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WEAR OF SPHERICAL JOINTS OF THE VEHICLES STEERING SYSTEMS. VIBRATIONS AND THEIR ROLE IN DIAGNOSIS

Mihai GINGARASU, Elena MEREUTA, Valentin AMORTILA, Costel HUMELNICU, Monica NOVETSCHI

"Dunarea de Jos" University of Galati, Romania

Corresponding author: mihai.gingarasu@ugal.ro

ABSTRACT

Motor vehicles have an important role in our lives, the need for mobility making them present in daily activities. In a more open world, people want to be able to move, not only more and more, but also increasingly better. In the current context of the intensification, both nationally and internationally, of road transport, the need for safe traffic traffic is a primary objective for the operation of motor vehicles. Combining vehicle technology enhancements with an improved driver training, with a better road infrastructure design and an enforcement of existing traffic regulations is an important goal for society in order to increase road safety. During the operation of the vehicles, their component systems interact both with each other and with the external environment and these interactions are generating variations of some technical state parameters. As a result, there is a continuous change in the technical state of the vehicles, which causes variations in the dynamic, economical, air pollution, ergonomic, comfort and safety performances. This paper analyzes the vibrations of the steering system components, under different operating conditions and according to the technical state of the spherical joints. The measurements were made using a 4-channel digital recorder DA20-RION, with data processing software DA-20 VIEWER and a triaxial accelerometer Brüel & Kjær, type 4321. The paper highlights the possibility of monitoring the technical state of the spherical joints, analyzing the vibrations produced under different driving conditions of the vehicles and, at the same time, it opens the perspective of the implementation of intelligent devices to ensure the early detection of these failures.

Keywords: diagnosis, steering system, vibrations, spherical joint.

1. INTRODUCTION

Motor vehicles have an important role in our lives, the need for mobility making them present in daily activities. In a more open world, people want to be able to move, not only more and more, but also increasingly better. In the current context of the intensification, both nationally and internationally, of road transport, the need for safe traffic traffic is a primary objective for the operation of motor vehicles.

Increasing road safety is an important goal for society and the improvement of vehicle technology, the development of road infrastructure, the driver training and compliance with traffic regulations are contributing to its achievement. During the operation of the vehicles, their component systems interact both with each other and with the external environment and these interactions are generating variations of some technical state parameters. As a result, there is a continuous change in the technical state of the vehicles, which causes variations in the dynamic, economical, air pollution, ergonomic, comfort and safety performances [1]. Spherical joint wear is common faults in the steering systems of motor vehicles (Fig. 1).

Defects of this type occur at the tie rod end, tie rod, king pin etc., having the effect of changing the geometry of the steering system. The consequences of these failures are the loss of stability of the vehicle both in corners and in straight driving, the difficulties in enrolling on the ordered trajectory, the accelerated wear of tires or other components of the steering system and even the risk of road accidents[3], [4].

This research aims to identify a method for diagnosing during driving of these defects, having as a starting point the symptoms that are perceived by an experienced driver (sounds, vibrations, abnormal shocks). Early detection of such malfunctions would play an important role in increasing road comfort and safety and reducing vehicle maintenance costs[3], [5], [6].

Fig. 1. The vehicle steering system [2]

This paper analyzes the vibrations of the steering system components, under different operating conditions and according to the technical state of the spherical joints.

2. MATERIALS AND METHODS

During the operation of the vehicle, the sources of noise and vibration are multiple (engine, additional systems, interaction between tires and road, etc.), being characterized by different frequencies and amplitudes and, especially, by their variation in time. However, an experienced driver may notice abnormal shocks, noises and vibrations in operation, symptoms that indicate the existence of malfunctions in the steering system.

The researched diagnostic method is based on the fact that driving over various bumps, frequent in urban traffic, determines the occurrence of shocks in worn spherical joints. The shocks produced in the worn spherical joints, defining for the analyzed diagnostic method, excite natural modes of vibration of the steering rod-head assembly. To estimate the response to multiple shocks produced in the joints, the Ansys Workbench finite element analysis program with the Modal module (not shown here) was used.

