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# EXPERIMENTAL STUDY OF PASSENGER VEHICLE VIBRATIONAL BEHAVIOR IN ACCORDANCE WITH ITS MAINTENANCE

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***Abstract:*** *Vehicles require maintenance and repair during the running period. Depending on the technical condition, namely parts and systems of their structure, vehicle vibrates with different intensities in different points. The study aims at highlighting the dependence of the technical condition, maintenance and vibrational behaviour of a passenger car. According to this purpose, there were made experimental measurements of vibrations on the stand for three significant measurement points: the screw at the cover cleats, the bodywork and the seat. The results are justified by the history of repairs and maintenance operations.*
***Key words:*** *vehicle vibration, vehicles maintenance, vibrational behaviour, vehicle wear.*

## 1. INTRODUCTION

The inspection operations, troubleshooting, repair, improvement, etc., which allows ensuring continuity of use, safely, an optimal overall cost of a vehicle, constitute maintenance vehicles [1].

Maintenance of vehicles is a necessity, because the technical condition significantly affects comfort, road safety and vehicle endurance as a whole.

The efficiency of conveyance maintenance is mainly determined by minimizing the costs of maintenance and repair, by the achievement of the higher running times between failures and the maintenance of high ecological parameters. This requires close and continous observation of the technical condition of cars and periodic testing and diagnosis of these processes in order to detect faults, even the minor ones and determining the most effective intervention solutions.

The most important vibration sources that occur while driving a vehicle are [2]:

- propulsion engine;
- transmission organs;
- air resistance to the advance of the vehicle;
- road surface quality.

During running, the most disturbing are the vibrations coming from the engine compartment or from the car decks. There are some possible causes of producing vibrations [3]:

1) Irregular functioning of the engine caused by insufficient air or fuel or faulty ignition received due to spark plugs, which may lead to mechanical vibration transmission throughout the car.
2) The precarious state suspension increases the level of vibration. Also, vibrations may occur due to the wear of rubber backing.
3) All vehicles have rotating components that are manufactured in tolerance class in sliding regime to function properly. If one of the axles is even slightly distorted, then it may cause vibration along the car. In this case, vibration increases while intensifying the running speed.
4) The vibrations are intensified when brake discs are slotted.
5) The vibrations caused by the deformation of wheels appear quite often.
6) Another reason for the occurrence of vibration is due to the tires. In general, if there are low quality tires they deform in time or suffer irregular wear and produce vibrations when running with certain speeds.

## 2. EXPERIMENTAL METHOD

### 2.1 Description of the of passenger cars whose vibration was measured

In the transport means maintenance, diagnosis on the items using experimental determination of vibration involves the establishment of the measuring device, depending on the parameter to be measured, the measurement points (items) where to put the accelerometer and method of the results analysis.

We used as a measuring instrument SVAN 958vibrometer, and the data obtained will be processed and analyzed using PC software SVAN ++ [4].

To highlight the vibrator response of a transport means, it was experimentally determined the vibrational behaviour of Volkswagen Caravelle vehicle, in the normal state, which has the following technical characteristics (as per registration certificate):

- manufacturing year: 2002;
- registration number: AB 07 WNT;
- number of seats: 8+1;
- power source: Diesel;
- maximum mass: 2800 kg;
- power: 75 kW;
- engine capacity: 2461 $cm^3$;
- total running: 428988 km.

**Fig. 1.** Vehicle with AB 07 WNT registration number.

### 2.2 The measurement of the vibration

The measurement was carried out according to the following conditions:

- measurements were performed on ITP stand (Periodic Technical Inspection);
- vehicles had a normal operating condition;
- measurement points for both vehicles were:
  - P1 - screw the cover cleats (rocker arms);
  - P2 - the bodywork (under the windshield);
  - P3 - front driver's seat.
- mounting accelerometers in the three measuring points was performed using special magnetic elements;
- measurement axes were complied according to ISO 8002: 1994standard. This standard presents analytical parameters and the presenting results method of vibration measurements for land vehicles.

