WORKBOOK

DIAGNOSTICS AND REPAIR OF VEHICLE DRIVELINE SYSTEM COMPONENTS

LUBLIN 2014

Author: Zbigniew Kiernicki

Desktop publishing: Zbigniew Kiernicki
Technical editor: Zbigniew Kiernicki
Figures: Zbigniew Kiernicki
Cover and graphic design; Zbigniew Kiernicki

All rights reserved.
No part of this publication may be scanned, photocopied, copied or distributed in any form, electronic, mechanical, photocopying, recording or otherwise, including the placing or distributing in digital form on the Internet or in local area networks, without the prior written permission of the copyright owner.

Publikacja współfinansowana ze środków Unii Europejskiej w ramach Europejskiego Funduszu Społecznego w ramach projektu
Inżynier z gwarancją jakości – dostosowanie oferty Politechniki Lubelskiej do wymagań europejskiego rynku pracy

© Copyright by

Zbigniew Kiernicki, Lublin University of Technology

Lublin 2014

First edition

TABLE OF CONTENTS

LIST OF MAJOR SIGNS AND ABBREVIATIONS

DIN – (Deutsche Industrie Norm) German Institute of Standards
EOBD – European On-Board Diagnostics
ε – angular acceleration (rad/s^2)
I – mass moment of inertia (kgm^2)
MIL – Malfunction Indicator Light
n – rotational speed (rpm)
N – power (kW)
OBD – On-Board Diagnostics
OHS – Occupational Health & Safety
RPM – Revolution Per Minute
T – torque (Nm)
t – time as a variable (s) or (min)
ω – angular velocity (rad/s)
VIN – Vehicle Identification Number

FROM THE AUTHOR

Dear students

This text has been written by this author for additional lessons during the engineers studies. It should help you in practical executing the exercises.

Welcome to study in the course Diagnostics and Repair of Vehicle Driveline System Components. The main objective in this course is to study some basic theoretical and practical aspects of testing driveline system of vehicles, recognize inefficiencies and repairing their components.

1. INTRODUCTION

During the course, “Diagnostics and repair of vehicle driveline system components”, the students will become familiar with the following scope of material:

- Diagnostics of motor vehicle in the systematic approach. Methods and methodology of a vehicle diagnostic test. Methods and methodology of repairing a motor vehicle.
- General diagnostics of a vehicle driveline system.
- Chassis dynamometers – test potentials and measurement procedures.
- Vehicle data buses.
- Diagnostics and repair of a vehicle main clutch.
- Diagnostics and repair of transmissions.
- Self-diagnostics of automatic transmissions.
- Diagnostics and repair of drive shafts and half shafts.
- Diagnostics and repair of a vehicle drive axle.

Practical exercises will start as Introductory class. Overview of the labclass structure will be presented. OHS training course will be first realized.

2. DIAGNOSING ENGINE CONDITION VIA DIAGNOSTIC INTERFACE. INTERPRETING FAULT CODES. REPAIRING DEFECTS DETECTED IN ENGINE SYSTEMS

2.1. Objectives of the exercise

1. Getting familiar with the use of on-board diagnostics.
2. Getting familiar with the functioning of a Malfunction Indicator Light (MIL).
3. Indicating the elements of vehicle equipment meeting the requirements of OBD and OBD II systems.
4. Distinguishing the types and explaining the location of sensors used in diagnostic systems for engines with spark or compression ignition.
5. Explaining the algorithms of fault detecting and reporting by the MIL indicator in EOBD system.
6. Getting familiar with the operating modes of a diagnostic tester.
7. Getting familiar with the techniques of reading and analyzing data via diagnostic interface.

In currently manufactured vehicles, on-board diagnostic systems are widely used. All measurement and repair work should be started with becoming familiar with the work history of a vehicle components, recorded in the memory of an on-board diagnostic system. Knowing the registered defects makes the diagnosis easier and accelerates the processes of technical condition evaluation and repair.

Car engine diagnosing starts with checking for potential faults recorded in the system, verifying if they exist, and the potential repair of damaged sensors or engine control system elements. Having excluded electric faults, tests showing the condition of the engine’s mechanics are conducted. The basic examinations are: measurement of the compression pressure and the fuel pressure in the petrol system as well as the oil pressure in the lubrication system. The obtained pieces of information guide the repairing process.

