THE APPLICATION OF VIBRATION ANALYSIS FOR DIAGNOSIS OF BEARINGS AND GEARS OF THE REAR AXLE ASSEMBLY OF THE PASSENGER CARS

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***Abstract**: Predictive maintenance of machines, also known as Condition Based Maintenance, is based on monitoring operating parameters, and comparison with corresponding values of parameters obtained for the new equipment.*

All machines with moving parts give rise to sound and vibration and each machine has a specific vibration signature related to the construction and the state of the machine. If the state of the machine changes the vibration signature will also change and a change in the vibration signature can be used to detect incipient defects before they become critical. The condition monitoring technique is based on detecting the presence of a fault, diagnosing the root cause of the fault, assessing its level of severity and making arrangements for its correction. A broad of condition monitoring and fault diagnosis techniques has been carried out for improving the accuracy and ability of condition monitoring and prognosis systems for bearing and gear components.

This paper introduces the method for diagnostic of the rear drive axle for the passenger cars without its demounting. The objective method of diagnosing the rear drive axle is done by vibrometer. Application of diagnostic method greatly would be contributed in quickly localization of the rear drive axle fault where diagnostic process of the servicer will done faster.

Keywords: Condition monitoring; vibration; fault diagnosis; bearing, gear;

1. Introduction

The rear axle assembly is used on rear-wheel drive vehicles. This assembly is the final leg of the drive train. It is often called the final drive or rear end. The rear axle assembly includes the differential assembly, the rear drive axles, and the rear axle housing. A typical rear axle assembly is shown in Figure 1.

In a rear axle assembly, engine power enters the drive pinion gear from the drive shaft assembly and differential pinion yoke/flange. The drive pinion gear, which is in mesh with the ring gear, causes the ring gear to turn. Power from the ring gear flows through the differential case, spider gears, and side gears to the drive axles. The drive axles transfer power from the differential assembly to the rear wheels.

The bearings and rear axle housing are components of the rear axle assembly. They are designed to support and align the differential assembly and the drive axles.

All moving parts of rear axle give rise to sound and vibration and each parts has a specific vibration signature related to the construction and the state of the rear axle assembly.

If the state of the machine changes the vibration signature will also change and a change in the vibration signature can be used to detect incipient defects before they become critical. This is the basics of vibration based condition monitoring methods. The condition monitoring technique is based on detecting the presence of a fault, diagnosing the root cause of the fault. A broad review of the state-of-art of condition monitoring and fault diagnosis techniques has been carried out for improving the accuracy and ability of condition monitoring and prognosis systems for bearing and gear components.

Early fault diagnosis of gears and bearings may prevent unnecessary failures of most of the parts and thereby increase operational reliability and availability of rear axle assembly. Fault diagnosis techniques are important for monitor the conditions in bearing and gear. Currently available fault diagnosis techniques have a variety of limitations. An effective and method has to be researched and automated system has to be developed for industrial machinery component health diagnostic activities. (Taylor, 1995) discussed the dynamic performance of the rotating components is highly influential in the performance of any rotating machinery. (Endo and Randall, 2007) gave the importance of gear and bearings in the industrial rotating and transport machinery applications. Fault detection is the process of observing the measured system data and system status information and comparing them with a normal range of observed attributes to determine whether some measurements fall outside the range representing the healthy condition of the system. Unfortunately, no one technique is able to detect all machine faults. However, it has been suggested that vibration measurement, which is the most widely used condition monitoring technique in industry, can accurately identify 90% of all machinery failures by the change in vibration signals which they produce and the level of signal can give an accurate prediction of future failure (Randall, 2011). The task is to diagnose the fault at an early stage so corrective action can be taken as early as possible to extend the life of the machine (Latino, 1999).

Tandon and Nakara, (1992) compared the most commonly used vibration analysis methods for mechanical fault diagnosis such as time domain analysis, frequency domain analysis; time frequency analysis for defect detection in bearings.