### 3.3. 3. EXPERIMENTAL MEASUREMENTS RESULTS OF PASSENGER VEHICLE VIBRATIONS

Vibration measurement mode, in the first measurement point, P1, is given in Figure 2.


**Fig. 2.** Location vibration measuring system for P1 measurement point.

According to Figure 2, the measurement axes of vibrations have the following correspondence with accelerometer measuring channels:

- Oz axis measurement for channel 1 - Ch1;
- Oy axis measurement for channel 2 – Ch2;
- Ox axis measurement for channel 3– Ch3.

Table 1 contains the effective values of vibration acceleration, type Peak, Peak-to-Peak (P-P), Maximum and RMS (Root Mean Square), obtained in P1 measuring point,

determined experimentally on the 3 coordinate axes.

*Table 1.*
Effective vibration accelerations obtained on the three channels, in P1 measurement point.

| Measurement canal | Acceleration [mm/s$^2$] | | | |
|---|---|---|---|---|
| | PEAK | P-P | MAX | RMS |
| Ch1 | 98.288 | 184.289 | 20.701 | 19.838 |
| Ch2 | 103.872 | 196.562 | 20.630 | 19.792 |
| Ch3 | 106.537 | 198.609 | 20.989 | 20.091 |

The numerical values in Table 1 are presented in graphical form in Figure 3.

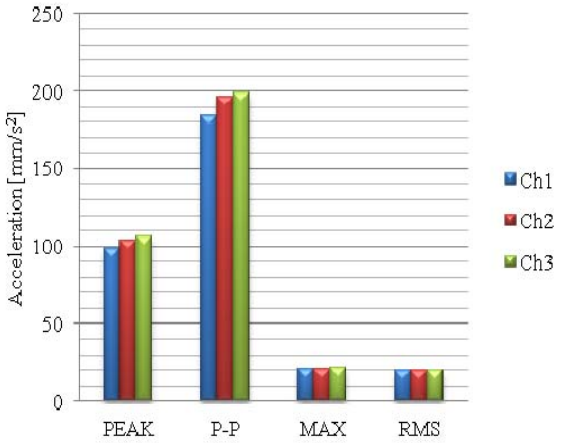


**Fig. 3.** Chart of effective vibration acceleration measured on the 3 channels, from P1 measuring point.

Figure 4 contains the oscillogram of RMS acceleration for three axes.

**Fig. 4.** Oscillogram of RMS acceleration from the P1 measuring point.

From the Table 1, Figure 3 and Figure 4, it is observed that the highest values of vibration acceleration are along the Ox horizontal direction.

For example, the maximum RMS acceleration along the Ox horizontal direction is by 20.09 mm/s$^2$.

Vibration measurement mode, in the second measurement point, P2, is illustrated in Figure 5.


**Fig. 5.** Location vibration measuring system for P2 measurement point.

According to Figure 5, the measurement axes of vibrations have the following correspondence with accelerometer measuring channels:

- Oz axis measurement for channel 1 - Ch1;
- Oy axis measurement for channel 2 - Ch2;
- Ox axis measurement for channel 3 - Ch3.

Table 2 contains the effective values of vibration acceleration, type Peak, Peak-to-Peak (P-P), Maximum and RMS (Root Mean Square), obtained in P2 measuring point, determined experimentally on the 3 coordinate axes.

*Table 2.*
Effective vibration accelerations obtained on the three channels, in P2 measurement point.

| Measurement canal | Acceleration [mm/s$^2$] | | | |
|---|---|---|---|---|
| | PEAK | P-P | MAX | RMS |
| Ch1 | 88.614 | 177.215 | 20.370 | 19.521 |
| Ch2 | 89.743 | 178.443 | 20.441 | 19.656 |
| Ch3 | 112.720 | 201.372 | 20.725 | 19.884 |

The numerical values in Table 2 are presented in graphical form in Figure 6.

