TEKA Kom. Mot. Energ. Roln. – OL PAN, 2007, 7, 266–276

DIAGNOSTIC EVALUATION OF ELECTRICAL EQUIPMENT IN AUTOMOTIVE VEHICLES

Stanisław Walusiak, Wiktor Pietrzyk

Department of Computer and Electrical Engineering
Lublin University of Technology
Nadbystrzycka Str. 38A, 20-618 Lublin, Poland, e-mail: swal@elektron.pol.lublin.pl

Summary. A number of electrical energy receivers and electronic systems installed in modern cars is considerable and that is why their reliable operation is of basic significance for correct performance of a vehicle. Fast detection of faults by the in-car diagnostics or at diagnostic stands makes an important question. Computer-based testing system ensures fast control of the tested element or system operation by measuring diagnostic parameters, comparing them to the required values and printing the results out. The paper presents results of diagnostic tests on electrical and electronic automotive equipment performed at selected diagnostic stations. Failure-rate analysis has been performed for circuits and elements of electronic systems installed in cars.

Key words: car diagnostics, electrical equipment, diagnostic tools, sensors, controller, ignition system, injection system

INTRODUCTION

Recently, a dynamic development of electronics and microelectronics has brought about modernization of automotive designs and an increased number of electronic systems installed in automotive vehicles. Modern electronic elements and systems are less expensive, smaller and more efficient than the previously used ones. Operation reliability of electrical equipment installed in cars and evaluation of a car technical condition have become an important issue for car users.

Permanent installation of sensors and measuring converters in a car is purposeful in the case when they are used to measure and control the car performance at test stands as well as in traction conditions with the application of board computers. Time of testing and diagnostic evaluation gets shorter. Computer-based testing systems ensure fast control of the tested element or system operation by measuring diagnostic parameters, comparing them to the required values and printing the results out.

A modern automobile contains up to a few dozens of measuring sensors. Developmental trends concerning reliability of automotive technology assume the application of highest-quality components and materials as well as of already used and verified production technologies. Consistent integration of the systems will develop in order to get rid of unreliable contacts.

Diagnostic instruments develop parallel to technological developments concerning electrical equipment for modern automotive vehicles. A diagnostic station has to deal with the whole variety of faults and car makes and for that reason it should be equipped with a wide range of diagnostic tools from simple multimeters to computer-supported automotive diagnoscopes. Presently, adequate software and vehicle databases, that replace service cards, are as important as tools and instruments. Computer-based diagnostic instruments use them to unmistakably find a fault. Such an intelligent combination of control system data and the Service Information System (SIS) data makes it possible to successfully diagnose a fault.

DIAGNOSTIC TESTS

Algorithms of diagnostic procedures applied at fault detection include:

- visual evaluation,
- passive parameter testing,
- input/output voltage check
- observation of signal waveforms.

At franchised service stations procedures were elaborated for car technicians to make their work more efficient. Fig. 1 presents an example procedure algorithm of fixing malfunction of the air/fuel ratio control system.

Because of a great variety car makes and car designs of varied electrical equipment carmaker companies elaborated „Information Service Cards" of the produced vehicles for diagnostic stations.

Some of the franchised service stations use diagnostic apparatus meant solely for the given car make as e.g. a diagnostic tool Tech2 made by the Vetronix company is designed for Opel vehicle diagnostics. It is built based on a microprocessor system with a Motorola MC68332 controller of replaceable storage unit. There is a socket at the bottom of the tester for a cable to connect it to the tested car. Extension cord is finished with a 19-pin connector for various replaceable terminals to be used depending on the kind of a diagnostic socket in a given car. In the year 2001 when a communication bus CAN was introduced to the Vectra C model design a problem of the tester communication via the bus appeared. It can be solved by an additional interface introduced between the tester and a diagnostic connector. The module is called CANdi and can be in-series connected to the diagnostic cable between the OBDII terminal and a socket at the cable end. The CANdi is used at the diagnostics of GM and Saab models.

When the diagnostic tester is connected to a diagnostic socket in a car, it gets powered and the communication is set up, then a welcome screen shows up followed by a master menu (Fig. 2) with five options to select

There are various trouble codes depending on a car make and an engine type. Only in the EOBD system they have been unified. Table 1 presents example trouble codes that occur in vehicles and concern their electrical equipment. Fig. 3 shows trouble-code printouts obtained at diagnosing an Opel Corsa C 2004 -Z10XE.

