568. Analysis of Vibration Effect in Cars and Driving Quality

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(Received 16 January 2010; accepted 10 September 2010)

Abstract. Contemporary research in the automotive vibration control area is well-developed. Ongoing studies are focusing on the quantification and identification of vibration sources. Vibration influence is a considerable effective factor in almost all industrial fields as well as in car driving as it is a concern related to ride comfort. Automotive industries are developing constantly and one of the important problems in this field is suspension and related vibration issues. Drivers and passengers in vehicles are directly affected by vibrations. In regard to this problem vibration control is improving continuously in automotive industry worldwide including Turkey. Vibration occurs in two ways: structural vibrations and engine vibrations in cars. Vibration levels of a passenger car have been measured and simulated in this study by means of experimental method and developed program respectively.

Keywords: vibrations, automobile, suspension, driving, comfort, analysis.

Introduction

Many drivers and passengers are exposed to a whole-body vibration on a road. Vibration is one of the main factors affecting travel comfort. Currently, there are two main standards for evaluating vibration with respect to human responses to the whole-body vibration. There are several differences in the measurement, evaluation and assessment procedures defined in the two standards. For example, BS 6841 (British standards) recommends measurement of vibration on the seat [1]. In ISO 2631 [2], it is about axes vibration measuring in several axes.

Car driving comfort has been an important interest for years and object of multitude of investigations on reduction of vibration values. Vibration is transferred from the seat, the steering, wheels, and pedals to human body parts. These vibration values of frequency range mainly from 20 to 100 Hz have been decreased [3]. It is an important problem from the viewpoint of ride comfort and maneuverability to reduce vibration transmitted to the human body. Structural vibration of a car body is caused by the engine, wheels, chassis and airflow [4]. Drivers or passengers of cars are exposed to vibrations that are directly related to the characteristics of the vehicle and road surface. Vibration sources come from conditions on the road, force of tire caused by the ups and downs of the road surface. The quality of road surfaces and the automobile suspension systems are also parallel with reducing vibration. Some vehicles have greater magnitude of vibration in fore or aft. These vibration are transmitted to the buttocks and the back of the occupant along the vertebral axis via the base and back of the seat. Exposure of the vibration the whole body of the drivers and are influenced by seating dynamics. Some seats can reduce as well as magnify vibration. In addition, the pedals and steering wheel transmit additional vibrations to the feet and hands of the driver [5]. In long journeys passenger and drivers feel fatigue, cramp, instability, numbness and some body pain. Significant amount of vibration transmitted to the driver or passenger is influenced by the posture of the person in a car.

It is an important problem from the viewpoint of ride comfort and maneuverability to reduce vibrations transmitted to the human body. When a driver sits on a vehicle seat, s/he chooses a positioning of the seat to operate the pedal easily. The seat may be moved backwards or forwards according to the stature of a driver in order to operate the pedals without difficulty. Studies of the transmission of vertical vibration through the cushions of conventional seats have shown that there is usually amplification at low frequencies, often with a resonance at about 4 Hz, and attenuation only at frequencies greater than about 6 Hz. Few studies have investigated the transmission of fore–aft vibration through seat pan cushions, but some data suggest that in the fore–aft direction the transmission is close to unity over a wide range of frequencies [6, 7]. The spacing between the steering wheel and the body then becomes small. The driver has to bend the arm considerably to operate the steering wheel. Such a tendency is often seen for woman drivers and taxi drivers. To keep the space in a back seat comfortably large, the driver's seat is often moved forward as much as possible for the taxi driver. We are interested in the elect of driving posture on vibration experienced by the human body. Several investigations of the elects of postural changes have been reported. Fairley and Griffin investigated the apparent mass of the seated human body [8].

This research examines the influence of seat vibration for driver and passenger and steering wheel vibration for driver. Vibration (vertical acceleration) was measured in the front driving seat and steering wheel point.

Experimental Design

Fig. 1. Measurement equipment

A set of Bruel and Kjaer Instruments equipment was used for vibration measurements in this experiment, namely Type3560-L. This equipment consists of a general purpose sound level meter, a triaxial seat accelerometer, and a serial interface module. That vibration measurement set complying with the ISO 2631 standard.