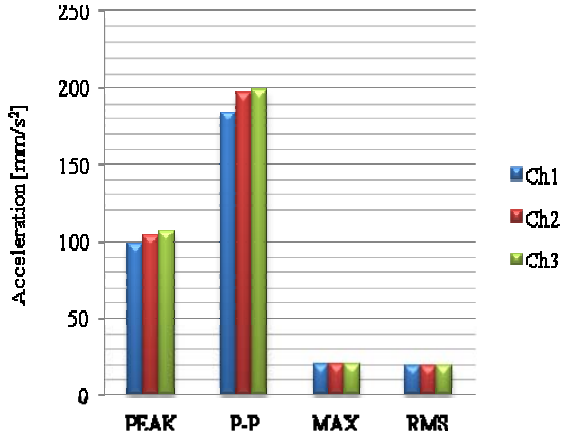


**Fig. 6.** Chart of effective vibration acceleration measured on the 3 channels, from P2 measuring point.

From the Table 2 and Figure 6, it is observed that the highest values of vibration acceleration are along the Ox horizontal direction.

For example, the maximum RMS acceleration along the Ox horizontal direction is by 19.88 mm/s$^2$. This is confirmed by the oscillogram given in Figure 7.

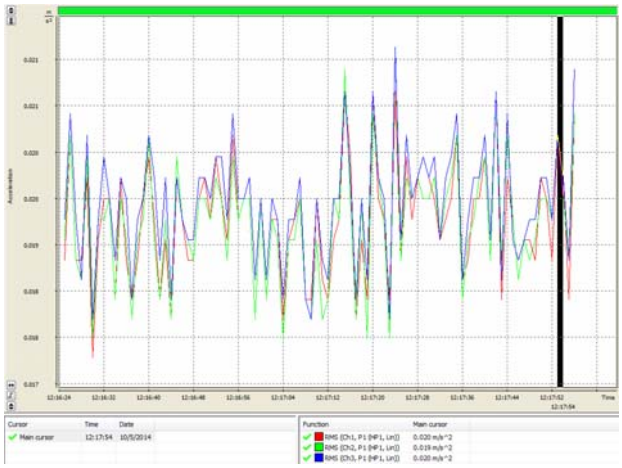

**Fig. 7.** Oscillogram of RMS acceleration from the P2 measuring point.

Vibration measurement mode, in the third measurement point, P3, is illustrated in Figure 8. According to this figure, the measurement axes of vibrations have the following correspondence with accelerometer measuring channels:

- Ox axis measurement for channel 1 - Ch1;
- Oy axis measurement for channel 2 - Ch2;
- Oz axis measurement for channel 3 - Ch3.

**Fig. 8.** Location vibration measuring system for P3 measurement point.

Table 3 contains the effective values of vibration acceleration, type Peak, Peak-to-Peak (P-P), Maximum and RMS (Root Mean Square), obtained in P3 measuring point, determined experimentally on the 3 coordinate axes.

*Table 3.*

Effective vibration accelerations obtained on the three channels, in P3 measurement point.

| Measurement canal | Acceleration [mm/s$^2$] | | | |
|---|---|---|---|---|
| | PEAK | P-P | MAX | RMS |
| Ch1 | 977.237 | 1634.933 | 447.198 | 437.019 |
| Ch2 | 869.961 | 1663.413 | 377.138 | 366.438 |
| Ch3 | 1144.195 | 2282.969 | 652.379 | 641.948 |

The numerical values in Table 3 are presented in graphical form in Figure 9.

