Setup of an assessment service for human body vibration analysis in the laboratory and on the field

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The Instituto de Biomecánica de Valencia (IBV) has developed an integral service for assessing mechanical vibrations that affect the human body in the transport sector. The aim of this service is to assess vehicle seats from a dynamic point of view. The service is complemented with the methodology and instrumentation setup required for assessing vibrations in actual field conditions that can influence the comfort and health of users.

Introduction

The driver and the occupants of an automobile or any form of transport are subjected to mechanical vibrations. These vibrations have a negative effect on comfort and are perceived according to their magnitude, direction and frequency, the point of contact with the body and the duration of the exposure to vibration. In vehicles subjected to large-scale vibrations the most common symptoms that appear after a short period of exposure include fatigue, insomnia, headaches and tremors.

During extended exposure to this type of vibrations, as in the case of professional drivers, there are potential risks for health and safety. In these cases, muscular-skeletal lesions and other pathologies (cardiovascular alterations, breathing alterations, etc.) may also appear. Furthermore, vibrations that invade the entire body can affect the way people drive, increasing the risk of accidents. Exposing a driver to vibrations results in loss of attention, disrupting the central cognitive mechanisms which are responsible for processing short-term memory.

Given the potential risks associated with exposure to vibrations, it is important to consider the phenomenon of vibration during vehicle design processes. Once the driver seat and the passenger seats have been designed, it is necessary to ensure that the levels of exposure to vibration are below the recommended limits.

Laboratory for analysing the dynamic comfort of vehicle seats

The comfort of a seat depends on both static and dynamic aspects. For this reason, the Institute of Biomechanics of Valencia (IBV), in collaboration with the Department of Mechanical and Materials Engineering (DIMM) of the Polytechnic University of Valencia (UPV), has created a testing laboratory for dynamic assessment of vehicle seats subjected to vibration (**Figure 1**).

Figura 1. Laboratorio de ensayos dinámicos de asientos de vehículos.

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Figure 2. Electrodynamic driver used in the platform.

Figure 3. Emergency stop mushroom button within the reach of the test subject.

The laboratory is equipped with a platform which produces vibrations by means of an electrodynamic driver (**Figure 2**). The control system can select the input signal of the driver and induce the movement of the bed plate. A system for adapting various types of seats (car seats, seats of railway vehicles, etc.) is provided on the platform. The assembly is completed with a footrest to ensure the feet are subjected to a similar amount of vibration as the seat.

The driving signal of the platform can be adapted so as to represent the vibrations experienced by a moving vehicle. It has also been decided to use white noise as an input signal, since it is a random temporal signal which is similar in nature to a signal measured in a vehicle, while also guaranteeing that the signal contains all the study frequencies, all with the same spectral frequency. The drive signal can also be similar to an actual signal of vibrations recorded in a vehicle. This makes it possible to check the performance of the seat when subjected to vibrations identical to those to which it may be exposed on a road or in specific circumstances.

The platform complies with the guidelines provided in the UNE-EN ISO 13090-1:1999 standard governing safety aspects in experiments conducted with persons subjected to vibrations. It has a controlled emergency stop system, which is activated in the event of a system failure or when the subject of the test needs to stop the platform by pressing a mushroom button (**Figure 3**).

Platform vibration is measured using a specific vibration-measurement device. An accelerometer is placed at the base of the seat in order to measure the input drive, and a disk accelerometer is placed inside the seat (specifically designed for measuring vibration at the person-seat interface) to record the vibrations transmitted to the user. The relationship between the two signals makes up the dynamic behaviour of the seat against mechanical vibrations (**Figure 4**).

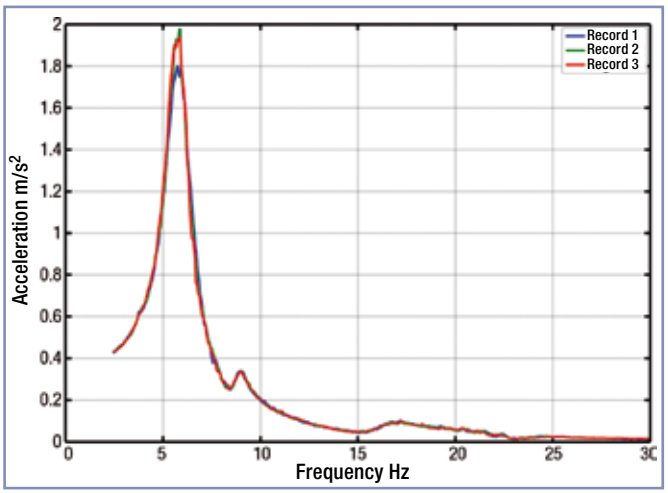

Figure 4. Frequency response function of an automobile seat.