In order to highlight the symptoms that attest the appearance of defects at the tie rod end, 20 tests were performed in urban traffic. The tests were performed in pairs, under similar conditions, the difference between them being the existence/non-existence of the defect at the left tie rod end of the vehicle. To initiate the shocks in the spherical joints, the tested vehicle was driven over the following bumps: slight asphalt bumps, level crossings over tram lines and roadway sewer covers.

The accelerometer was fixed on the left tie rod end of the vehicle (Fig. 2), the pair tests being performed with the alternative mounting of 2 tie rod ends, with or without wear of the spherical joint.


Fig. 2. The accelerometer fixed on the left tie rod end

The tests were performed on a Dacia Logan vehicle, with the following technical characteristics: year of manufacture 2016, cylinder capacity 1189 cm3, gasoline engine, engine power 55 Kw, tires dimensions 185/65 R15, tires pressure 2.2 bar. The measurements were performed using a DA20-RION 4-channel digital recorder with DA-20 VIEWER data processing software and a Brüel & Kjær triaxial accelerometer, type 4321. To perform the measurements, taking into account previous results, the measuring equipment was set for recording in the frequency range of 0-500 Hz [3]. The range of the vibration frequency measurement was set between 0-500 Hz.

3. RESULTS

The analyzed tests A and B represents paired tests, the difference between them being the existence of wear on the spherical joint of the left bar end in test A, respectively the absence of the defect in test B. The tested vehicle was driven at a constant speed of 40 km/h, with the gearbox engaged in 4th gear and engine speed of 1500 rpm. The running was carried out rectilinear, in urban traffic conditions, over slight asphalt bumps.

Figures 3, 5 and 7 represent vibration spectra recorded on the OX, OY and OZ axes, in the situation of mounting on the vehicle a tie rod end with spherical joint wear of 0.6 mm/radius. Figures 4, 6 and 8 represent vibration spectra recorded on the axes OX, OY and OZ, in the case of mounting a defective bumper head on the vehicle. The recorded vibration spectra represent the response to multiple excitations (operation of the engine and additional systems, interaction with the roadway, shocks in spherical joints).

The comparative analysis of the vibrograms, with or without the existing defect of the tie rod end, aimed the variations in time of the amplitudes of the vibration accelerations and the establishment of their correspondence with the occurrence of multiple shocks in the spherical joint.

The spectral analysis in the time domain reveals that in the case of wear at the spherical joint of the bar end, the amplitudes of vibration accelerations recorded are significantly higher, on all 3 axes, compared to those recorded in the same test conditions, but without defect. The conclusion is also supported by the overlapping in time of signals, with and without defect (Fig. 9).