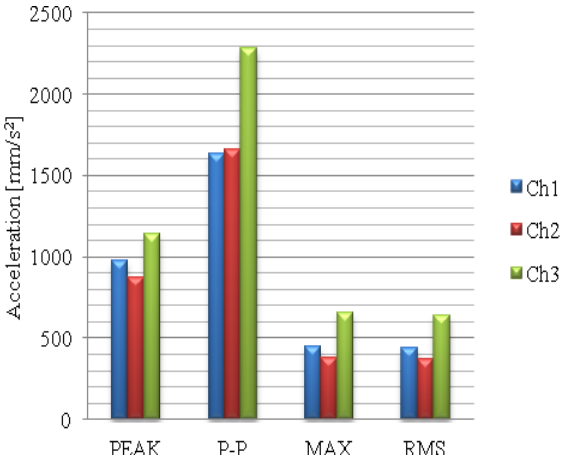


**Fig. 9.** Chart of effective vibration acceleration measured on the 3channels, from P3 measuring point.

From the Table 3 and Figure 9, it is observed that the highest values of vibration acceleration are along the Oz vertical direction.

For example, the maximum RMS acceleration along the Oz vertical direction is by 641.95 mm/s$^2$. This is confirmed by the oscillogram given in Figure 10.

**Fig. 10.** Oscillogram of RMS acceleration from the P3 measuring point.

Analyzing the results of vibration obtained in the 3 measuring points of the passenger vehicle, it follows that the acceleration is greatest at the P3 point, i.e. the front seat, along the vertical direction. Also acceleration values obtained for the first two measurement points are very close.

Following the analysis of the data obtained and the specialist recommendation has performed interventions for the first vehicle. Were replaced distribution belts and water pump.

## 4. OPERATIONS HISTORY OF MAINTENANCE

Knowing the maintenance operations history, it is necessary to make a correct analysis of the results as vibration measurements in order to make a diagnosis by comparing the values obtained.

To prevent technical failures and restoring regular working capacity of vehicles is performed a number of periodical works with preventive or corrective character, by various complexity. Routine maintenance is characterized by typology, periodicity and planning.

Table 4 contains the history of the passenger vehicle maintenance operations, the last 7 years.

*Table 4.*

The passensger vehicle maintenance operations.

| **Type of intervention** | **Date** | **Indicated km** |
|---|---|---|
| Replace distribution system | 25.07.2007 | 158 000 |
| Change engine-oil and filter | 29.08.2007 | 160 000 |
| Change clutch kit: disc, pressure bearing, pressure plate | 01.02.2008 | 166 820 |
| Change rotule (upper and lower) | 01.02.2008 | 166 820 |
| Change alternator belt | 01.02.2008 | 166 820 |
| Change gas oil filter | 06.04.2008 | 175 000 |
| Change return hose (injectors) | 06.04.2008 | 175 000 |
| Change engine-oil and filter | 11.04.2008 | 175 000 |
| Change gearbox oil | 11.04.2008 | 175 000 |
| Change right steering power link and bellows | 17.05.2008 | 178 300 |
| Change engine-oil and filter | 09.09.2008 | 196 399 |
| Change pollen filter | 09.09.2008 | 196 399 |
| Change brake pads, front | 12.09.2008 | 197 000 |
| Change distribution system: rollers, water pump, belts, valves, cleats | 04.02.2009 | 205 000 |
| Change engine-oil and filter | 06.07.2009 | 212 331 |
| Change alternator bearings | 06.07.2009 | 212 331 |
| Change brake pads, rear left | 07.07.2009 | 225 000 |
| Change air filter | 20.07.2009 | 225 250 |
| Change engine-oil and filter | 29.07.2009 | 226 770 |
| Change two tires, front | 29.07.2009 | 226 770 |
| Change: - 4 rotule (2 inferior, 2 superior), head straight bar 4 bushings steering box, torsion bar bushings. | 12.08.2009 | 229 900 |
| Change power steering oil | 12.08.2009 | 229 900 |
| Setting direction | 12.08.2009 | 229 900 |
| Change clutch kit: disc, pressure bearing, pressure plate, flywheel | 10.09.2009 | 236400 |
| Change engine-oil and filter | 28.09.2009 | 240 629 |
| Change front brake pads | 06.11.2009 | 244 000 |
| Change engine-oil and filter | 22.12.2009 | 253 240 |
| Change gas oil filter | 22.12.2009 | 253 240 |
| Change airflow | 22.12.2009 | 253 240 |
| Change air filter | 20.03.2010 | 262 580 |
| Replace distribution system | 22.03.2010 | 263 000 |
| Change engine-oil and filter | 15.04.2010 | 267 020 |
| Replace belts, accessories | 26.04.2010 | 271 000 |
| Change tensioner belt accessories | 30.05.2010 | 273 000 |
| Change pollen filter | 30.05.2010 | 273 000 |
| Change front tire | 21.06.2010 | 276 214 |
| Change engine-oil and filter | 25.06.2010 | 279 300 |
| Change engine-oil and filter | 20.12.2010 | 293 000 |
| Change brake pads, front and rear | 23.12.2010 | 296700 |