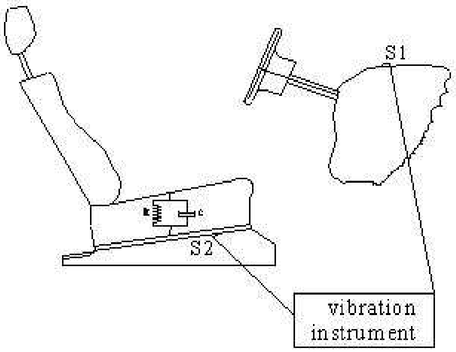

Fig. 1. b Measurement equipment schematics

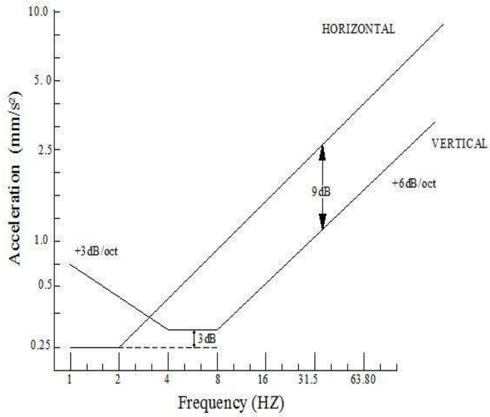

Fig. 1. c Sensitivity of human body against vibration

Car is Opel Astra (2000). Accelerometers are mounted in two points in this car. One of them is fore of steering wheel (Signal 1- S1), other is mounted under the seat on strict part (Signal 2 – S2). Both measurement points are shown in Fig. 1.a and Fig 1.b. Measurements (FFT applications) were performed on a motorway and at all gear speed accelerations. Steering wheel vibration is measured in point S1. With S2 measured seat vibration hard part that soft part of seat is mounted on this hard part. On account of this passenger feels vibration less than measured vibration. The seat consisted of a backrest (reclined at 15° to the vertical) and a seat pan (inclined at 12° to the horizontal). Characteristic of sensitivity of human body to vertical and horizontal vibration is given in Fig. 1. c (ISO 2531).

In each measurement FFT analyzer registers frequency and time associated with acceleration values. During 1 minute, the device 88 times in total performs FFT analysis and displays "average" measurements. For example, during 1 minute in the 1st gear at 20 km/h speed and 88 measured by the average value was graphing. These measurement was made in speed g1 (gear 1), g2, g3, g4, g4(80), g5, g5(110) g5(120).

Table 1. Scale of discomfort suggested in ISO 2631 [2] and BS 6841 [8]

Less than 0.315 m/s^2	Not uncomfortable
0.315-0.63 m/s^2	A little uncomfortable
0.5-1 m/s^2	Fairly uncomfortable
0.8-1.6 m/s^2	Uncomfortable
1.25-2.5 m/s^2	Very Uncomfortable
Greater than 2 m/s^2	Extremely uncomfortable