In this work is presented condition monitoring of: ring and pinion gear, two side bearing and pinion bearing of the rear axle based on vibration analysis, through two parameters: frequency and amplitude of the vibrations.

In vibration analysis, measuring the vibration amplitude is made in broadband measurement. Broadband or overall measurement of the vibration amplitude is a measure of the total energy of all components of the machine vibrations. Generally accepted frequency range for broadband measurements is 10…10000Hz. An overall vibration measurement is a single value that is relatively easy and cheap to collect, process, analyzes and trend. Scales factors used to characterize the amplitude of vibration are: Peak value (Pk), Peak to Peak value (PtP) or Root Mean Square value (RMS).

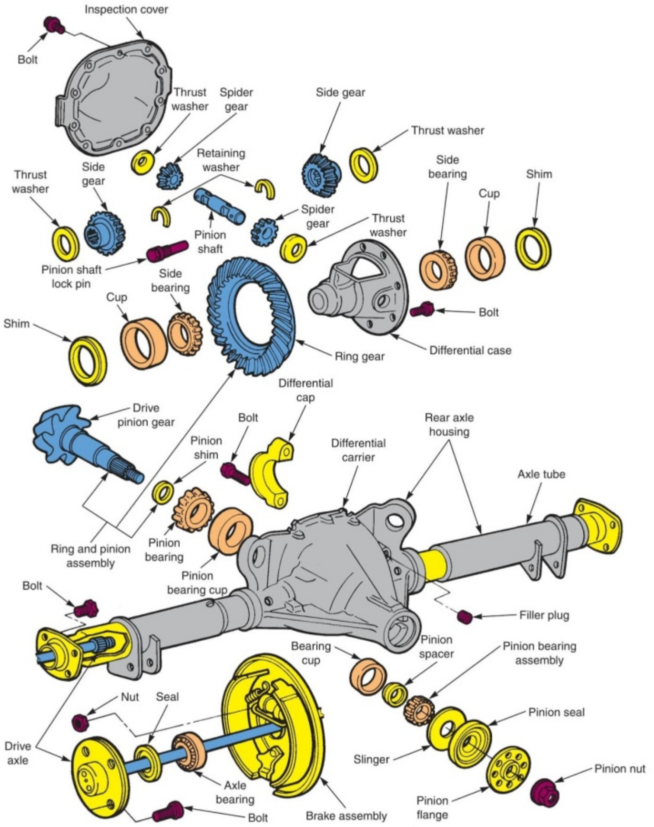

Figure 1. *Exploded view of a rear axle assembly*

2. Methodology for diagnostic of bearings and gears of the rear axle assembly for the passenger car Mercedes 190D

The preparation of the passenger car Mercedes 190 D to measure vibrations velocity, vibrations displacement and vibrations acceleration of the rear drive axle is presented in Figure 2. The vehicle is raised from the ground with crane and placed into two supports on both sides in order that during rotations of the wheels do not come into contact with the surface of the earth.

Figure 2*. Preparing the passenger car Mercedes 190 D for vibrations measurement at the rear axle assembly*

In the absence of the tachometer for measuring engine speeds, the measurements were made in the fourth gear of gearbox transmission (direct transmission ratio). In this case the vehicle speed is 100 [km/h], which corresponds to engine speed, respectively the speed of input drive pinion gear of rear axle assembly at 3000 rpm (Figure 3).

Figure 3*. The **vehicle** speed which corresponding speed of drive pinion gear for rear axle assembly at 3000 rpm*

During the test part of the handbrake is activated to simulate the rear axle load. The braking force is the same for both the left and right rear axle assemblies in order to simulate the straight movement of the vehicle.

Used tools to measure vibration have improved significantly in the past 25 years. The sensor of choice for most vibration data collection on industrial machinery is an accelerometer. As the name implies, the output is proportional to acceleration; however, it is normally integrated to display in units of velocity and displacement. Measurements of vibrations in the rear axle assembly of the passenger car Mercedes 190 D are made with vibrometer MANUAL PCE-VT 3000. Technical specification of vibrometer MANUAL PCE-VT 3000 is presented in Table 1.

