Impact of maintenance in the automotive field. Experimental study of mechanical vibration

O I Vulcu\textsuperscript{1} and M Arghir\textsuperscript{1}

\textsuperscript{1}Mechanical Engineering Systems Department, Technical University of Cluj-Napoca, Cluj-Napoca, Romania

E-mail: vulcu_ovidiu@yahoo.com

Abstract. In order to determine the impact of maintenance for vehicles, by analyzing the vibrating behaviour, were performed experimental measurements using specific equipment for vibration determination. Two measures were performed for the same vehicle. The period between actions was by one year. The results of analysis obtained by experimental measurements performed in the three critical points of the two passenger vehicles from mechanical vibration point of view are followings: vibrating behaviour is different in each point of the vehicle structure; technical state of vehicles depends on the maintenance applied and not of the using time or running distance. It is important to note that it was not taken into account the quality of the running.

1. Introduction

Maintenance includes overall operations (inspection, troubleshooting, repair, improvement etc.), which allows ensuring continued use, safely at an optimum overall cost. Maintenance of vehicles is a necessity because the technical condition significantly affects comfort, traffic safety and vehicle endurance as a whole [1].

Figure 1 presents the structure of the main activities of automotive maintenance.

![Diagram](https://example.com/diagram.png)

**Figure 1.** Structure of automotive maintenance [2].
Preventive maintenance can be programmed and the frequency can be enacted through legislation or can be recommended by the manufacturer [3]. This type of maintenance must provide keeping the vehicle in normal technical operating condition by performing some regular maintenance and regular replacement of components before predictable failure. Preventive maintenance includes the control operations, diagnostics, tightening-fixing, adjustment and lubrication [4].

Corrective maintenance includes unscheduled interventions imposed by defection components needed to restore the technical condition of the vehicle. Goals corrective maintenance refers in particular to the removal of faults through inspections and repairs [4].

Transport mains maintenance efficiency is determined mainly by minimizing costs, maintenance and repair by achieving a higher running between failures, also the maintenance by high ecological parameters. This requires careful and continuous observation of operation and technical condition. In order to detect faults even the minor is important to choose and perform the most effective intervention solutions and periodic testing and diagnosis of these processes [5].

Component of maintenance vehicles based on mechanical vibration assessment involves obtaining an accurate description of the vibrating phenomenon by measurement and analysis.

2. Initial data regarding the experimental study
In order to evaluate the maintenance impact in automotive field using vibration analysis were performed experimental measurements. The study was started in 2014. The first results obtained for other measurement points, but for the same samples, was published thanks to Springer International Publishing in Tom named ‘Ideas, Challenges, Solutions and Applications’ (see reference [3]).

For maintenance of vehicles, diagnostics on elements by experimental determination of vibration requires presetting the measuring device, depending on the parameter that is intended to be measured, points (elements) which will place the accelerometer and method of analysis of the results obtained.

The measuring device used in this study was vibration analyzer SVAN 958 and the PC software use for analysis and processing was SvanPC++.

2.1. Technical data of the samples
As samples they were chosen two vehicles, presented in figure 2, of the same brand Volkswagen Caravelle, different manufacturing years, and different owner and different maintenance.

![Figure 2. Measured samples. (a) First sample. (b) Second sample.](image)

The vehicles for which measurements were performed, shown in figure 2, has the technical characteristics (as per registration certificate) presented in table 1.shoen below.

The main maintenance operation performed during the life of cars were: distribution system replacement, changing of filters (air, gas, oil, pollen), tires, brakes, bearings, bushes, water pump, belts, clutch kit, and other specifically parts.

The major intervention for the second vehicle was changing the engine.
Table 1. Technical characteristics of the samples.

| Characteristics      | First sample | Second sample |
|----------------------|--------------|---------------|
| Manufacturing year   | 2002         | 1999          |
| Power source         | Diesel       | Diesel        |
| Maximum mass         | 2800 kg      | 2800 kg       |
| Power                | 75 kW        | 75 kW         |
| Engine capacity      | 2461 cm³     | 2461 cm³      |

2.2. Experimental method

They were performed experimental measurements using specific equipment, type SVAN 958, made by SVANTEK Society, Japan.

Two measures were performed. The period between actions was by one year. Both vehicle samples were tested on ITP (Periodic Technical Inspection) test station. Experimental determinations were made for two vehicles of the same brand, different manufacturing years; the first was produced in 2002 and second in 1999, as were described in previous chapter.

At the first measurement, first vehicles indicated a running of 428988 km for the first sample and second probe of 575366 km. At the second measurement, indicated a running of 474551 km in case of first car and by 623173 km for second car.

The measuring points were chosen on the below critical components of vehicles (the same for both cars):

- P1 - Support screw of the brake pump – figure 3 (a).
- P2 - Trigger (intercooler support) – figure 3 (b).
- P6 - Rear seat – figure 4 (c).