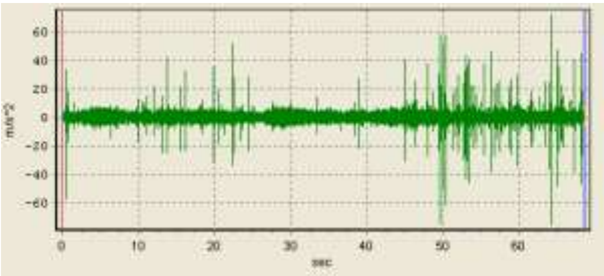

Fig. 3. Vibration spectra of test A, OX axis, with defect

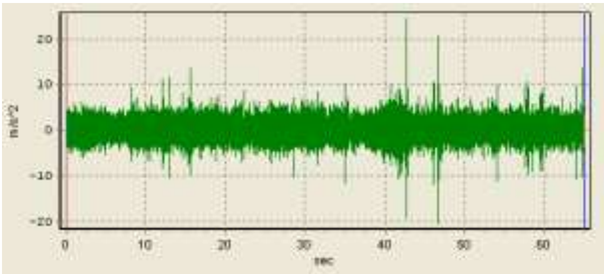

Fig. 4. Vibration spectra of test B, OX axis, without defect

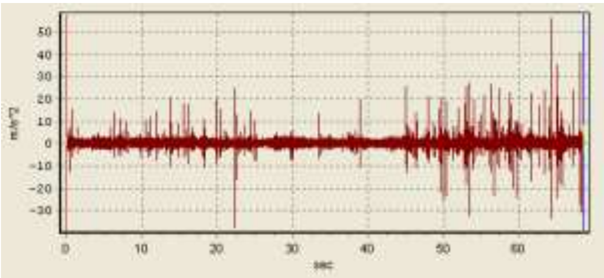

Fig. 5. Vibration spectra of test A, OY axis, with defect

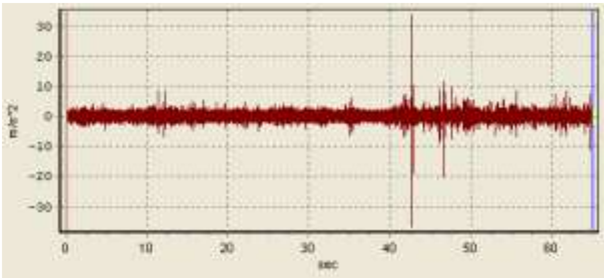

Fig. 6. Vibration spectra of test test B, OY axis, without defect

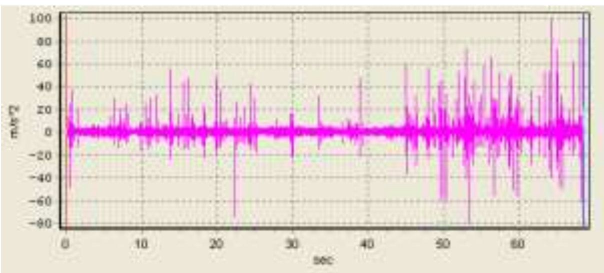

Fig. 7. Vibration spectra of test A, OZ axis, with defect

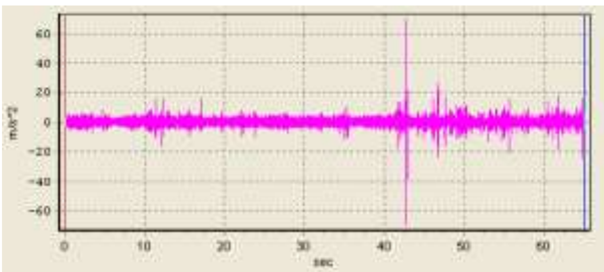

Fig. 8.Vibration spectra of test B, OZ axis, without defect

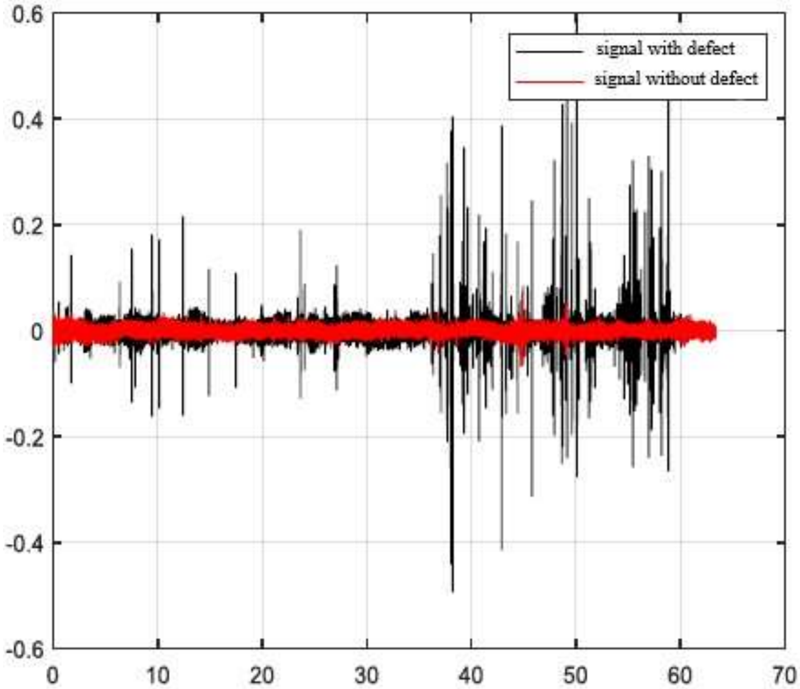

Fig. 9. The overlap in time of vibration spectra, with and without defect

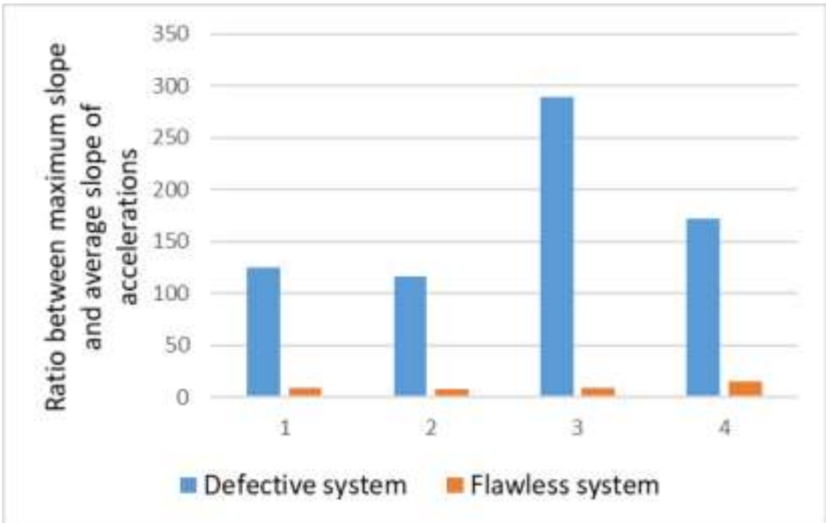

Fig. 10 The ratio between maximum slope and average slope of accelerations on the OX axis, corresponding to 4 pairs of systems (with and without defect)

The acceleration peaks in the spectra related to the defective tests correspond in time to the moment of occurrence of the shocks in the worn joints. The analysis of the data recorded in all 20 tests performed (not shown here) with different bumps (slight asphalt bumps, level crossings over tram lines and roadway sewer covers) reveals similar results, leading to the same conclusion, namely that the amplitudes of vibration accelerations recorded with existing defect are significantly higher, on all 3 axes, compared to those recorded in the same test conditions, but without existing defect.

The comparative analysis of 4 pairs of tests on systems with or without defect, at the speed of 40vkm/h of the vehicle, based on the signals recorded on the OX axis, in the frequency range of 0-500 Hz, reveals that the ratio between the maximum slope and the average slope of acceleration is considerably higher in the case of systems with defect compared to system without defect. From the comparisons presented in figure 10 it results that a limit ratio between the maximum slope and the average acceleration slope with a value above 50 can indicate the occurrence of the wear in the spherical joints.

4. CONCLUSION

The analysis of the data resulting from the measurements revealed that there are significant variations of the vibration accelerations measured at the steering elements, in the situation of the existence of defects of the spherical joints, compared to the tests without defects.

Setting a limit value of the ratio between the maximum slope and the average slope of accelerations may indicate the occurrence of the defect in the analyzed system.

Early detection of spherical joint failures in the steering system can result in: minimizing the maintenance costs, judicious use of financial, human and material resources, increasing comfort and, most importantly, increasing road safety.

The paper highlights the possibility of monitoring the technical state of the spherical joints, analyzing the vibrations produced under different driving conditions of the vehicles and, at the same time, it opens the perspective of the implementation of intelligent devices to ensure the early detection of these failures.

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