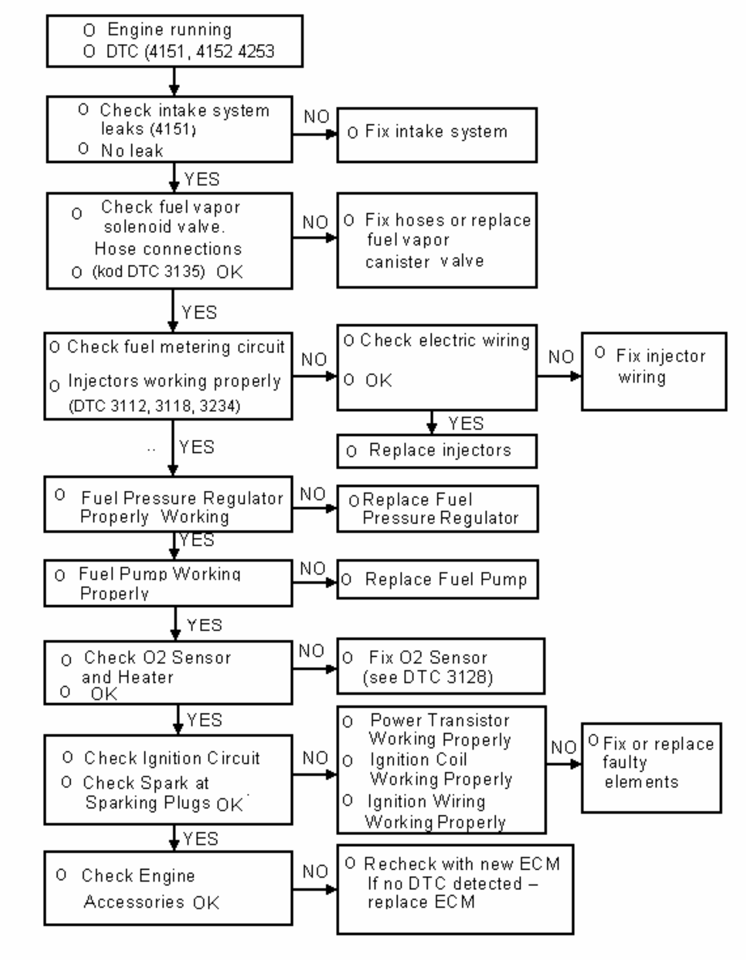

Fig. 1. Algorithm of fixing malfunction of the air/fuel ratio

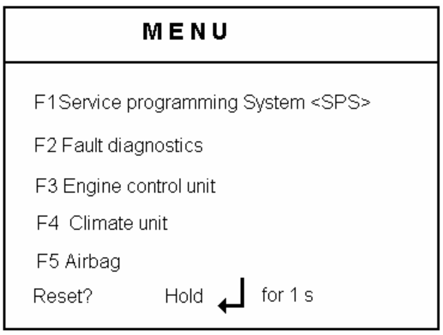

Fig. 2. Master menu of the Tech 2 tester

Table 1. Example trouble codes of the OBD II system

Trouble code	Trouble code description	Trouble code	Trouble code description
B0300	„Cooling Fan 1 Circuit Malfunction”	B0558	„Brake Indicator - High Input”
B0501	„Right Direction Indicator Range/Performance	B0850	„Battery Circuit - Malfunction”
B0516	„Speed Meter Circuit Range/Performance „	C0268	„Pump Motor Circuit Open/Shorted“
B0525	„Temperature Indicator Circuit - Malfunction”	P0481	„Cooling Fan 2 Control Circuit Malfunction”
B0532	„Fuel Level Indicator – Low Input „	P0503	„Vehicle Speed Sensor – Intermittent/Erratic/High”

At FIAT service stations a diagnostic tool called „Examiner” is used (Fig. 4). Starting from January 2005 the tester has been equipped with the „Smart” software, whose storage volume has been extended to include all kind of faults that occurred in Fiat cars since the date when the previous version of the software was implemented. Owing to the stored data the Examiner provides a possibility of fast finding solutions to „difficult” and non-standard faults. It automatically detects the fault and suggests the repair procedure (Fig. 5) and there is no need to organize specialized trainings for all the service staff.