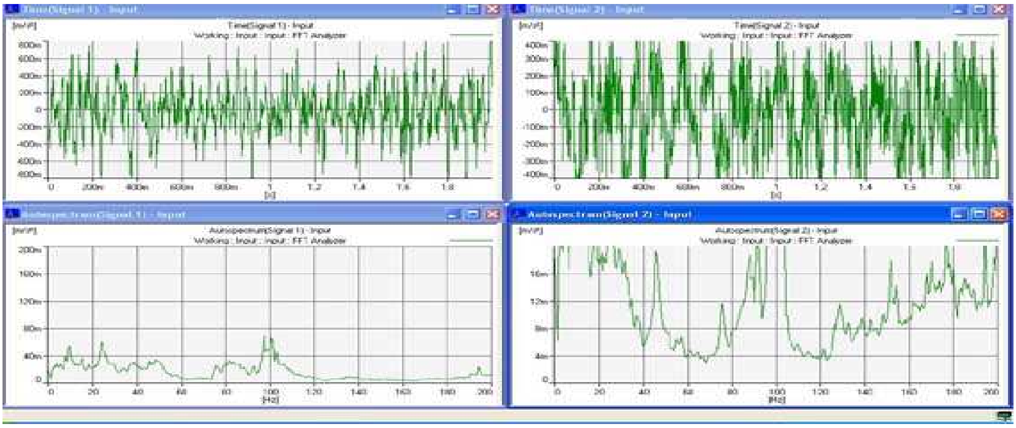

Fig. 2. Time and acceleration spectrum graphics in gear 1

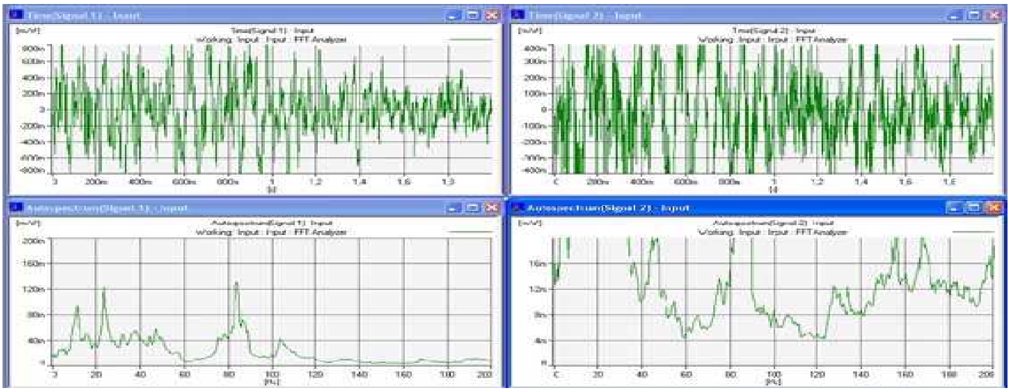

Fig. 3. Time and acceleration spectrum graphics in gear 2

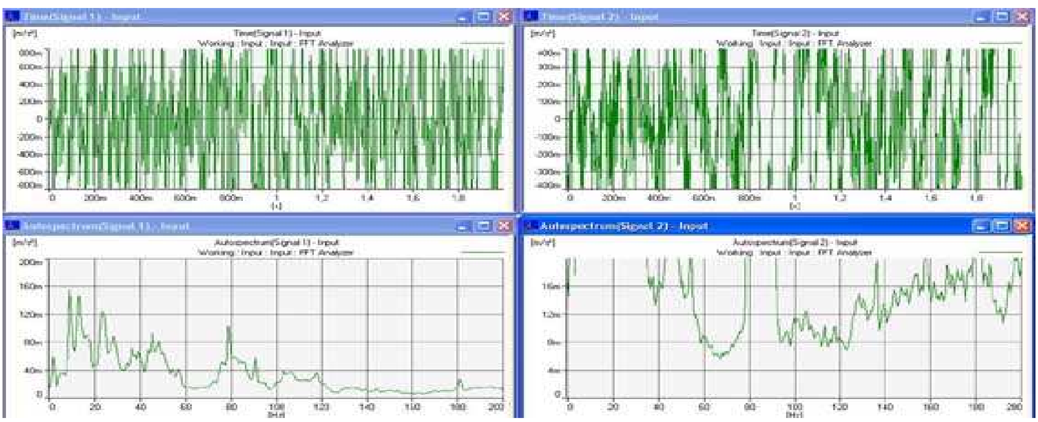

Fig. 4. Time and acceleration spectrum graphics in gear 3

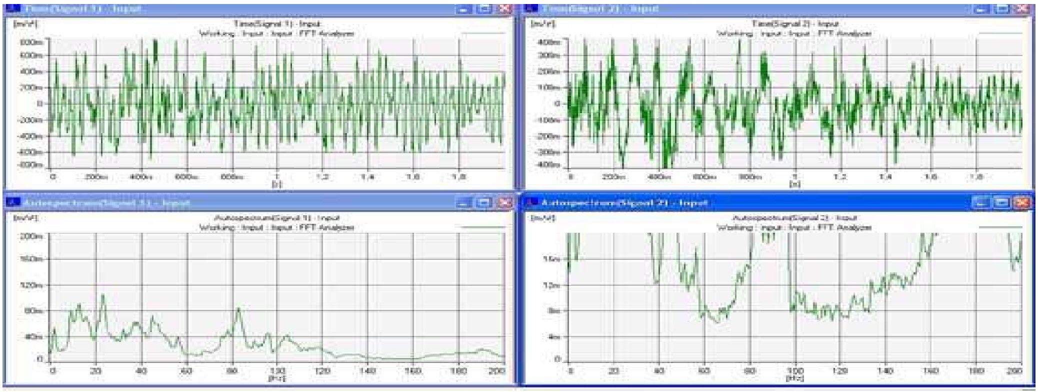

