a_y on the stand for checking the slack in the car suspension

Checking the braking system with ABS / ESP at level IV allows detection of the following failures which are not indicated by OBD on-board diagnostics system: incorrect or unstable vehicle wheel speed sensor readings, possibility of connecting electric or hydraulic cables by mistake, leaking or mechanical blocking of modulator valves, impediment or blockage of the brake fluid flow to the brake calipers, improper ABS pump operation, improper zeroing of the steering angle sensor, of angular velocity sensor and acceleration sensor, lack of reaction of these sensors to dynamic enforcement.

BAS – brake assist system

Levels I, II and III

Status of signaling device on the instrument panel, reading error codes.

Checking of the sensor depending on the design of the system:

- for the system with calculation of the brake pedal speed – test of the brake pedal displacement sensor,
- for the system with the calculation of the rate of pressure rise – test of the pressure sensor in the brake hydraulic system,
- for the system with time measurement between removing the leg from the accelerator pedal and the moment the pedal is pressed on the brake pedal – according to the instructions for the given vehicle.

Level IV

Roller position: control of the rate of increase of braking forces at sudden pressure on the brake pedal.

Electric power steering (EPS)

Level I

Status of signaling device on the instrument panel. This control is currently performed.

Level II

Driver identification, reading error codes.

Levels III and IV:

Control of the readings of the speed and torque sensors with the tester at the wheels set on the turntables:

- steering angle sensor: control of zeroing and display of the sensor when turning the steering wheel to the right and left by 90º and 360º,
- control of the torque sensor on the steering shaft and the auxiliary steering current: control of zeroing and change of signal when turning to the right and left – tester,
- control of wheel speed sensors – as for ABS / ESP

Note: sensor zeroing can be checked at the roller stand

Systems protecting the person in the vehicle (SRS)

The quantity and quality of these systems depends on the vehicle model, the year of production and the vehicle's individual equipment. Currently, mandatory equipment includes seat belts with pre-tensioners, air bags, gas curtains are very often used.

Levels I and II

Control of signaling devices.

Identification of controllers, reading of error codes, status control of signaling devices (on - off).

Level IV

No possibility of level IV check (system operation check)

Automatic braking and maintenance system

Levels I and II

Control of signaling devices on the instrument panel.

Driver identification, reading error codes.

Level IV

Stand tests:

- control of directional settings of sensors and cameras,
- control of distance sensor signals (radar, lidar),

Road test:

- brake activation test: linear braking against an elastic obstacle, not causing damage in the event of a collision, initial test speed determined by the manufacturer,
- lane maintenance road test

Level IV is carried out when testing vehicles after collisions and at the request of relevant services.

Vehicle lighting (headlamps) and driver assistant camera

Lights

Levels I and II

Visual inspection, state of signaling devices.

Driver identification, reading error codes,

Level III

Power supply control

Level IV

Stand for controlling the lighting settings:

- controlling the setting of low beam – according to the current regulations, taking into account the manufacturer's requirements as to the course of the light and shadow line, fig. 1,

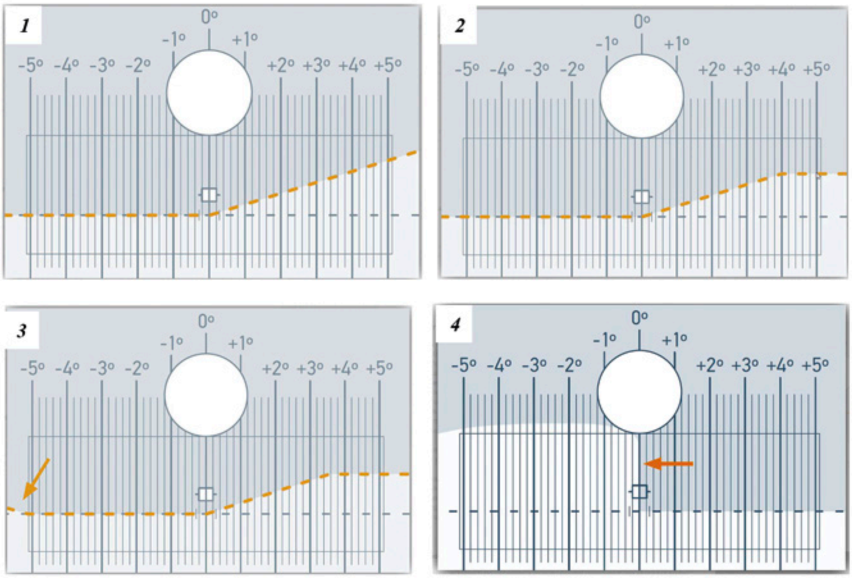

Fig. 1. Differences between the light and shadow boundary of the low beam: 1 – headlamps with halogen bulbs, angle of elevation of the light and shadow boundary 15º, 2 – reflector with discharge lamps, angle 12º (up to 75º) and limitation of heights, 3 – headlights with LED diodes, angle of elevation 12º (up to 75º), limitation of elevation of the shadow border on the left, 4 – limit of light and shadow of headlights in the car with the assistant of high beam [10, 11]

- high beam control – according to the applicable regulations, taking into account the requirements of the manufacturer.