| | | |
|---|---|---|
| Repair steering box | 20.01.2011 | 300 000 |
| Change engine-oil and filter, air filter | 22.03.2011 | 302 500 |
| Change front tire | 01.06.2011 | 311 000 |
| Change engine-oil and filter | 09.07.2011 | 317 800 |
| Change pollen and airs filters, distribution system, bellows,belt, drive shaft | 25.07.2011 | 319450 |
| Change telescopes | 21.09.2011 | 325 500 |
| Change engine-oil and filter, air filter, gas oil filter | 31.10.2011 | 333 626 |
| Change front brake pads and pollen filter | 10.03.2012 | 344 825 |
| Change engine-oil and filter and air filter | 05.04.2012 | 345 500 |
| Change brake pads and bearing, rear | 06.06.2012 | 352 00 |
| Change vacuum pump, tires, gas oil filter, stabilizer bar bushings, anti-roll connecting rods | 12.11.2012 | 366 295 |
| Change engine-oil and filter | 20.12.2012 | 371 000 |
| Change engine-oil and filter | 22.06.2013 | 382 359 |
| Change distribution system, water pump, compressor bearing | 26.06.2013 | 382 441 |
| Change rear brake pads | 10.10.2013 | 392000 |
| Change engine-oil and filter and air filter | 09.11.2013 | 393 434 |
| Change pivots, bushings, gearbox support | 04.12.2013 | 395 000 |
| Change engine-oil and filter and air filter | 03.03.2014 | 404 146 |
| Change alternator bearings, brushes, coil collectors | 28.05.2014 | 414339 |
| Change engine-oil and oil filter, air filter, gas oil filter, brake sleeves | 28.05.2014 | 414339 |
| Change engine oil and oil filter, air filter, gas oil filter, brake sleeves | 27.08.2014 | 426 000 |

From Table 4 is observed that for the passenger vehicles was respected periodic maintenance periods and was performed current repairs and media interventions.

## 5. CONCLUSION

After the study of maintenance by using vibration measurements, can conclude the following:

- vibration behaviour of vehicles differ according to the measuring point;
- vibratory behaviour of the vehicle depends on how their maintenance and repairs carried out especially during the operation;
- maximum acceleration values are mainly along vertical direction, i.e. along the piston engine movement direction.

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**Studiu experimental al comportamentul vibraţional al unui autoturismul de transport persoane, în acord cu mentenanţa acestuia**

Vehiculele necesită întreţinere şi reparaţii în timpul perioadei de exploatare. În funcţie de starea tehnică, în speță a pieselor şi sistemele de structură, vehiculul vibrează cu intensităţi diferite, în diferite puncte. Studiul are ca scop evidenţierea dependenţei dintre starea tehnică, mentenanţa şi comportamentul vibraţional al unui autoturism. În acord cu acest scop, s-au făcut măsurători experimentale ale vibraţiilor, pe stand, în trei puncte de măsurare semnificative: şurubul de la capacul tacheților, caroserie şi scaun. Rezultatele sunt justificate de istoria reparațiilor şi operațiunile de mentenanță.

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