2.2. Test stand

The test stand includes:

a) Diagnostic tester, e.g. Bosch KTS-540, Axone Direct,
b) Motor vehicle with an OBD slot,
c) Compression pressure tester,
d) Fuel pressure tester and lubrication system pressure tester;

2.3. Structure of the exercise

The structure of the exercise is as following.

1. Identifying the motor vehicle through the identification plate and VIN.
2. Locating EOBD slot in vehicles of different manufacturers.
3. Searching for sensors of EOBD system and locating them in the vehicle by using the manual.
4. Diagnostics of an OBD II interface.
5. Reading fault codes by using a tester and explaining their meaning.
6. Repairing defects diagnosed by means of diagnostic interfaces.
7. Measuring the compression pressure.
8. Measuring the fuel pressure and the pressure in the lubrication system.

2.4. The report

The report should contain the following elements:

1. Subject of the exercise,
2. Objectives of the exercise,
3. Object of testing,
4. Steps taken during tests,
5. Results of measurements and calculations,
6. Conclusions.

3. CHASSIS DYNAMOMETER. COMPLEX DIAGNOSTICS OF DRIVELINE SYSTEM PERFORMANCE.

3.1. Objectives of the exercise

1. Getting familiar with chassis dynamometer vehicle tests.
2. Getting familiar with the criteria for assessing vehicles' technical condition.
3. Acquiring competence in carrying out vehicle handling tests.
4. Acquiring competence in operating a chassis dynamometer.

Inertial measurement (measurement method feasible on an 'inertia' or 'load' dynamometer).

The inertial measurement consists in setting a vehicle in motion on a dynamometer, and then, after decoupling, on waiting until the car stops without using breaks. Engine load is comprised of: mass of the rolls, tire rolling resistance and driveline system resistance. The measuring takes about 10 to 30 seconds of accelerating with the full load and a few minutes of rolling loose until the full stop. Power and torque are measured as functions of the vehicle's acceleration on the rolls of the dynamometer (power, torque on the wheels) and the vehicle's slowing down (power and torque loss moment). Their sum forms an outcome showing the power and the torque of the vehicle's engine.

Load measurement (at constant engine speed)

A measurement conducted with the use of this method consists in balancing a vehicle's momentum by breaking and measuring the torque with a strain gauge. Engine load is then comprised of: eddy-current break (fluctuating load) and, as on 'inertia' dynamometer, mass of the rolls as well as tire rolling resistance and driveline system resistance. The measuring takes about 10 seconds of accelerating with the full load (in order to stabilize engine speed and read the results) for each rotation point.

Power and torque are measured as a function of the fluctuating load taken on the breaks by eddy-current break, having taken into consideration the power and the torque loss moment measured earlier in the inertial mode.

Chart 1. The criteria for assessing a vehicle's technical condition on the basis of the power measured.

Amount of power measured on the wheels	**Evaluation of engine and driveline system**

(percentage of engine power according to DIN)	performance
80±5	efficient —vehicle’s mileage is less than 50%
above75	efficient —vehicle’s mileage is more than 50%
below 75	inefficient

3.2. Test stand

The test stand includes:

a) Diagnostic tester, e.g. Bosch KTS-540, Axone Direct,

b) Motor vehicle with an OBD slot,

c) Chassis dynamometer.

3.3. Structure of the exercise

The structure of the exercise is as following.

1. Identifying the motor vehicle through the identification plate and VIN.
2. Reading fault codes by using a tester and explaining their meaning.
3. Placing the vehicle on a chassis dynamometer.
4. Carrying out appropriate vehicle tests.
5. Removing the vehicle from the dynamometer.

3.4. The report

The report should contain the following elements:

1. Subject of the exercise,
2. Objectives of the exercise,
3. Object of testing,
4. Steps taken during tests,
5. Results of measurements and calculations,
6. Conclusions.

4. Diagnosing manual and automatic transmissions. Interpreting fault codes. Repairing defects detected in the transmission

4.1. Objectives of the exercise

1. Getting familiar with the principles of transmission diagnostics.
2. Acquiring competence in diagnosing a manual transmission.
3. Acquiring competence in diagnosing an automatic transmission.

Diagnosing a manual transmission consists in observing its work without and with a load. The ease of switching gears, leaks, amount of noise when working on each speed, temperature of the housing, values of axial and angular clearance are observed. These checks are done during a test drive, when a transmission is installed in a vehicle. These checks could be also done when a transmission is installed on a test stand. In case of a transmission being equipped with control system sensors, a preliminary check of fault codes with the use a diagnostic tester is carried out.

