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A NEW METHODOLOGY FOR DETECTION OF A LOOSE OR WORN BALL JOINTS USED IN VEHICLES SUSPENSION SYSTEM

Luís Carvalho[1(*)], Sérgio Santos[1], Carlos Ferreira[1,2]
[1]Escola Superior de Tecnologia e Gestão (ESTG), Instituto Politécnico de Leiria, Leiria, Portugal
[2]INESC Coimbra, Rua Antero de Quental 199, 3000-033 Coimbra, Portugal
[(*)]*Email:* luisandre_rato@hotmail.com

ABSTRACT

The present work aims to develop an automated tool to determine the wearing condition of ball joints used in vehicles suspension system. A methodology based on the transmissibility between accelerations, measured in two points of the suspension system, is proposed. Multiple vehicles, with ball joints in known condition, were tested using the excitation generated during the suspension test, performed during the vehicle periodic technical inspection required by law. Actually the evaluation of the wearing condition of ball-joints is done through visual inspection witch does not represents a well-defined and homogeneous criteria. The experimental results obtained proved that the proposed methodology can be successful applied to determine the ball joints wearing and its clearance in a quantitative and automated manner, promoting the vehicle safety.

Keywords: ball joint, mechanical failure, transmissibility, vehicle inspection, vehicle safety.

INTRODUCTION

Ball joints have a critical function on automotive suspension and steering systems. They are responsible for connecting the suspension lower arms to the vehicle steering knuckles, allowing the suspension to move up and down and the steering movement of the wheels/tires. However, due to its working principles, lack of lubrication (ruptured seals) and to the efforts/vibrations they are subjected, with time, ball joints are prone to wear and fail [1, 2]. A loose ball joint will originate noises and vibration during the vehicle operation, may lead to the abnormal wearing of the tires, suspension and transmission components and, ultimately, will result in an undriveable and unsafe vehicle. Nowadays, ball joints are mainly tested by visual inspection, during vehicles periodic inspection, or using very expensive tools [3], which require the ball joints to be removed from the vehicle so they can be tested.

In vehicles technical inspection, ball joints are “manually” tested in a moving plates platform, where an operator (with the aid of a hydraulic assisted system) forces the displacement of the tires relatively to the vehicle body, while checking for any signs of looseness. In this test a second operator, or the driver, is necessary to operate the steering wheel and the vehicle brakes. The test is unautomated, quite intrusive for the suspension components and results are dependent of the human factor and very susceptible to a wrong diagnosis. In opposing, the diagnosis of the suspension/shock absorbers and brakes, during the vehicle technical inspection, are effusively automated. In particular ground suspension tests apply a shaking displacement to the vehicle tires, at the range of the natural frequencies of the suspension system, and measure the tire contact force with the platform. The result, called adhesion, is a measure of the suspension system conditions and an indicator of the shock absorbers status/wearing [4].

Moreover, methodologies based on a transmissibility analysis (study of the ratio between to signals in the frequency domain), have been proposed and used to determine the condition of other vehicles components, such as shock absorbers [5] or the comfort of vehicle seats [6].

METHODOLOGY

In the follow up, we propose a new methodology to test the suspension ball joints based on a transmissibility analysis between the acceleration measured on both parts of the suspension where ball joints are attached (Fig. 1). Two three-axis accelerometers are required, which in turn are fixed to the vehicle suspension using strong magnets. Fig. 2 shows a possible practical placement of the accelerometers in the suspension lower arm and in the steering knuckle. The test will be performed in simultaneous with the suspension test, made on the vehicle annual inspection, were excitation up to 20 Hz is applied to the vehicle wheels. Fig. 3 presents an example of the accelerations time plots, in the accelerometers axis parallel to the suspension movement, acquired in both sides of a ball joint during a suspension test. The time domain data is then used to compute the power spectral densities of both signals, and its ratio in the frequency domain will be an indicator of the ball joints looseness.

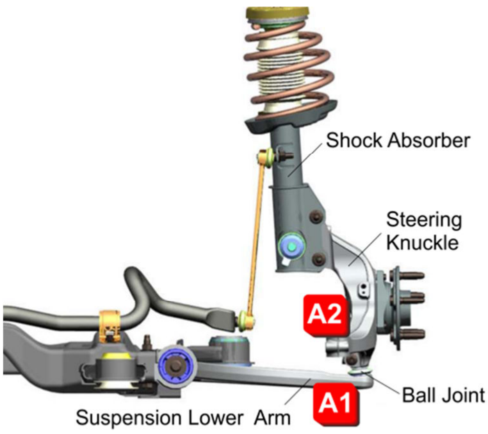

Fig. 1 - Accelerometers placing.

Fig. 2 - Example of a practical test.