Control of the automatic system: headlight leveling: control and possible adjustment of the zero position: mechanical adjustment with the use of the light setting device, or stepper motor control and write with a diagnostic tester in the controller's memory of the new zero values.

High-beam assistant: control of adjusting the light and brightness setting to the current lighting status of the road.

Control of the operation of the headlamps system when driving in a curve – use of turntables.

LED headlamps with the assistant of high beam and dynamic change of the lighting pattern of the roadway require the use of a screen and tester for their control and calibration [11]. The tester is switched on by a single diode (master), and the necessary correction is read on the position screen (Fig. 2), the value of which is entered via the tester into the lights controller.

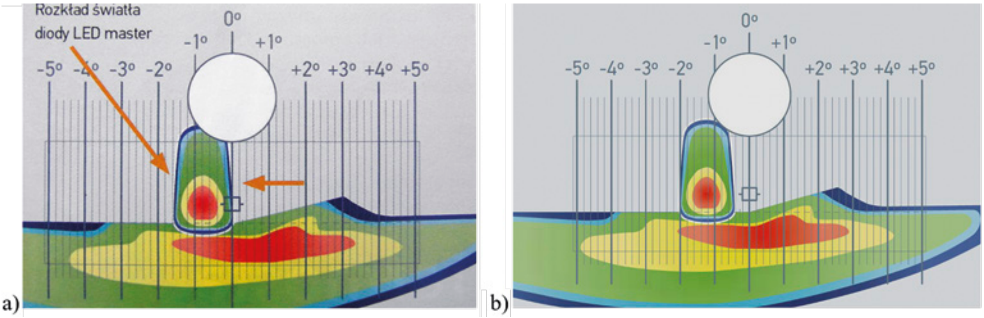

Fig. 2. Control of light distribution of the LED master in LED reflector Matrix. a) location of the field illuminated by the master diode – correct, b) incorrect [11]

Cameras for the control of the driving path

Level IV

Checking the setting and calibration of the camera requires the use of the stand with the control board and the system of laser markers to set the table in relation to the geometric axis of the car (fig. 3) and the diagnostic tester.

The control consists in comparing, by the program in the controller of the camera, the image of the position board as seen by the camera during the inspection, with the image stored in the memory of the camera controller and saving the new zero position.

Test of the camera setting and its calibration should be carried out after the suspension repairs, replacement of windows, and bodywork repairs that affect the suspension geometry. Due to the time-consuming nature of this inspections, its implementation during basic periodic research is debatable.

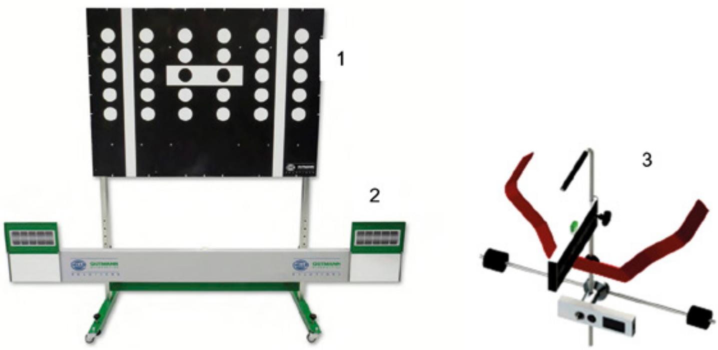

Fig. 3. The stand for tests of the setting and calibration of cameras for the control of the driving path. 1 – calibration board, 2 – screens for setting the board relative to the vehicle body, 3 – holder for fixing the laser pointer to the tire of the vehicle wheel [12]

Tire pressure monitoring system

The method of control depends on the measurement method: the pressure sensor, or on the principle of the analize of the rotational speed of the wheels.

Measurement of pressure sensors

Level I

The state of pressure reduction signaling devices on the instrument panel.

Level II

Driver identification, reading error codes.

Level III

Reading the pressure values with the tester; the pressure should be equal to the nominal value of ± 20%. Signaling of an abnormal condition at the pressure differing by 0.5 bar from the nominal value after about 10 min. from the occurrence of an abnormal condition.

Measurement based on the evaluation of the wheel speed difference

Level I

Checking the signaling devices on the instrument panel.