Table 1. Technical specification of vibrometer MANUAL PCE-VT 3000

Technical Specifications	Measuring Range
Rang og aceleration	0.1......392 m/s^2 (Peak); (39.95 g force)
Range of Velocity	0.01..... 80 cm/s (RMS)
Range of Displacement	0.001....10 mm (Peak – Peak)

3. Results of vibration measurements for rear drive axle of the passenger car Mercedes 190

Measurements of the vibration are done in five specific points, which are presented in Figure 4. The measuring sensor with needle shape is used for measurements in points 3 and 4, while the measuring sensor with electromagnet is used in other measurement points.

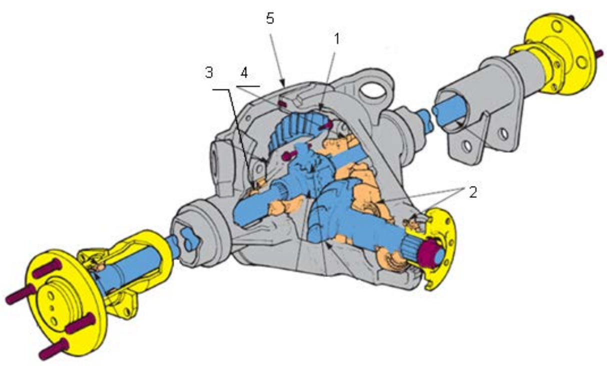

Figure 4*. Measurement points in the rear axle assembly: 1 - Differential carrier, 2 – Bearing of the pinion gear, 3 –Right side bearing differential case, 4 - Left side bearing differential case, 5 - Back part of the rear drive axle*

In Figures 5, 6 and 7, are shown the measured values for the vibration velocity, vibration displacement, and vibration acceleration at the five specific points for rear axle assembly of passenger car Mercedes 190 D, when the input speed of the drive pinion gear is 3000 rpm (50 Hz).

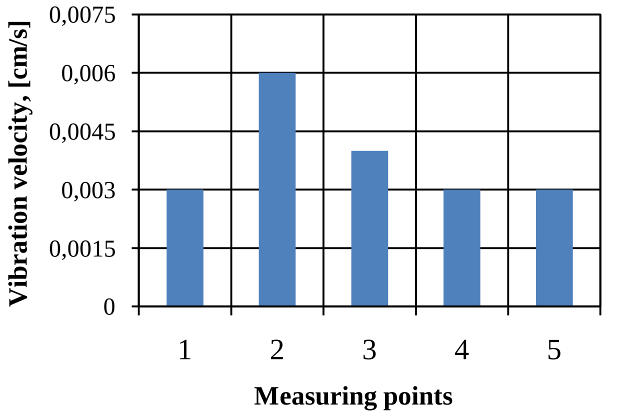

Figure 5. *Graphic presentation of the vibration velocities at the five specific measuring points*

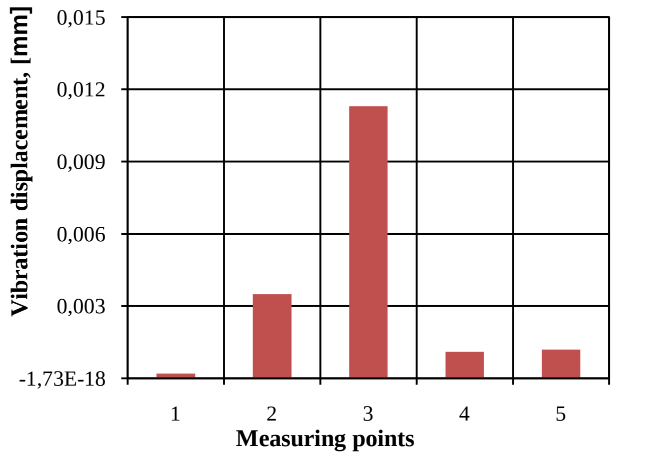

Figure 6. *Graphic presentation of the vibration displacements at the five specific measuring points*