Fig. 5. Time and acceleration spectrum graphics in gear 4

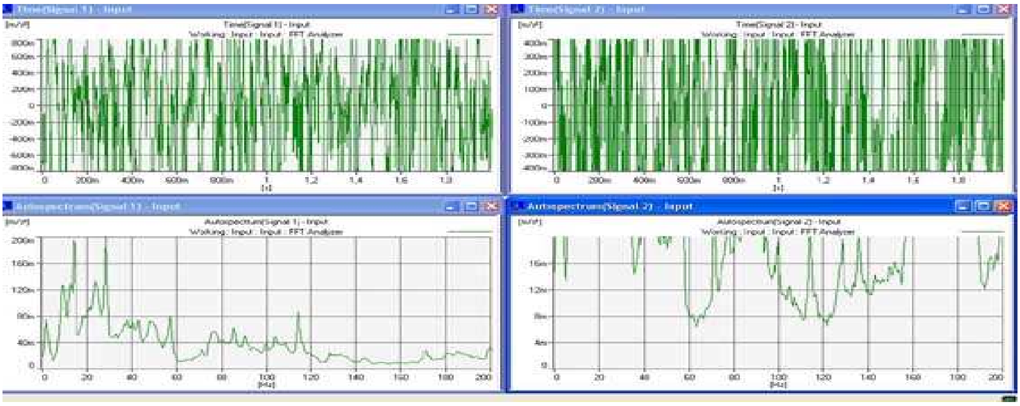

Fig. 6. Time and acceleration spectrum graphics in gear 5

With data obtained from experimental measurements, the following graphs were drawn. The acceleration-velocity and acceleration-frequency curves are illustrated in these graphs.