A diagnostic measurement of circumferential backlash in the driveline system consists in measuring an angle or a curve made by the driven pulley within the backlash margin. The result obtained by using this method is a sum of all clearances, starting from the driven pulley and ending with the engine's flywheel.

The limit value of the total circumferential backlash for a transmission: L-SBgr = 5-15°.

The criteria for assessing technical condition of a transmission and the transfer case are as follows:

- all gears should be switchable;
- self-switching off of a gear during a ride is unacceptable;
- bumps and excessive noise in the transmission during a ride are unacceptable;
- no exception is allowed for:
- oil leaks,
- cracks in the housing,
- overheating of the transmission.

Automatic transmission diagnosing, as a part of on-board diagnostics, is performed by means of a scan tool-type factor or manufacturer's diagnostic tool. It is feasible to read fault codes (universal codes of P07XX group), measure parameters, test actuators and an initialization procedure (e.g. downloading accelerator pedal sensor or resetting oil consumption gauge).

Reading memory fault codes of a transmission controller is done by diagnostic readers that enable reading the fault codes saved in the controller's memory as well as reading current parameters, whose range depends on a particular gearbox controller. In order to carry out an examination of the controller memory, it is necessary to plug a diagnostic tester in, and then follow the manual of the tester.

The following procedures are carried out:

1. Establishing a connection with the controller.
2. Reading the fault codes saved in the controller's memory.
3. Checking current parameters and recording them.
4. Testing actuators.

Detecting defects of an automatic transmission is based on the results of the performed check controls – diagnostic tests. Exemplary checks done during a diagnostic test of an automatic transmission:

Engine de-throttling test.

Test performed in order to check the functioning of the engine and the gearbox generally.

During the test we measure a value of the motor speed with the transmission switched to a D or R working range.

Transmission control system fluid pressure test.

During the test we measure the pressure value proportional to speed, that is, to engine speed (RPM), and to the pressure value of the control supply. Through this test we check the functioning of individual valves of the hydraulic system.

Gears switching time test.

Firstly, we measure the time that has elapsed from the moment of switching gearbox selector from a N to D position to the moment of noticing a strong bump caused by switching gears. This test is performed to detect outwearing of such elements as: friction lining and breaks in a planetary gear set. It is also used to examine the functioning accuracy of hydraulic controls.

Gears switching test.

We carry out the test in a test site, controlling the range of speed at which gears are being switched (to higher ones and to lower ones). We make assessment of preliminary vibrations, bumps, operation noises of the transmission working at a different speed range under load, clutch and break slippage.

Plugging a tester into the system so as to diagnose it. Reading codes and identifying causes of defects by using the manual as well as removing fault sources and deleting the codes, then retesting to check whether the fault codes occur again.

Chart 2. Faults in the functioning of the automatic transmission

Symptoms of malfunction	**Reasons**	**Fault removing methods**
Oil pressure too low	▪ Oil level too low ▪ Clogged strainer/filter ▪ Damaged oil pump ▪ Damaged pressure regulator ▪ A leak in oil circulation	• Adjust • Clean or replace • Replace • Replace • Seal
Oil pressure too high	▪ Damaged pressure regulator	• Change
Faults in the functioning of the gearbox, e.g. gear switching is faulty or too difficult, lack of power	▪ Oil level too low or too high ▪ Clogged oil strainer/filter ▪ Damaged Oil pump ▪ Damaged pressure regulator	• Adjust • Clean or replace • Replace