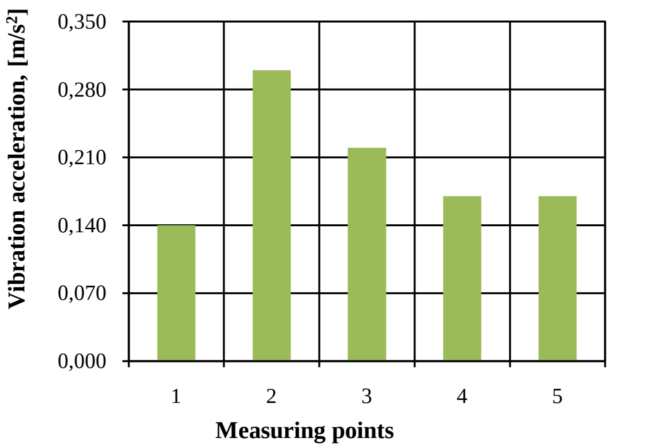

Figure 7. *Graphic presentation of the vibration acceleration at the five specific measuring points*

Figure 8 shows the measured values for displacement, speed and vibration acceleration on the display of the measuring device *MANUAL PCE-VT 3000*.

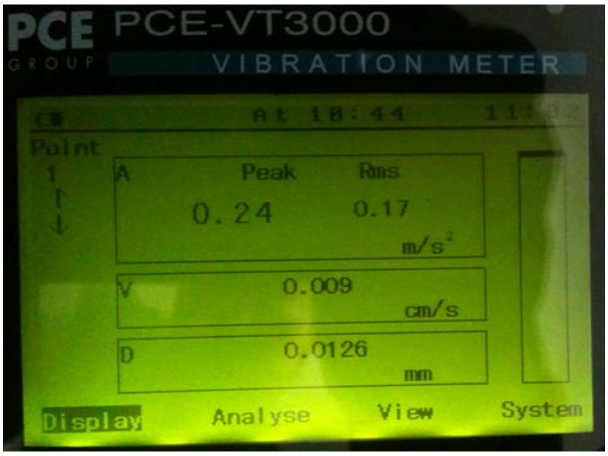

Figure 8. *The values of vibration measuring for: the vibration acceleration, vibration velocity and vibration displacement are shown in display of vibrometer, MANUAL PCE-VT 3000*

4. Vibration analysis

After measuring the vibration is necessary to evaluate the vibration severity. At the first method is compared the measured values with the vibration severity charts. Depending on the recorded values of the vibrations speed (RMS values) and the size of equipment, the ISO 10816-1995 standard evaluates the vibrations severity as in the Table 2. The ISO 10816-1995 standard is the most common example of absolute criteria and is a good guide for engineers who do not have any historical data on a machine.

Table 2: Vibrations Severity *Chart – ISO 10816-1995*

<table>
<tr><th rowspan="2">Vibration velocity v_{max} [mm/s]</th><th colspan="4">Type of machine</th></tr>
<tr><th>Class I $P_e < 15$ [kW]</th><th>Class II 15 [kW] $<P_e<75$ [kW]</th><th>Class III $P_e > 75$ kW</th><th>Class IV</th></tr>
<tr><td>0.00 ÷ 0.28</td><td rowspan="3">A</td><td rowspan="4">A</td><td rowspan="5">A</td><td rowspan="6">A</td></tr>
<tr><td>0.28 ÷ 0.45</td></tr>
<tr><td>0.45 ÷ 0.71</td></tr>
<tr><td>0.71 ÷ 1.12</td><td rowspan="2">B</td></tr>
<tr><td>1.12 ÷ 1.80</td><td rowspan="2">B</td></tr>
<tr><td>1.80 ÷ 2.80</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>2.80 ÷ 4.50</td><td rowspan="2">C</td><td rowspan="2">B</td></tr>
<tr><td>4.50 ÷ 7.10</td><td rowspan="6">D</td><td rowspan="2">C</td></tr>
<tr><td>7.10 ÷ 11.20</td><td rowspan="5">D</td><td rowspan="2">C</td></tr>
<tr><td>11.20÷18.00</td><td rowspan="4">D</td></tr>
<tr><td>18.00÷28.00</td><td rowspan="3">D</td></tr>
<tr><td>28.00÷45.00</td></tr>
<tr><td>45.00</td></tr>
</table>

Note:
Area A - Good condition of machine,
Area B – Operation of machine is satisfactory,
Area C - Operation of machine is unsatisfactory, and
Area D – Operation of machine is unacceptable (to repair).