Figure 3. The vehicle measuring points of vibration.
(a) Support screw of the brake pump. (b) Trigger (intercooler support). (c) Rear seat.

3. First experimental results

Table 2 and table 3 contains the effective values of vibration accelerations, 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 for both samples took in consideration. Following the data given in table 2 it can be observe that the highest vibration acceleration is along the horizontal direction Ox. The maximum value of the RMS acceleration in the directions Ox and Oz, is 19.3 mm/s².

Checking the information given in table 5 it is observed that the highest vibration acceleration is along the vertical direction Ox. The maximum value of the RMS acceleration in the direction Ox and Oz is 18.2 mm/s².
The figure 4 contains the comparative chart between the measurement results in first P1 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one.

**Table 2.** Effective vibration accelerations obtained for P1 measurement point for the first vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 99.3                 | 181.1| 20.1| 19.3|
| Oy               | 90.3                 | 173.6| 19.7| 18.9|
| Oz               | 99.3                 | 181.1| 20.1| 19.3|

**Table 3.** Effective vibration accelerations obtained for P1 measurement point for the second vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Oy               | 106.1                | 200.5| 19.7| 18.2|
| Oy               | 102.6                | 183.7| 19.9| 18.6|
| Oy               | 109.8                | 197.7| 19.7| 18.2|

**Figure 4.** Comparative vibration chart of the first P1 measurement point.

As a comparative observation it can be said that first car have higher level of vibration than second one.

Table 4 and table 5 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 for both samples took in consideration.

**Table 4.** Effective vibration accelerations obtained for P2 measurement point for the first vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 103.2                | 193.4| 20.1| 19.1|
| Oy               | 97.5                 | 191.2| 19.8| 19.01|
| Oz               | 104.5                | 197.1| 20.2| 19.1|

**Table 5.** Effective vibration accelerations obtained for P2 measurement point for the second vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 107.2                | 200.5| 19.1| 17.8|
| Oy               | 113.5                | 201.4| 19.1| 17.9|
| Oz               | 101.7                | 190.1| 19.1| 18.1|

According to the values given in table 5 the accelerations are very close along all 3 axes, about 19 mm/s².
From table 5 is noted that the accelerations are very close along all 3 axes. The maximum value of the RMS acceleration in the direction Oz is 18.03 mm/s².

Figure 5 contains the comparative chart between the measurement results in first P2 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one.

![Figure 5. Comparative vibration chart of the first P2 measurement point.](image)

As a comparative observation it can be said that first car have higher level of vibration than second one.

Table 6 and table 7 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 for both samples took in consideration.

**Table 6.** Effective vibration accelerations obtained for P3 measurement point for the first vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 1008.1 1733.8 432.1 410.7 |      |     |     |     |
| Oy               | 799.8 1538.2 404.1 388.6 |      |     |     |     |
| Oz               | 556.5 1097.7 220.1 210.1 |      |     |     |     |

**Table 7.** Effective vibration accelerations obtained for P3 measurement point for the second vehicle.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Oy               | 669.1 1295.7 258.2 248.9 |      |     |     |     |
| Oz               | 763.8 1470.6 248.9 241.3 |      |     |     |     |

As it can be observed from table 6 the acceleration has the highest value along horizontal direction. The maximum RMS acceleration value is along the direction Ox and is about 410.7 mm/s².

From table 7 it can be observed that the accelerations are very close along all 3 axes. The maximum value of the RMS acceleration in the direction Oy is 248.9 mm/s².

Figure 6 contains the comparative chart between the measurement results in first P3 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one. As a comparative observation it can be said that first car have higher level of vibration than second one. Also, it is evident that the first car has double value of accelerations than the first.

A general conclusion after first batch of measurements is that even that first car is newer than second one, the vibration behaviour is warts than in the second case.
4. Second experimental results one year later

Table 8 and table 9 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 for both samples took in consideration.

**Table 8.** Effective vibration accelerations obtained for P1 measurement point for first vehicle one year later.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P   | MAX   | RMS   |
|------------------|----------------------|-------|-------|-------|-------|
| Ox               | 939.7                | 1817.6| 401.8 | 311.5 |
| Oy               | 1788.5               | 2654.6| 217.5 | 209.4 |
| Oz               | 1445.4               | 2707.1| 125.2 | 108.5 |

**Table 9.** Effective vibration accelerations obtained for P1 measurement point for second vehicle one year later.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P   | MAX   | RMS   |
|------------------|----------------------|-------|-------|-------|-------|
| Ox               | 321.7                | 572.1 | 102.1 | 98.5  |
| Oy               | 265.5                | 482.5 | 85.3  | 82.4  |
| Oz               | 129.6                | 252.9 | 38.8  | 37.4  |

From table 8 is observed that the highest vibration acceleration are along the direction Ox. The maximum value of the RMS acceleration in the direction is about 311.5 mm/s².