Level II

Identification of the controller, reading error codes, checking the status of the pressure drop signaling device.

Level IV

Roller stand: control of the wheels speed difference – tester reading.

Note: In order to obtain the proper measurement accuracy, it is advisable that the test stand enables the peripheral speed of the wheels about 10 km / h.

Suspension check

Level IV

Control of clearance in the suspension on the vibration stand.

Shock absorber check: forced vibration method, bench test, assessment of the EUSAMA coefficient and amplitude of resonance vibrations (currently performing), evaluation of the relative damping (Lehr) coefficient.

Road test: free damped vibration method. The acceleration of the vehicle body is recorded during the drive through the fixed beam, fig. 4. This is an additional test. The results of measurements from acceleration sensor are saved to the PTI diagnostic tester. This method of inspection is in the field of technical research developed by FSD – Central Agency for PTI in Germany [7, 8].

Fig 4. Investigating of the condition of shock absorbers using a body acceleration sensor. Vibration recording with a PTI tester [8]

3. Possibilities to extend the scope of the braking tests

The braking system with ABS / ESP is now a standard in the equipment of motor vehicles. So far, the periodic inspection of this system is very limited and provides for the control the state of the ABS / ESP signalig lamp, organoleptic control of the wheel speed sensors, control of electrical connections, control of completeness and state of the other external components of the system [1]. The individual electrical and electronic components of this system are protected by the on-board diagnostic system. However, the executive elements and operation of the whole of this system are not controlled.

Due to the long service life of cars, very often without replacing the brake fluid, with the deteriorating performance of calipers or brake cylinders, it seems necessary to check the dynamics of the system of valves, calipers and brake cylinders, because the quality of ABS / ESP depends on the mechanical efficiency of these elements as a whole. The optimal test is the road brake test. However, due to the difficulty of its implementation, a method of controlling the system on a roller stand was developed. It allows to evaluate the system response in the form of changes of braking forces to being forced by an electrical signal sent from the diagnostic tester to the ABS / ESP valve controller.

Because on a low-speed roller stand with a circumferential speed of rollers up to approx. 5 km / h, the ABS system does not start itself, it is necessary to force it to operate via a diagnostic tester.

An example of such a test is shown in Fig. 5. Scale A of the graph shows the course of the braking force after activation of inlet and outlet valve of the front left wheel and ABS pumps, part B for the right wheel valves, and part C the increase of braking force and blocking of the right wheel when the ESP valves and pump are working. The course of change of braking forces as well as the rate of increase and decrease of these forces is assessed.

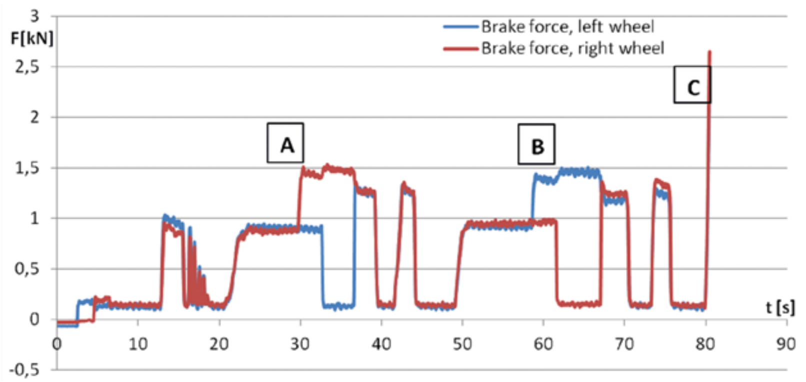

Fig. 5. Example of valve and ABS pump system control of the rear axle of a passenger car. F – braking force, t – measurement time. Description in the text.

The second extension of the tests includes clarifying the method of testing the braking effectiveness [9]. It consists in simultaneous measurement of braking forces and pressure in the braking hydraulic system and registration of this dependence, fig. 6. This is possible for cars with ESP system equipped with a pressure sensor. Execution of the braking force characteristics from pressure allows to precisely calculate the braking effectiveness coefficient and the distribution of braking forces between the front and rear axles. The values of the braking forces of the front and rear wheels for the same pressure values are used for calculations[2]. The second option is to calculate the force gradient as a function of pressure and verify with the car manufacturer's data [4].