At the second method is compared the measured values with the blake chart. Depending on the recorded values of the vibrations displacement, speed and acceleration, and the frequency, the blake chart evaluates the vibrations severity as in the Figure 9 (Eshleman, 1999).

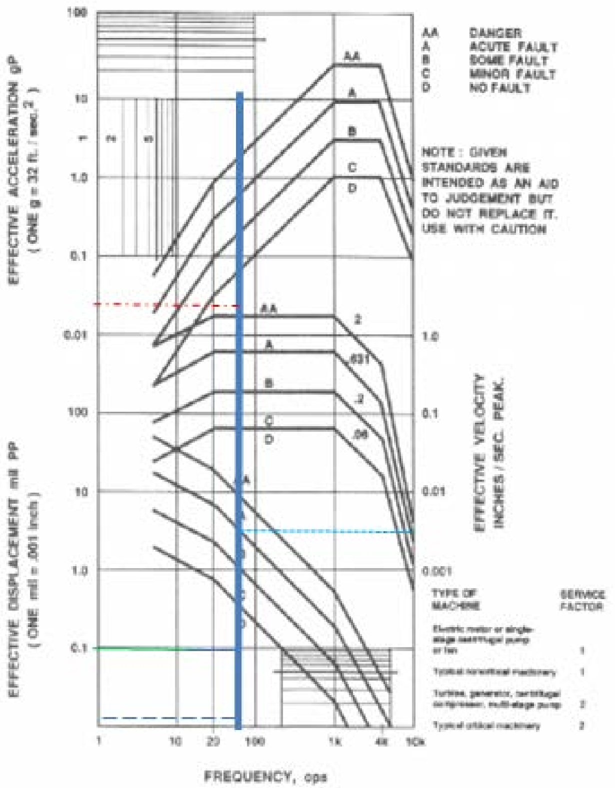

Figure 9. Blake chart: displacement, velocity and acceleration as function of frequency

In Figure 9 is drawn the vertical line at a frequency of 50 Hz that corresponds to the input speed of the drive pinion gear at 3000 rpm (blue line), then draw horizontal lines corresponding to the maximum displacement value (green line), speed (blue line) and acceleration (red line).

After comparing the results with the norms, it is noted that the values obtained correspond to the good condition of the bearings and the pinion and ring gear.

In Figure 10 is shown condition of component of the rear drive axle after measuring of vibration (after disassembling).

Figure 10. *Condition of components of rear axle after disassembling*

After measuring, the rear drive axle is disassembled and its components are observed carefully, where components are in good condition (haven't shown any damage).

4. Conclusion

The presented paper introduces diagnosing method for the gear mesh pinion gear and ring gear, two side bearing and pinion bearing of rear axle condition monitoring based on vibration analysis.

During the condition monitoring technique are made vibration measurements of the vibration velocity, vibration displacement and vibration acceleration by vibrometer device MANUAL PCE-VT 3000, when the vehicle speed is simulated to be 100 [km/h], which corresponds with speed drive pinion gear 3000 [rpm].

Obtained results for the vibration velocity, vibration displacement, and vibration acceleration measuring for five points in the rear drive axle are:

- In Area A - good condition (according to ISO),
- Greater values of vibration velocity are appeared in the side bearing differential case (points 3 and 4 of measurement),
- Vibration velocity and acceleration have similar behavior compared with vibration displacement.

The obtained results are suitable because after disassembling, the condition of the component of the rear drive axle are good (don't shown any damage) after measuring.

5. References

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