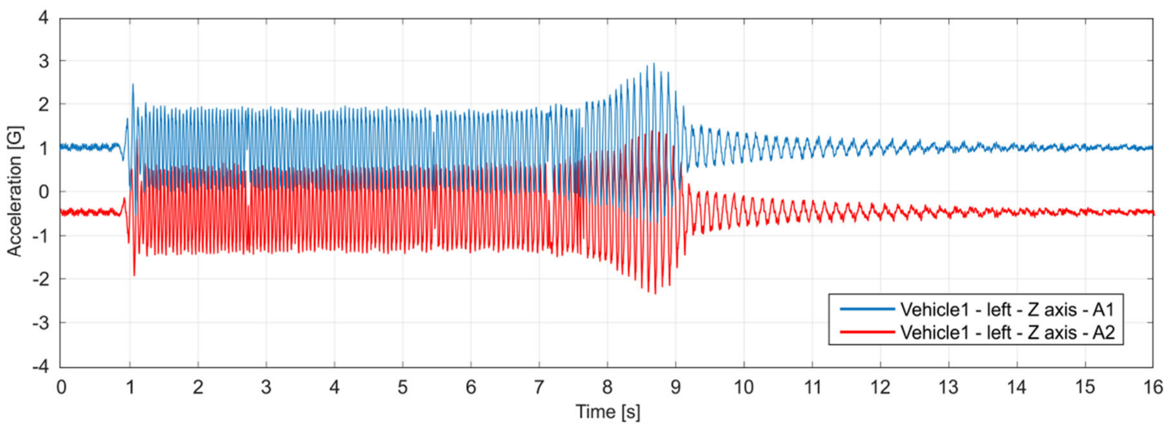

Fig. 3 - Acceleration time plots in both sides of a ball joint, acquired through the suspension test during the vehicle technical inspection.

Given the diversity of suspension geometries and its components, three-axis accelerometers will enhance and facilitate the tests, since accelerometers could be placed in one of different positions: top, bottom or on side (vertical or horizontal), thus, simplifying and making its fixation to the suspension stronger.

TESTS AND RESULTS

Tests with multiple vehicles with ball joints in good and bad condition, identified by visual inspection on a moving plates platform, were made. A tool was developed to acquire accelerometers time data at a rate of 400 Hz and to compute the transmissibility between accelerations. The fast Fourier transform algorithm was verified and calibrated using known sinusoidal waveforms and a digital oscilloscope PicoScope® 2205 MSO (FFT spectrum analyzer tool). As shown in Fig. 4 the measured excitation ranges from 7 Hz to 17 Hz, being is power density a function of the tested vehicles suspension geometry and characteristics, such as: suspension spring constant, damping factor, unsprung mass, sprung mass, tire stiffness and other suspension compliances. Obtained values are in accordance with reference values [4], centered around the wheel/sprung mass resonant frequency (typically 12 Hz). Fig. 5, Fig. 6 and Fig.7 show the transmissibility results for three vehicles (different brands and suspensions geometries), all with both ball joints, left and right, in good conditions. As seen, in the excitation range, 7 Hz to 17 Hz, the transmissibility presents a quite high linearity. In this range the mean value of the transmissibility is a function of the accelerometers position/fixation and their alignment with the suspension working axis.

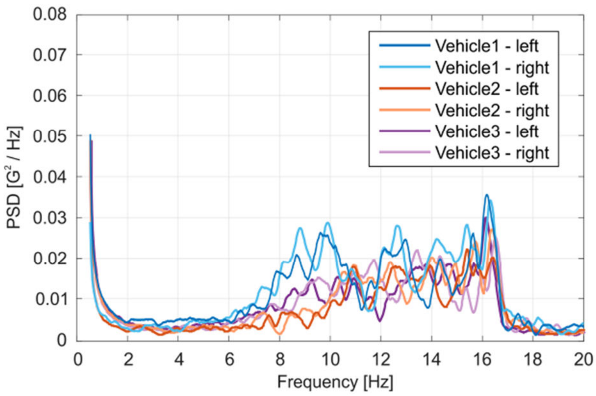

Fig. 4 - Accelerometer A1 power spectral density for both front wheels of three different vehicles.

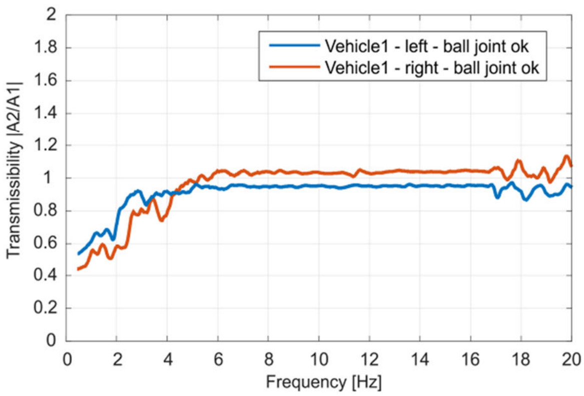

Fig. 5 - Transmissibility results for vehicle 1, with two good ball joints.