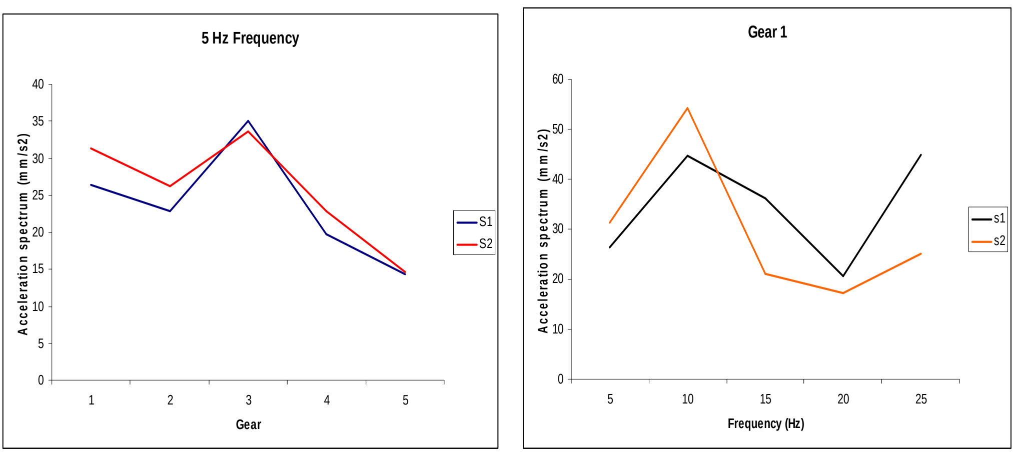

Fig. 7. Speed (g1) and frequency (5 Hz) coherence

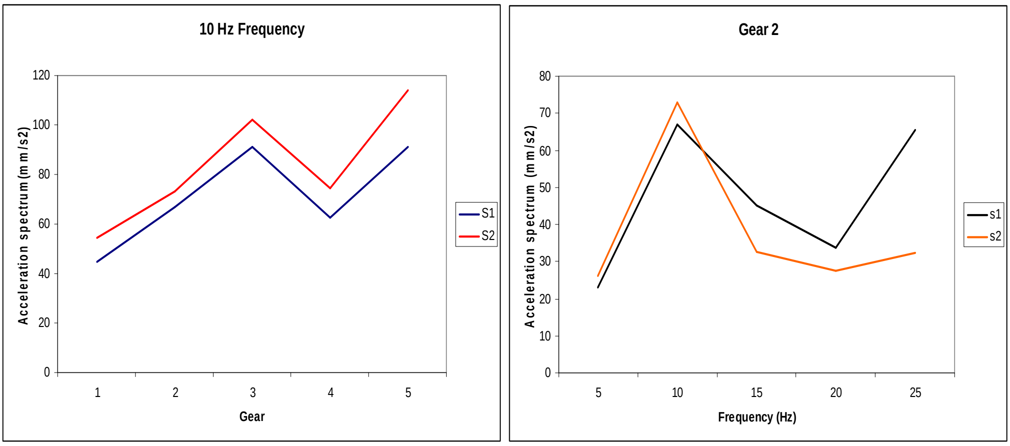

Fig. 8. Speed (g2) and Frequency (10 Hz) coherence

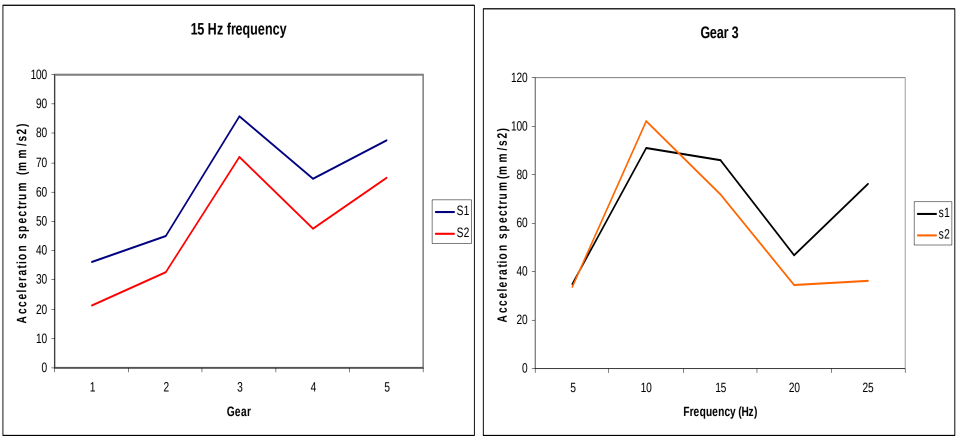

Fig. 9. Speed (g3) and frequency (15 Hz) coherence

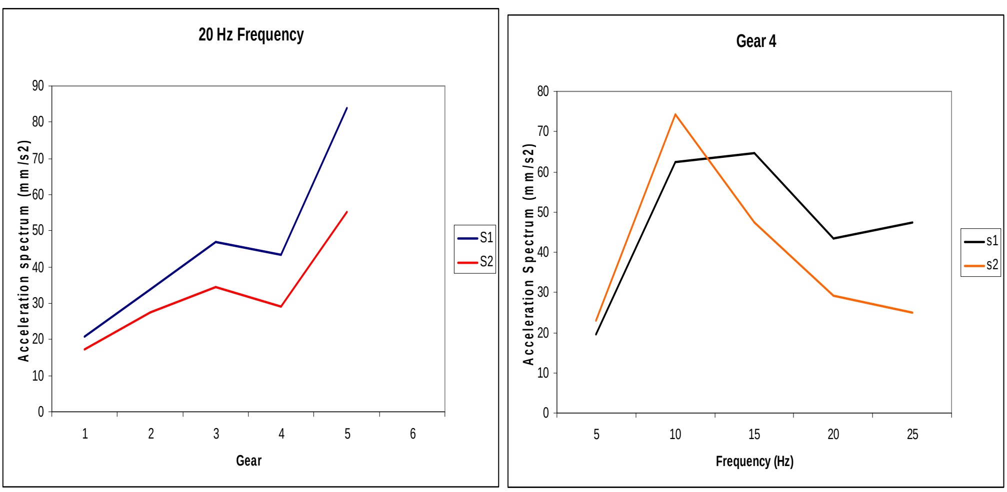

Fig. 10. Speed (g4) and Frequency (20 Hz) coherence

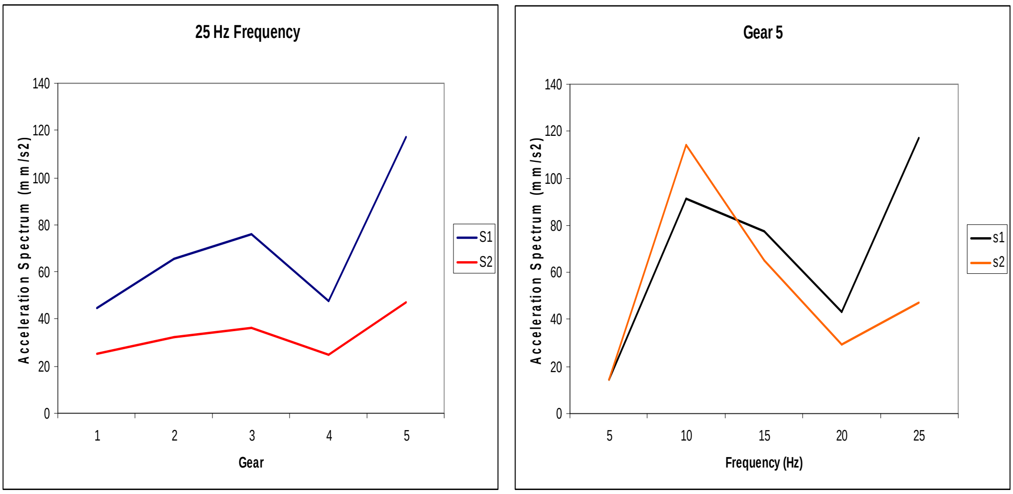

Fig. 11. Speed (g5) and frequency (25 Hz) coherence

Results of analysis

Test results indicate that possible explanations of this finding is that in the course of the car ride lower acceleration produces lower frequency too. In the same way in low gear the vibration value is lower (Fig. 7). Medium-speed and gear size increased vibrations rapidly (Figs. 8-9). Especially at the 4th and 5th gear, vibration value and curve is quickly increased (Figs. 10-11). Provided results indicate reduction of the vibration between the 4th and 5th gear and also we are aware of reduction of fuel consumption in that speed range between graphics of Fig. 7 to 11. Moreover, although low-speed vibration is high in the seat but in mid-and high-speed steering wheel vibration is more then seat vibration. According to the results of FFT analysis, ISO 2631/1 [2-8] standard of driving comfort indicators demonstrate driving comfort in this case. However, bad road conditions, high speeds and sudden stop-act induce considerable vibrations thereby dramatically deteriorating driving comfort.

Conclusions