Service stations also use diagnoscopes produced by Bosch and Gutmann. A Mega-macs 55 diagnostic scanner made by Gutmann is an electronic multi-purpose diagnoscope that provides the following functions: reading and clearing of trouble codes, the OBD system inspection, measurement of the real-time engine operation parameters via the diagnostic socket, testing of subsystem performance, clearing of oil and service survey records, basic regulation tasks, and engine diagnosis.

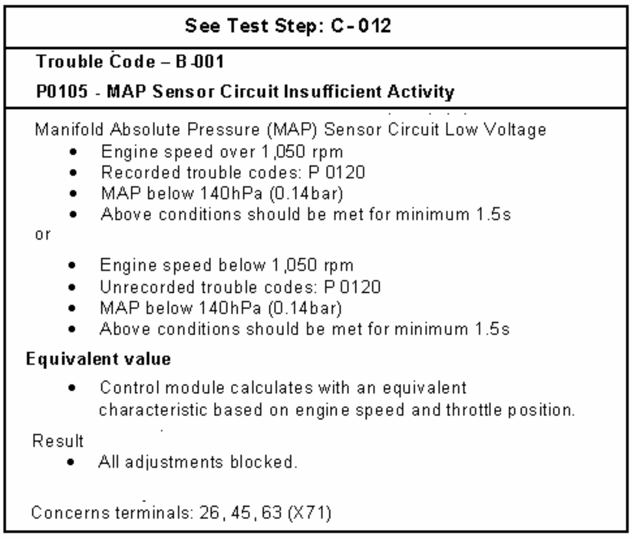

Fig. 3. Trouble codes for Opel Corsa C 2004 r.-Z10XE read on the Tech 2 tester

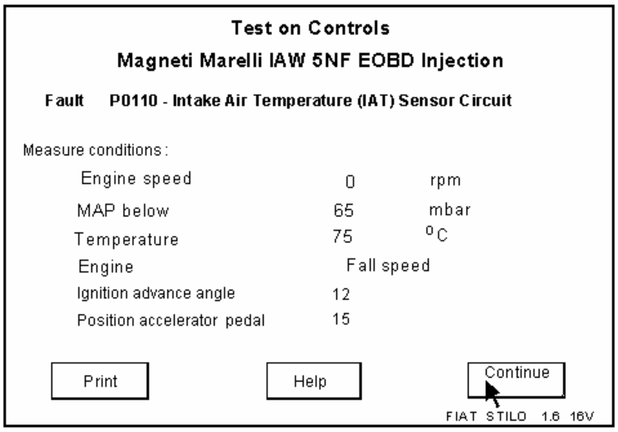

Fig. 4. Screen of the „Examiner" tester with a fault description and parameters of its occurrence

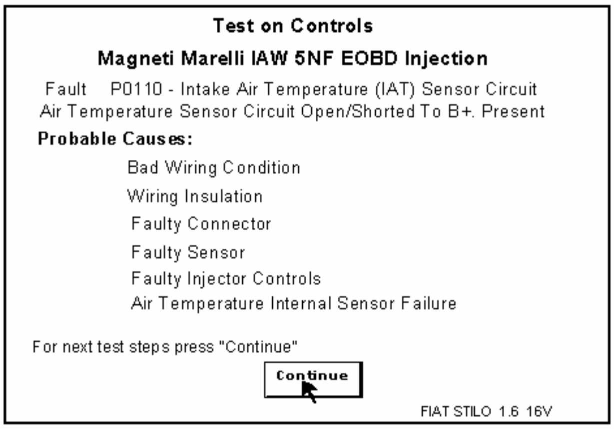

Fig. 5. Probable reasons for the occurrence of a fault detected by the „Examiner"

KTS 550 scanner made by Bosch (Fig. 6) includes similar functions as the Megamacs55 except for an engine diagnoscope and CAN readout (the latest version KTS 650 includes the CAN readout function).

Several dozen of cars underwent diagnostic testing at selected service stations. The stations deal with all kinds of mechanical repairs and fixing of electrical and electronic systems Table 2 presents example information acquired at the diagnostic testing.

The tested cars were classified into 4 age categories (Fig. 7). The greatest number of faults – 39 (44.83 %) were observed within the 5–10 year range and the smallest - 3 cases (3.45 %) for vehicles up to 2 years old. Detection of the greatest fault number in cars of the 5–10 year group follows from the fact that a lot of such cars is presently in use. Cars of over 10 years exhibited fewer faults – 32 (36.78%) because their electronic systems are less complex.