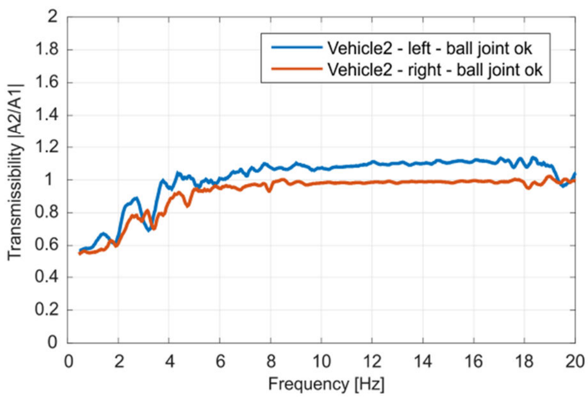

Fig. 6 - Transmissibility results for vehicle 2, with two good ball joints.

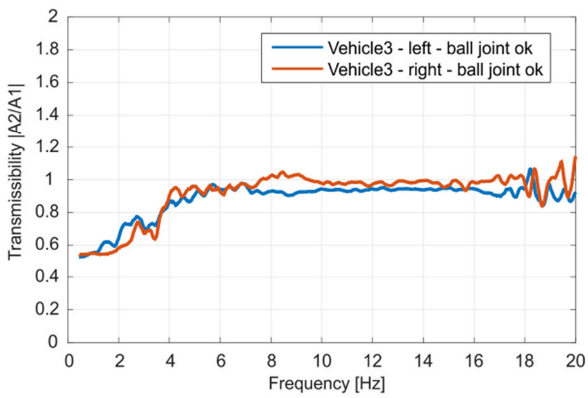

Fig. 7 - Transmissibility results for vehicle 3, with two good ball joints.

Furthermore, Fig. 8 compares the transmissibility obtained for both front suspension ball joints of the vehicle 4, where the right one is damaged. While the transmissibility mean value is related to the position on the accelerometers and its alignment, oscillations in the transmissibility curve were observed in the excitation range (7 Hz to 17 Hz) and for frequencies above (> 17 Hz and with no input, A1, excitation) for the faulty ball joint.

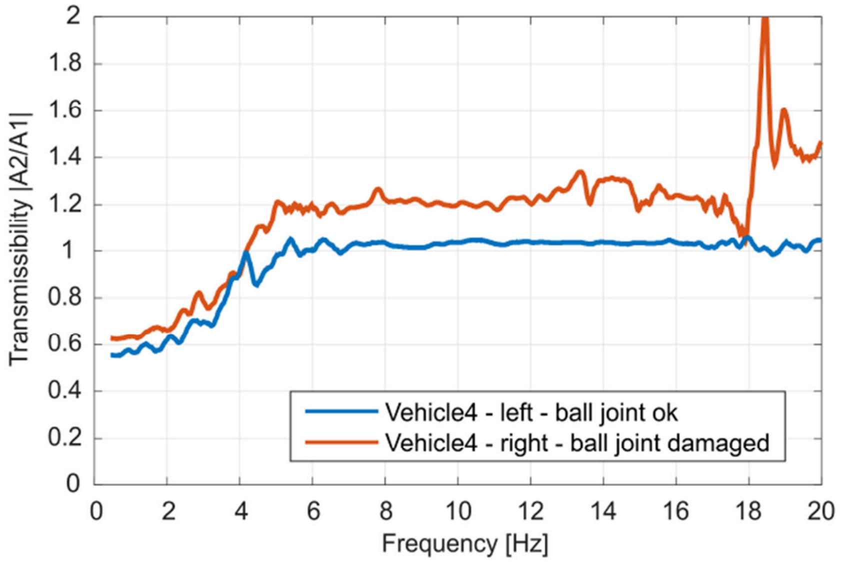

Fig. 8 - Transmissibility results for vehicle 4, with a good ball joint (left side) and a damage one (right side).

To verify the accelerometers placing effect in results, a vehicle was tested using different positions and working axis for the accelerometers (as shown in Fig.9). In cases a) and b) accelerometers were fixed near to the ball joint, while, in case c) accelerometers were placed in other suspension parts (also connected to both sides of the tested ball joint) far from the ball joint. The transmissibility results, shown in Fig. 10, confirm that for frequencies in de excitation range and above (> 6 Hz for vehicle 1), the mean value is a function of the accelerometer alignment and calibration, and it should not be used to identify damaged ball joints. For low frequencies, it was verified that results depend of the accelerometer axis used.

a) b) c)

Fig. 9 - Same vehicle tested with different positions for the accelerometers:
a) position 1, b) position 2 and c) position 3.