The test is completed with a procedure for subjective assessment of seat comfort by the users. The seat is assessed according to static criteria (comfort status, dimensions and materials) and dynamic criteria (degree of discomfort caused by the perception of vibrations).

The vibration platform is mainly used for designing seats while taking dynamic aspects into consideration without needing to install the seats in the vehicle. Moreover, the platform guarantees controlled, repeatable tests, allowing us to compare the dynamic behaviour of several seats in order to select the one that it best suited to the nature of the vibrations.

The platform is especially useful during the seat design stage, since the components of the seat have a major influence on the dynamic comfort of the user. The use of certain materials for manufacturing the seat and the backrest can help absorb vibrations. If the seats have suspension systems for reducing the potential vibration transmitted to the occupant these need to be assessed, since a system that is unsuitable for the nature of the vibrations experienced by the vehicle may cause greater transmission of vibrations than a seat without any form of suspension.

Measurement and assessment of vibration measurements in the field

Assessment of the driver's seat

Professional drivers as a whole (road transport and railway vehicles) are exposed to mechanical vibrations in their vehicles during extended periods of time (**Table 1**). This population group is most exposed to the negative effects of vibration..

Table 1. Driver seats that may be exposed to vibration.

Professional driving by road (buses, trucks, vans, etc.)
Railway vehicles (subways, trams, engines, high-speed rail, etc.)
Machinery (industrial, earthworks, maintenance, etc.)
Farming vehicles (tractors, harvesters, etc.)
Others (armoured combat vehicles, etc.)

Directive 2002/447/EC defines the minimum health and safety provisions relating to the exposure of workers to risks associated with vibrations. This Directive makes it compulsory to assess the levels of mechanical vibration to which workers are exposed in work places that are subject to vibrations.

The assessment consists of quantifying the risk by determining the normalised daily exposure value parameter A(8). Once the measurements have been taken and the signal has been processed with weighting filters to take into account the influence of the drive frequencies on the human body, the value A(8) obtained is compared with the limit daily exposure values and the daily exposure values that give rise to an action, as set forth in the Directive (**Table 2**).

Table 2. Limits set forth in the Directive 2002/447/EC.

VIBRATION TRANSMITTED TO THE WHOLE BODY	
Standardised daily exposure value for an 8-hour period which gives rise to an action	Standardised daily exposure limit value for an 8-hour period
0,5 m/s^2	1,15 m/s^2

If the level of vibration in the study is higher than the exposure value which gives rise to an action, the health of the worker must be adequately monitored. If the exposure limit values are exceeded, immediate measures must be taken in order to reduce exposure.

The IBV has the equipment required for measuring and assessing vibrations in the driver's seat in accordance with the methodology described in the Directive 2002/447/EC (**Figure 5**).

Figure 5. Vibration acquisition device for measuring driver seat vibrations.

These vibration limit criteria can also be used during the design phase. By measuring the input vibrations of the seat (devices installed in the floor of the study vehicle) and obtaining the dynamic behaviour of the seat (on the test platform), it is possible to select a seat with the necessary level of absorption to ensure that the vibrations to which the driver of the vehicle would be exposed are below the limit value.

Assessment of passenger comfort

The vibration measurements are taken at the interfaces between the passenger and the vehicle (seat, backrest and floor). These measurements are analysed according to their amplitude and frequency. The effect of the measured vibrations on the human body are assessed in a subsequent step.

The IBV has the resources required for measuring, assessing and analysing dynamic comfort aspects that affect the passengers of automobiles and railway vehicles.

The instruments, which comply with the requirements of the ISO 8041:2005 standard on measurement instruments for measuring human response to vibrations, comprise data-acquisition devices and transducers, which make it possible

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> to acquire temporal acceleration signals for subsequent processing and analysis (**Figure 6**).

Figure 6. Vibration acquisition device for measuring vibrations in passengers.

The methodology of the tests complies with the requirements stipulated in the reference standards for measuring vibration in the rail industry: ISO 2631-4:2001, ISO 10056:2001 and UNE-ENV 12299:2000.

Conclusions

The Instituto de Biomecánica de Valencia has designed and perfected a service for assessing vibrations in a laboratory by building a dynamic platform and, in the field, by measuring vibrations using specific instruments.

The methodology developed can be applied to any type of vehicle: automobiles, trucks, trams, subways, trains, etc.

The described service offers companies the possibility of checking the behaviour of seats from a dynamic point of view, assessing driver seats in public transport vehicles and analysing passenger comfort, as well as technical support for reducing levels of exposure to vibrations.

As a result of this service, the level of exposure to vibrations will be reduced, benefiting the users of all forms of transport, from drivers to passengers.

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