flow in all positions of the transmission lever	▪ Damaged, badly adjusted or malfunctioning (due to other reasons) parts of the hydraulic/electronic control system, e.g. yokes getting frozen ▪ Damaged brake bands starter or damaged multi-plate brake	• Replace • Badly adjusted – correct, replace damaged parts • Replace
Lack of power activation in individual gears	▪ Damaged related elements (brake band, multi-plate brake, overrunning clutch) ▪ Damaged hydraulic/electronic control system, e.g. valve seizing	• Replace damaged parts • Replace damaged parts
Abnormal switching point, transmission lever movements too long	▪ Damaged, badly adjusted or malfunctioning (due to other reasons) parts of the hydraulic/electronic control system, e.g.valves seizing ▪ Wasted friction lining of brake bands/brake plates, brake bands too loose ▪ Oil level too low or too high ▪ Damaged oil pump/pressure regulator, incorrect oil level	• Correct bad adjustments, replace damaged parts • Replace wasted parts, adjust brake bands • Adjust • Replace damaged parts
Power transferred with a delay in individual or all gears, slow acceleration and low maximum speed	▪ Wasted friction lining of brakes and clutches ▪ Brake bands too loose ▪ Damaged oil pump/pressure regulator, oil level too low ▪ Oil level too low ▪ Clogged oil strainer/filter ▪ Wasted fix torque converter	• Replace wasted parts • Adjust the band • Replace outworn parts • Adjust • Clean or replace • Replace
The gearbox switches to a lower gear when the speed is too high	▪ Damaged pressure regulator	• Replace
Forced gear reduction valve isn't working or is malfunctioning	▪ The valve is seizing or is damaged ▪ Badly adjusted or damaged valve ties/cable	• Eliminate the seizing or replace the valve • Adjust, replace damaged parts

4.2. Test stand

The test stand includes:

a) Diagnostic tester, e.g. Bosch KTS-540, Axone Direct,
b) Motor vehicle with an OBD slot,
c) Automatic transmission test stand,
d) Manual transmission test stand.

4.3. Structure of the exercise

The structure of the exercise is as following.

1. Identifying the motor vehicle through the identification plate and VIN.
2. Carrying out tests of a manual transmission in the test stand for manual transmissions.
3. Carrying out the following tests of an automatic transmission:

1. Leakage checking and measuring oil level.
2. Visual control of joints and wires.
3. Reading transmission controller's memory.
4. Saved and unsaved fault codes.
5. a) No codes – conducting a test and localizing defects in mechanical, hydraulic and electronic units.
   b) Codes saved.
4. Carrying out tests of an automatic transmission installed in a vehicle or in the test stand for automatic transmissions.

4.4. The report

The report should contain the following elements:

1. Subject of the exercise,
2. Objectives of the exercise,
3. Object of testing,
4. Steps taken during tests,
5. Results of measurements and calculations,
6. Conclusions.

5. DIAGNOSING TECHNICAL CONDITION OF THE DRIVE AXLE AND THE DRIVE SHAFT. SYMPTOMS OF WEAR AND THE CAUSES OF DAMAGE. MEASURING THE TOTAL BACKLASH IN THE DRIVELINE SYSTEM

5.1. Objectives of the exercise

1. Getting familiar with the principles of diagnosing the drive axle and drive shaft.
2. Acquiring competence in diagnosing the drive shaft.
3. Acquiring competence in diagnosing the drive axle.

Technical condition of the driveline system can be assessed through the total circumferential backlash. The total circumferential backlash of the kinematic chain, namely the driveline system, depends on the clearance value of each connection. Thus, knowing its value, one can make a deduction on the clearance scale and the wear of driveline system components.

A diagnostic measurement of circumferential backlash in the driveline system consists in measuring an angle or an arc defined by the driven road wheel within the backlash margin. The result obtained by using this method is a sum of all clearances, starting from the driven road wheel and ending with engine flywheel.

The limit values of the total circumferential backlash:

- L-WNgr = 5-10° — for the drive shaft;
- L-MNgr = 50-60° — for the drive axle (the main gearbox with the differential).

Upon reaching these values, further car usage is unacceptable because it is in unfit condition.

The criteria for evaluating technical condition of the drive shaft are as follows:

- universal joints ought to be properly aligned;
- no exception is allowed for:
- shaft runout,
- loosening of the securing screws,
- joint clearances larger than allowed by manufacturer,
- multi-splined connections clearances larger than allowed by manufacturer.

The criteria for evaluating technical condition of the drive axle are as follows:

- horizontal straightness to the longitudinal axis of the car ought to be preserved;

- the total backlash in the drive mechanisms of the rear axle, measured on the wheel rim circumference, ought not to larger than 30...60 mm (1,18…2,36 in);
- axial clearance of the gearbox input shaft cannot be larger than 0,05...0,10 mm (0,002…0,004 in);
- no exception is allowed for:
- oil leaks,
- cracks in the housing,
- loud functioning.

5.2. Test stand

The test stand includes:

a) Diagnostic tester, e.g. Bosch KTS-540,
b) Motor vehicle with an OBD slot,
c) Hydraulic scissor jack,
d) Angular and axial clearance measuring gauge,
e) Acoustic probe.