Bosch Service "SAS" Poland

OPEL SIMTEC 56.5 Controllers Diagnosed. Trouble Storage

P1690 Malfunction Indicator Lamp (MIL) Control Circuit Malfunction

P0130 O2 Sensor Malfunction (Bank 1, Sensor 1)

P1230 Main Relay Circuit Malfunction

P0335 Crankshaft Position Sensor A Circuit Malfunction

Trouble Number – 4

Fig. 6. Printout of the KTS550 diagnostic tool

Table 2. Example diagnostic information on a tested vehicle

No.	Car make	Engine code	Description of a trouble	Identified malfunction and the fixing action	The trouble diagnosis method
1	Renault Megane Scenic 2,0 B, '00 82 000 km	F4R	Startup problems at hot engine	Defective crankshaft position sensor. Sensor replacement	Trouble code readout by a „Clip" diagnoscope
2	Fiat Doblo 1,2B, '01 69 000 km	223A5.00	Anomalies within the whole electrical system	Faulty ground connection Connection replacement	Trouble code readout by a Gutmann diagnoscope Analysis of the electrical system
3	Audi S3, 1,8T, '01 120 000 km	APY	One cylinder does not work	Defective ignition coil. Coil replacement	Trouble code readout by a Gutmann diagnoscope. Ignition system check by an oscilloscope
4	Volkswagen New Beatle 2,0B, '01 63 000 km	AQY	Stumbling operation of the engine, Misfire indications	Defective oxygen sensor. Sensor replacement	Trouble code readout by a Gutmann .diagnoscope
5	Seat Leon 1,9TDI, '02 76 000 km	AHF	No power, High smoke	Leak in the intake system at the intercooler-turbine joint. Replacement of the connecting pipe	Trouble code readout by a KTS 500 scanner

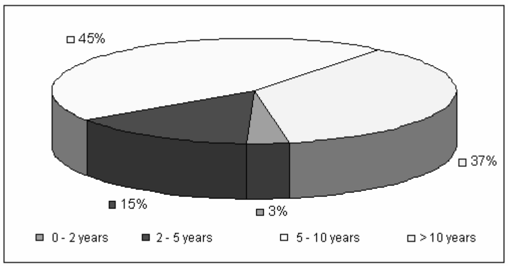

Fig. 7. Failure rates within car age groups

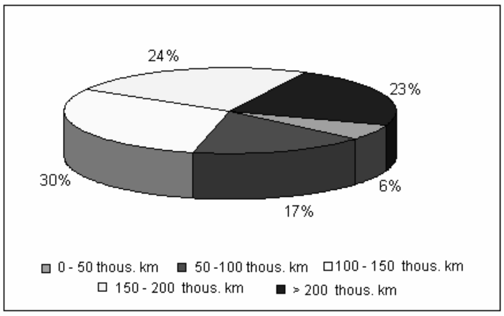

Fig. 8. Failure rate within the car mileage groups

The cars were also classified into 5 groups according to their mileage (Fig. 8): up to 50 000 km, from 50 000 to 100 000 km, from 100 000 to 150 000 km, from 150 000 to 200 000 km and over 200 000 km. The greatest failure rate was observed in cars of over 100 000 km mileage (ca 77%) and the smallest – in the group of up to 50 000 km, which follows from the fact that they are comparatively new, usually short after the warranty period extinction.

Electronic systems were classified into 6 groups: ignition system, ABS, SRS, injection system, A/C and other systems and faults (e.g. mechanical defects that influence electronic systems). Table 3 presents fault numbers within the mentioned groups and their percent rate against the total of recorded faults.

Table 3. Fault rate within electronic system groups

Electronic system	Fault number	Fault percentage
Ignition system	28	31.46
Injection system	32	35.96
ABS	9	10.11
SRS	3	3.37
A/C	1	1.12
Other system and faults	16	17.98

As can be seen in the table within the total fault number of 89 the biggest number of faults (32–35.96%) concerns the fuel injection system. The next-numerous group comprising 21 fault cases (31.46%) concerns the ignition system. The smallest number of faults was observed in the A/C control system and in the air-bag SRS system.

Ignition system problems were divided into 9 groups (Table 4) and the injection system faults – into 16 groups (Table 5) according to the defected elements.

Table 4. Ignition system faults

Fault	Quantity	%
Shaft position sensor	3	10.71
Ground connection	2	7.14
Ignition coil	9	32.14
Controller	2	7.14
Ignition module	6	21.43
Hall effect sensor	2	7.14
Electrical system	2	7.14
Tachometer sensor	1	3.57
Sparking plug	1	3.57

Based on an analysis of all the recorded faults 32 groups can be distinguished depending on the fault kind.