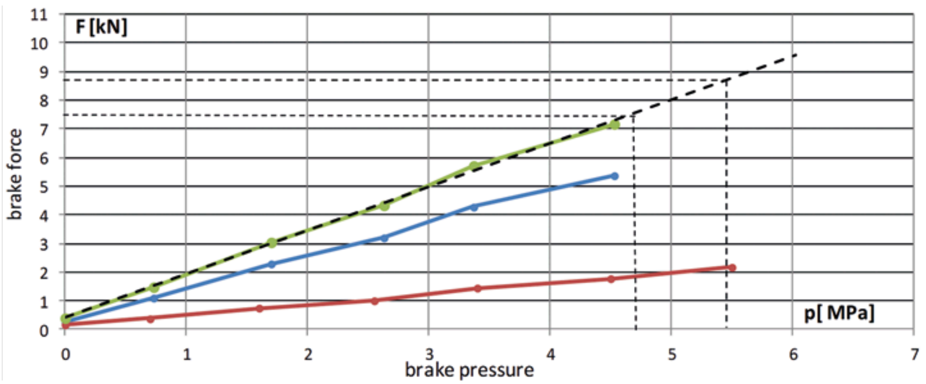

Fig. 6. Results of measurement of braking forces as a function of pressure in the passenger car's braking system. ——— front brakes, ——— rear brakes, ——— sum of forces, – – – regression function and values of forces and pressure necessary to achieve the required braking performance of 50% and 58% for the tested vehicle with a mass of dmc 1500 kg

2 In the brakes with ABS / ESP have been eliminated the traditional braking force equalizer

4. Diagnostic tester for testing in PTI stations, acquisition of diagnostic data, test time, costs

New control methods are based on supporting bench tests with a diagnostic tester. The optimal solution would be the tester as the individual diagnostic tool and software for selected test stands enabling the start of the tested mechatronic system. The individual tester is mobile, allowing to perform road tests. An example is a PTI-specific scan tool with an integrated acceleration sensor and the angle speed sensor (Fig. 7). It allows you to extend the methods of measuring the damping effect of shock absorbers on the road tests (Fig. 4), to check the braking performance by measuring the deceleration in road conditions (sensor in the tester equipment), and to test the operation of ESP sensors in road conditions. Integration of selected parts of the tester's program with the test bench software is necessary eg when examining the brakes and performing the braking forces characteristics as a function of the pressure in the hydraulic system, and significantly accelerates the testing of the ABS / ESP valves.

Fig. 7. Periodic Technical Inspection (PTI) tester for vehicle inspection stations [8].

The second key issue that determines the possibility of extending the scope of controls to the mechatronic systems of the vehicle is obtaining diagnostic data for research purposes in SKP, containing the reference values of the measured parameters. Based on the previous update periods of the universal tester diagnostic software, it can be assumed that the SKP tester software update should take place once a year. This will ensure the ability to inspect vehicles subject to periodic technical inspections.

The flow of diagnostic information from vehicle manufacturers to PTI stations should be determined by state regulations. For example, it could be: vehicle manufacturer – an institution responsible centrally for the supervision of vehicle inspection stations – voivodship office units responsible for issuing permits and supervising PTI – vehicle inspection stations – diagnosticians equipped with a tester and a computer program .

The tests have shown that the inspection of safety systems in the full range presented in point 2 extends the vehicle test time by more than 1.5 hours in relation to current procedures. This is an important factor increasing the cost of the test and the waiting time for the result and confirming the condition of the vehicle. This time can be shortened using a diagnostic tester with IT-related software for PTI stations. The second method of shortening the research time is the software of test stands, eg roller stations, so that the diagnostician, after starting the workstation, has an easier and uniform control procedure for the ABS / ESP systems.

Extending the scope of the diagnosis should take into account the already existing national regulations [1], in line with EU regulations [2]. However, test methods can be developed individually at the national level. Proposals for extending the scope of control tests may be verified, supplemented and introduced gradually. The priority is to equip the PTI diagnosticians with specialized testers and develop the system for providing the reference database for the control of safety systems.

5. Conclusions

1. The development of mechatronic active and passive safety systems requires the extension of the scope of periodic vehicle technical tests to the following systems: ABS / ESP, electronic power steering system EPS, seat belts with pre-tensioners, airbags, tire pressure monitoring systems TPMS, lighting control systems.
2. Extending the scope of periodic diagnostic tests in the field of security requires the development of software for periodic technical tests. This software can be created on the basis of programs used in universal testers. Program should contain requirements for the tested systems and criteria for their evaluation and should be periodically supplemented with new vehicle models.
3. The diagnostic tester software for the purposes of PTI station should enable the collection of test results with their evaluation and the printing of results in a form comprehensible to the user of the vehicle.
4. Modification of the method of determining the braking efficiency coefficient, which consists in determining the braking forces characteristic as a function of the pressure in the hydraulic system, requires the transmission of information from the controller of this system to the program of the roller stand for brake testing.
5. Facilitating and accelerating the control of the operation of valves and pump of ABS / ESP systems during periodic technical inspection of the vehicle requires the unification of programs for diagnosing these valves by software producers.

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