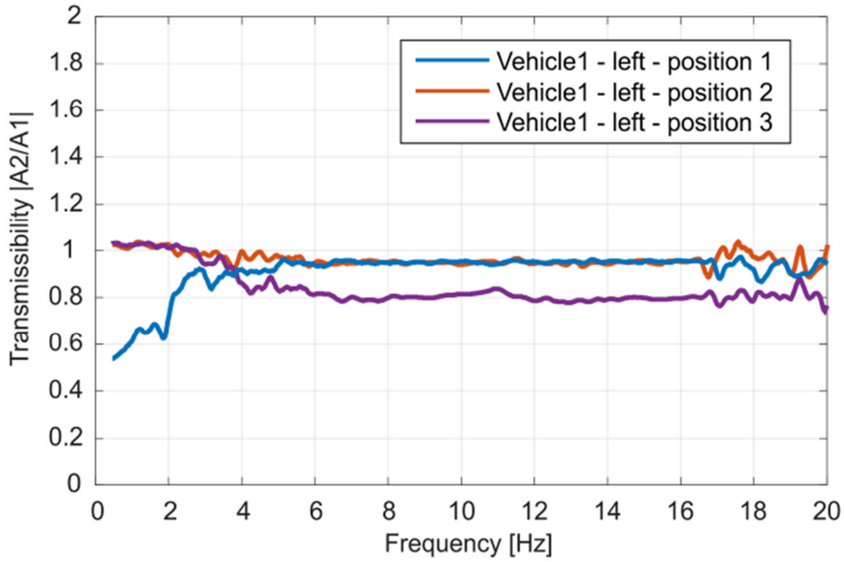

Fig. 10 - Transmissibility results for the same ball joint but with different positions for the accelerometers.

Moreover, additional tests were performed in another vehicle, named vehicle 5, where the right ball joint was successively unfasten (enlarging its clearance/looseness), to simulate its wearing/damage condition. As the transmissivity results for the right ball joint show (Fig. 11), the amplitude variation (modulus of the difference between its maximum and minimum values) of the transmissibility in the excitation range (from approximately 6 Hz to 17 Hz, for vehicle 5) and/or in frequencies above (>17 Hz) are proportional to the looseness/wearing state of the tested ball joint, and therefore, may be used as a quantitative indicator of its condition.

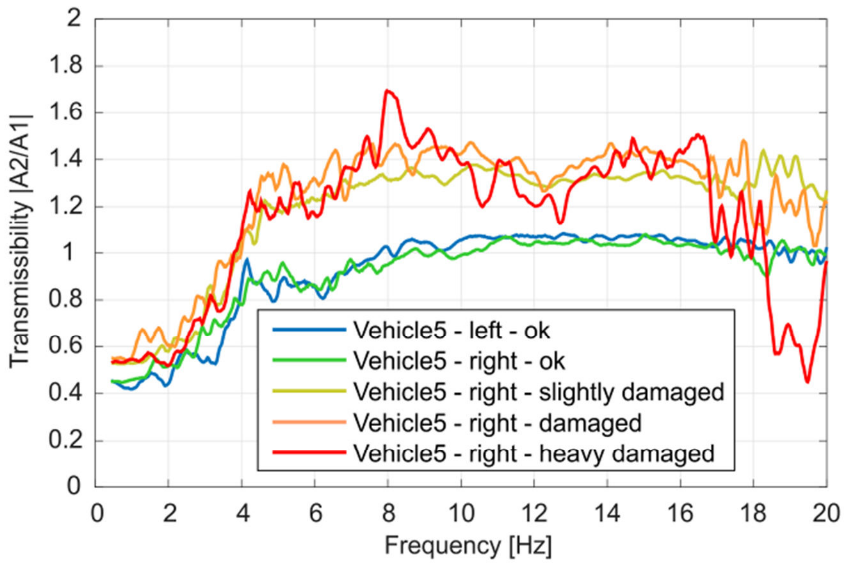

Fig. 11 - Transmissibility results for a vehicle, where the ball right joint was progressively unfasten.

CONCLUSIONS

The obtained results validate the proposed methodology to evaluate the wearing condition of ball joint in vehicle suspension, using the suspension tester and its excitation.
The accelerometers orientation plays no effect in the assessment, and its placement could be relaxed. Thus, making the methodology viable to be used in practice, where multiple geometries of suspensions are available and small time to do the test is required.
The post processing calculations of the transmissibility and the quantitative characterization of the ball joints wear condition /looseness, can be included in the proposed tool, which in turn will send a test report to the centralizer system (already available in vehicle inspection centers).
Such a system is a reliable alternative for the visual inspection of ball joints performed nowadays, less prone to errors and miss diagnosis, and will be a step forward towards vehicle and road safety.

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