Table 5. Injection system faults

Fault	Quantity	%
Crankshaft position sensor	3	9.38
Ground connection	1	3.13
Controller	2	6.25
Throttle potentiometer	1	3.13
LPG controls	1	3.13
Oxygen sensor	4	12.50
Leaks or damages of vacuum pipes	6	18.75
Gas pedal sensor	1	3.13
Improper fuel usage	1	3.13
Injector	2	6.25
Fuel metering controller	2	6.25
Cecondary air valve	1	3.13
Stepper motor	2	6.25
Fuel pump	2	6.25
Exhaust gas recirculation valve	1	3.13
Air-flow meter	2	6.25

Fig. 9 presents quantitative fault distribution in ignition systems depending on the car production year.

The biggest number of repairs concerns cars of the age of over 8 years (Fig. 9), which is related to the fact that a great number of imported second-hand cars of high mileage is presently in use. Fig. 10 shows that car mileage effect on the wear of engine elements is considerable and the most common damages concern pipes and wires, frictional elements of potentiometers and dirty contacts.

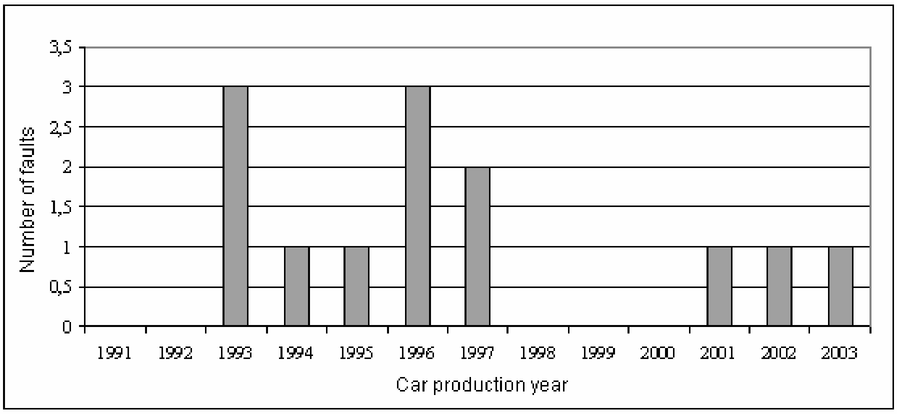

Fig. 9. Ignition system faults

Many faults result from incorrect operating of a vehicle e.g. a part of the ignition coil defects could be avoided if sparking plugs and high-voltage wiring were replaced in time.

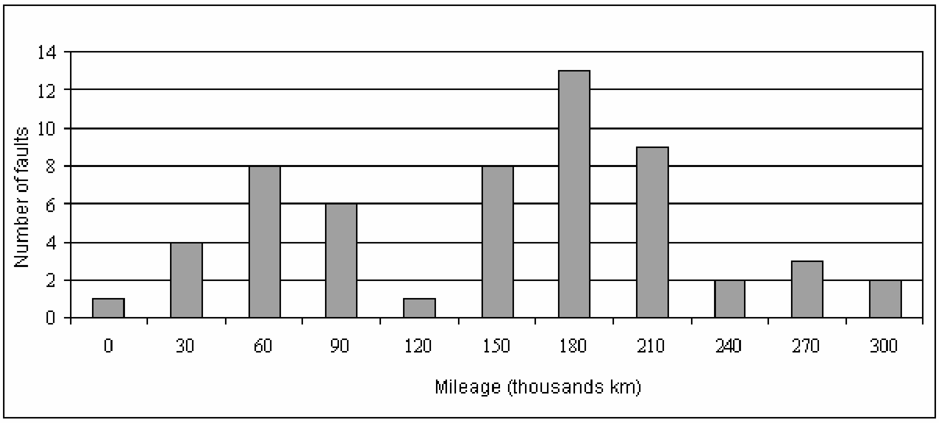

Fig. 10. Fault number vs. mileage

Fig. 11 presents failure rate analysis for electrical and electronic system elements of the tested cars.