As it is known ride comfort and performance are affected negatively by excessive vibration. Several investigations of the elects of postural changes have been reported. Fairley and Griffin [9] investigated the apparent mass of the seated human body. The arm angle, seat position, steering and pedal system are very important for driving comfort. Passenger car floor and seat vibration levels have no significant correlation with engine displacement or vehicle weight. On average, levels are about the same for all cars. Contemporary cars have developed with respect to ride comfort. From the perspective of driving posture, an arm angle of about 120° degrees is preferred with respect to ride comfort and handling of the steering wheel and pedals [9].

The transmissibility and the resonance frequency vary with body parts. It is desirable to reduce the vibration experienced by arms and legs in order to operate the steering wheel and pedals. But, in ride comfort, the amount of vibration for the head, the chest, and the hip may be more important. It is therefore necessary to investigate the vibrational characteristics of various body parts [10].

In terms of vertical acceleration, passenger car floor vibration has increased by roughly 0,13 to 0,3 m/s^2 over the last ten years. Seat and floor vibration levels have no significant correlation with engine displacement or vehicle weight. When vehicle speed increase seat vibration is not impacted but it causes a moderate increase in floor vibration.

Vibration test demonstrated that for achieving lower vibration levels, car maintenance must be performed, high speeds and immediate stop-act avoided, suitable seat position ensured, good road conditions and constant acceleration used.

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