5.3. Structure of the exercise

The structure of the exercise is as following.

1. Identifying the motor vehicle through the identification plate and VIN.
2. Reading fault codes by using a tester and explaining their meaning.
3. Conducting a test drive.
4. Measurements and visual inspection of the components (the shaft and the axle) with a car on a jack.

5.4. The report

The report should contain the following elements:

1. Subject of the exercise,
2. Objectives of the exercise,
3. Object of testing,
4. Steps taken during tests,
5. Results of measurements and calculations,
6. Conclusions

6. Diagnosing vehicle engine by brakeless technique. Execution an acceleration-retardation cycle. Interpretation of results - repair instructions

6.1. Objectives of the exercise

a) Getting familiar with the engine testing procedure for the inertial method
b) Carrying out a test for diagnostic purposes
c) Interpreting test results in order to detect faults.

The inertial method allows measuring efficiency parameters of an engine performance and an engine internal losses in transient operating conditions. It uses the occurrence of the reactive torque effect T_I during each change in the angular velocity of the engine crankshaft:

Reactive torque values T_I depend only on the angular acceleration movement value because the reduced torque of inertia remains practically unchanged during engine exploitation. With the engine working in the idle speed mode (without external load) the reactive torque T_I may be used for engine self-loading or self-driving.

Applying then option of the total torque of internal losses(T_{sw}), meaning the sum of the mechanical resistance torque (T_m) and the load conversion loss torque (T_{wl}),

an equation for engine performance (in stipulated conditions), in the following form, is obtained:

T_d — torque generated during fuel charge combustion.

In case of the engine working in transient conditions and in the idle speed mode, when$\varepsilon > 0$ (accelerating after a sudden increase in combustion charge or after throttle valve opening), the engine inertial self-loading effect occurs. The torque T_d generated during fuel combustion is balanced by the internal loss torque T_{sw} and the reactive torque T_I:

Thus in the described conditions

one can estimate the effective torque T_e by calculating the values of the engine's reactive torque T_I.

The engine self-driving effect occurs in case when e<0 (a running-engine retardation, e.g. after turning off the ignition or fuel dosage when the engine is working in the idle speed mode). The reactive torque T_I is the driving force, then, and is balanced by the internal loss torque T_{sw}. Then

The presented method allows one to draw characteristics of performance efficiency $T_e = f(n)$ and $N_e = f(n)$ and internal losses $T_{sw} = f(n)$ and $N_{sw} = f(n)$.

6.2. Test stand

The test stand includes:

a) Diagnostic tester, e.g. Bosch KTS-540,
b) Motor vehicle with an OBD slot,
c) Engine shaft angular acceleration meter.

6.3. Structure of the exercise

The structure of the exercise is as following.

1. Identifying the motor vehicle through the identification plate and VIN.
2. Connecting the tester, reading fault codes and explaining their meaning.
3. Connecting the angular acceleration gauge.
4. Measuring torque and power of the vehicle engine.
5. Analysing the graphs obtained.

6.4. The report

The report should contain the following elements:

1. Subject of the exercise,
2. Objectives of the exercise,
3. Object of testing,
4. Steps taken during tests,
5. Results of measurements and calculations,
6. Conclusions

BIBLIOGRAPHY

1. Bocheński C.: Badania kontrolne samochodów. WKŁ, Warszawa 2000.
2. Frei Martin: Samochodowe magistrale danych w praktyce warsztatowej. Budowa, diagnostyka, obsługa. WKŁ, Warszawa 2010.
3. Gołębiowski S., Stanisławski J.: Badania kontrolne samochodów. WKŁ, Warszawa 1982.
4. Hebda M., Niziński S., Pelc H.: Podstawy diagnostyki pojazdów mechanicznych. WKŁ, Warszawa 1984.
5. Niziński S.: Diagnostyka samochodów osobowych i ciężarowych. Dom Wyd. Bellona, Warszawa 1999.
6. Orzełowski S.: Eksperymentalne badania samochodów i ich zespołów. WNT, Warszawa 1995.
7. Piekarski W., Krasowski E., Kiernicki Z.: Diagnostyka pojazdów rolniczych. Wyd. AR, Lublin 1988.
8. Trzeciak K.: Diagnostyka samochodów osobowych. WKŁ, Warszawa 1996.