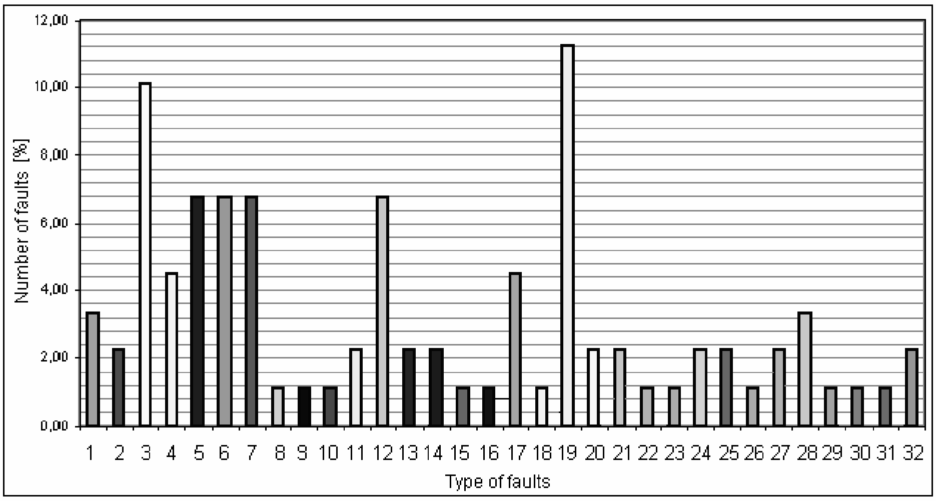

Fig. 11. Failure rate of electronic system elements: 1 – crankshaft position sensor, 2 – ground connection, 3 – ignition coil, 4 – oxygen sensor, 5 – pipe leaks, 6 – controller, 7 – defective parts to be repaired, 8 – gas pedal sensor, 9 – wrong fuel, 10 – glow plugs, 11 – injector, 12 – ignition module, 13 – fuel pressure regulator , 14 – hall effect sensor, 15 – throttle potentiometer, 16 – LPG controls, 17 – faulty repair , 18 – alternator, 19 electrical installation, 20 – fuel metering controller, 21 – relay, 22 – secondary air valve, 23 – tachometer sensor, 24 – stepper motor, 25 – exhaust gas recirculation valve, 26 – fuel pump, 27 – ABS sensor, 28 – air-flow meter, 29 – faults at no voltage, 30 – sparking plugs, 31 – fuse, 32 – LPG converter

CONCLUSIONS

1. Contemporary diagnostics of electric and electronic car systems has considerably reduced the range of routine car inspections as compared to mechanical systems. At the same time, the significance of information systems and specialized measurement-control tools has increased.
2. Presently used diagnostic methods usually consist in searching for electronic system faults with the use of a code reader or a diagnoscope equipped with an oscilloscope and a multimeter. It is so, because there is no universal trouble-code reader to be applied to all cars and self-diagnosis systems are not perfect.
3. The performed tests on selected electronic systems indicate that injection and ignition systems are the most damageable. Faults concerning those systems make over 60% of all the recorded failures of electric and electronic automotive systems.
4. The most often recorded injection system problems concern leaks and damages of vacuum pipes (ca 18%) and oxygen sensor failures (ca 12.5%). As the injection system operation essentially influences noxious exhaust gas emissions developmental research aims at enhancing its self-diagnosis system by elaborating better diagnostic tests and the OBD system..
5. Developmental trends for ignition systems involve integration of ignition circuits into one ignition panel located on plugs.

REFERENCES

Bocheński C. 2000: Badania kontrolne samochodów. WKiŁ, Warszawa.
Stróżek M. 2006: Diagnostyka elektronicznych układów pojazdów samochodowych. Politechnika Lubelska. Praca dyplomowa. Lublin.
Topyła J. 2006: Diagnostyka czujników w pojazdach samochodowych. Politechnika Lubelska. Praca dyplomowa. Lublin.
Trzeciak K. 2000: Diagnostyka samochodów osobowych. WKiŁ, Warszawa.
Walczak D. 1999: Analiza uszkodzeń układów zapłonowych w samochodach. Politechnika Lubelska. Praca dyplomowa. Lublin.
Walusiak S., Dziubiński M. 1999: Analiza uszkodzeń wyposażenia elektrycznego pojazdów samochodowych. TEKA Kom. Nauk.-Probl. Mot. PAN o/Kraków, z. 11.
Wiśniewski P. 2006: Diagnostyka układów elektronicznych w pojazdach samochodowych. Politechnika Lubelska. Praca dyplomowa. Lublin.