According to the data presented in the table 9 is observed that the highest vibration acceleration are along the vertical direction Ox. The maximum value of the RMS acceleration in the direction Ox is 98.51 mm/s².

Figure 7 contains the comparative chart between the measurement results in first P1 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one. As a comparative observation it can be said that first car have higher level of vibration than second one. Also, it is evident that the first car have triple value of accelerations than the first.

Table 10 and table 11 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 for both samples took in consideration.

From table 10 are noted that the accelerations are very close along all 3 axes. The maximum value of the RMS acceleration in the direction Oz is 36.9 mm/s².

From table 11 it can be observed that the maximum value of the RMS acceleration along the direction Oz is 61.66 mm/s².
Figure 7. Comparative vibration chart of the first P2 measurement point.

Table 10. Effective vibration accelerations obtained for P2 measurement point for first vehicle one year later.

| Measurement axis | Acceleration [mm/s²] |  |  |  |
|------------------|----------------------|---|---|---|
|                  | PEAK | P-P | MAX | RMS |
| Ox               | 158.5 | 309.7 | 34.2 | 33.6 |
| Oy               | 120.9 | 240.2 | 31.9 | 31.3 |
| Oz               | 177.1 | 309.7 | 37.1 | 36.9 |

Table 11. Effective vibration accelerations obtained for P2 measurement point for second vehicle one year later.

| Measurement axis | Acceleration [mm/s²] |  |  |  |
|------------------|----------------------|---|---|---|
|                  | PEAK | P-P | MAX | RMS |
| Oy               | 99.7  | 184.1 | 20.1 | 19.5 |
| Oz               | 116.3 | 228.3 | 30.2 | 29.6 |
| Oy               | 201.1 | 398.6 | 63.2 | 61.7 |

Figure 8. Comparative vibration chart of the first P2 measurement point.
Figure 8 contains the comparative chart between the measurement results in first P2 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one.

As a comparative observation it can be said that first car have higher level of vibration than second one, but only along Ox and Oy axes. Along Oz axis, the second car have almost double value of vibration than first.

Table 12 and table 13 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 for both samples took in consideration.

### Table 12. Effective vibration accelerations obtained for P3 measurement point for first vehicle one year later.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 726.1                | 1442.1 | 424.6 | 423.6 |
| Oy               | 399.0                | 737.1  | 162.7 | 161.9 |
| Oz               | 285.1                | 503.5  | 120.9 | 117.1 |

### Table 13. Effective vibration accelerations obtained for P3 measurement point for second vehicle one year later.

| Measurement axis | Acceleration [mm/s²] | PEAK | P-P | MAX | RMS |
|------------------|----------------------|------|-----|-----|-----|
| Ox               | 443.1                | 883.1 | 90.9 | 89.8 |
| Oy               | 666.1                | 981.7 | 69.1 | 67.7 |
| Oz               | 412.1                | 790.7 | 99.8 | 97.1 |

From table 12 are noted that the accelerations have the highest value along horizontal direction. The maximum value of the RMS acceleration in the direction Ox is 423.6 mm/s².

According the data from the table 13 it can be said that the maximum value of the RMS acceleration is along the direction Oz is by 97.1 mm/s².

The figure 8 contains the comparative chart between the measurement results in first P3 point of first and second vehicle. Item 1 corresponds to the first car and item 2 corresponds to the second one.

As a comparative observation it can be said that first car have higher level of vibration than second one. Also, it is evident that the first car have the highest value of vibration than first.

In order to evaluate the technical condition of the two vehicle chose as samples it is necessary to make an analysis regarding the vibration behaviour in time and also, in comparison from each other.
The below figures contain the graph of the evolution of RMS acceleration values, for both samples and for both measurements.

Figure 10 contains the RMS acceleration of vibration values, obtained on the first batch of measurements: (a) first vehicle; (b) second vehicle.

![First measurement results](image1)

Figure 10. First measurement results. (a) First vehicle/ (b) second vehicle.

Figure 11 contains the RMS acceleration of vibration values, obtained on the second batch of measurements, performed one year later: (a) first vehicle; (b) second vehicle.

![Second measurement results](image2)

Figure 11. Second measurement results: (a) first vehicle; (b) second vehicle.

The charts from the figures 10 and 11 it can be observed that the first car have highest RMS acceleration of vibration than in case of second vehicle, even that the first is newest that the second.

5. Conclusions

The final conclusions of this study is below: The vibrational behaviour not depends on the how old is the car, but depends on the type on maintenance operations. Also, depend on shape of road (was not took into account the type of road); In time, the evolution of technical characteristics of vehicle structure behaviour is not linear; In case of both samples, the critical measurement point is P2, trigger (intercooler support). This is a connection point between internal structure of the chassis and the chassis. That can be explain taking into account the whole system and the position and connections of the part in the chassis system; In case of first car, the vibration level of rear seat is maintained in time, even that the values of other parts are higher than at the firs measurement.
6. References

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