Structure borne noise inside a coach

Joanes Berasategi, Unai Galfarsoro, María Jesús Elejabarrieta and Igor Insausti

Mondragon University, Loramendi 4, Apdo 23, 20500 Arrasate, Spain
ugalfarsoro@eps.mondragon.edu

Nowadays the use of coaches as ground collective transport is generalizing in society and besides, its use is encouraged by all public institutions. Users of this type of vehicles request that they are comfortable, even more in long trips. Therefore, decreasing noise and vibrations inside the coach is a essential requirement to obtain a good quality of the vehicle and the satisfaction of the traveller.
To increase the vibroacoustic comfort it is necessary to know qualitatively and quantitatively the noise and vibration sources, as well as their transmission paths. Thus, in this work a procedure has been defined and applied to measure and analyse the vibration and acoustic behaviour of a coach in different operating modes: idling, three constant speeds, acceleration and deceleration. 32 acceleration and sound pressure signals have been acquired, corresponding to different interior and exterior points of the coach. The analysis of the acceleration autospectra has allowed to determine the contribution of elements like floor, glasses and lateral panels to the sound pressure perceived by the traveller in the passenger compartment in the different studied operating modes.

1 Introduction

A major goal of coach design engineers is to improve the comfort of passengers. Both noise and vibrations are important features to define the comfort of a coach, so it is necessary to know its vibroacoustic behaviour. In order to know the vibroacoustic behaviour of the coach a procedure to measure noise and vibration from has been established. With the results of these measurements the noise level inside the passenger compartment has been defined, together with the contribution of the vibrations of various components of the coach to the noise.

The selected model has been a luxury coach with advanced technology, designed to make long voyages. In this type of vehicles the comfort of passengers is very important.

In a vehicle there are different noise and vibration sources affecting differently to the interior noise [1], since the transmission of noise from the sources takes place by various phenomena [2]. The main sources are the engine, the gearbox, the transmission group, rolling motion and aerodynamics. The engine is the most important source because it is in operation at all operating conditions of the coach. The other sources come into operation when the bus moves, and the importance of rolling motion and aerodynamics increases as the running speed of the coach increases [3].

2 Procedure of experimental measurements

ISO 5128-1980 standard [4] details how to carry out noise measurements inside motor vehicles. Based on this standard the procedure for measuring noise and vibration on the coach has been established.

Measurements have been carried out on a flat road with asphalt in good condition and with a stable time without wind or rain. Traffic from other vehicles has not interfered during the measurements and operating conditions were as follows:

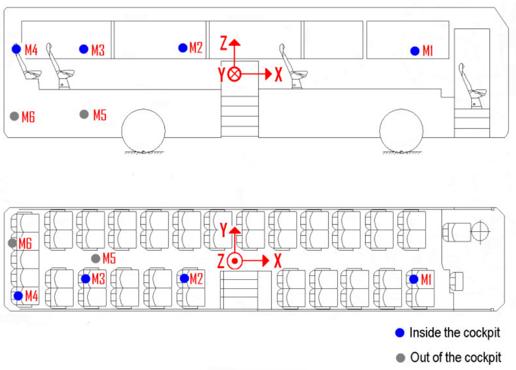
- Background noise: With all equipments of the coach off.
- Coach stopped and the engine at 500 rpm, 1400 rpm and 1800 rpm: The main objective of these measurements is to characterize the engine vibrations and the noise generated by these vibrations.
- Coach at constant speed of 50 km/h, 70 km/h and 100 km/h: In these measurements all major noise and vibration sources of the coach are present.
- Idling at 100 km/h: With this measurement the noise emitted by the engine is minimized. This way the contribution of other noise sources like rolling or aerodynamics is established.

32 acquisition channels have been used, of which six are for microphones. Two of these microphones are placed outside the passenger compartment next to the engine and transmission group. Figure 1 shows the distribution of these microphones M1 to M6.

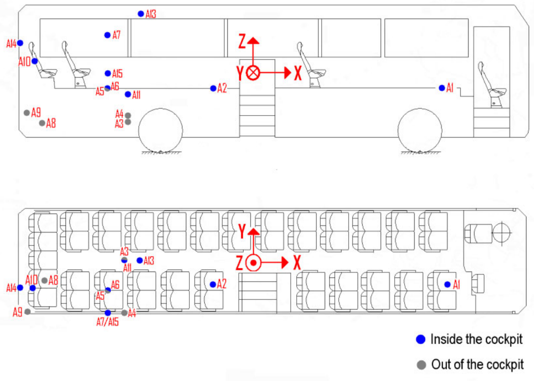
With regard to vibration, acceleration is measured in 15 positions, using ICP accelerometers. Four of the accelerometers are positioned outside the passenger compartment near the engine and the transmission group, and in these points triaxial accelerometers are used. The other accelerometers are in the interior. Figure 1 shows the distribution of accelerometers A1 to A15.

Finally, the engine revolutions are recorded in all measurements using a photoelectric tachometer.

In Figure 1 the main axes of the coach are defined, being X the longitudinal, Y the transversal and Z the vertical directions.



a) Microphones



b) Accelerometers

Figure 1: Position of transducers

The results shown below are representative of the selected coach model, because two coaches of this model have been measured and the results of both measurements are very repetitive.

3 Results

The analysis of the autospectra of the 32 signals acquired has made it possible to establish the contribution of the vibration of different elements of the coach to the acoustic pressure perceived by the traveller. All autospectra shown below are narrowband with a resolution of 0.625 Hz, and cover the frequency band from 10 Hz to 8 kHz. Besides, noise autospectra are A weighted.

The first important result is that the attenuation at frequencies above 1 kHz is very good, hence the noise problem occurs mainly below that frequency.

Next, as an example, the results of the measurements at idle and at 100 km/h are presented for being the most representative operating conditions for the use of the coach. The analysis carried out is focused below 1kHz, as it is in this band where higher noise levels have been detected.

Figure 2 shows the noise recorded by all microphones at idle. Microphones M5 and M6 are outside the passenger compartment next to the engine and the gearbox, while the other four are placed inside. This autospectrum shows that below 100 Hz the noise is similar in the inside and outside microphones, and also that the highest noise peaks in the interior are in this frequency band.

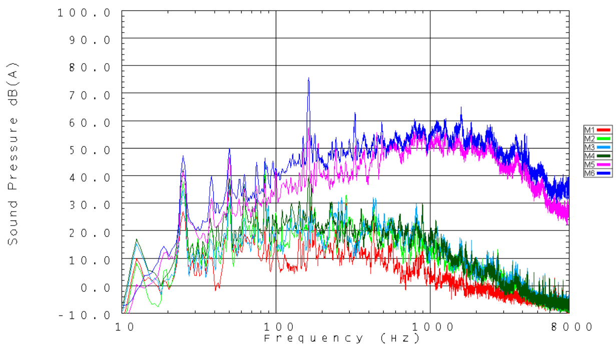


Figure 2: Noise autospectra of all microphones at idle.

In the autospectrum of microphone M4, Figure 3, the two main peaks are at 25 and 50 Hz. It is worth to remark that in the idle measurement the engine rotates at 500 rpm, so the rotation frequency is 8.3 Hz, and the main peaks at 25 and 50 Hz coincide with the third and sixth rotation order of the engine.

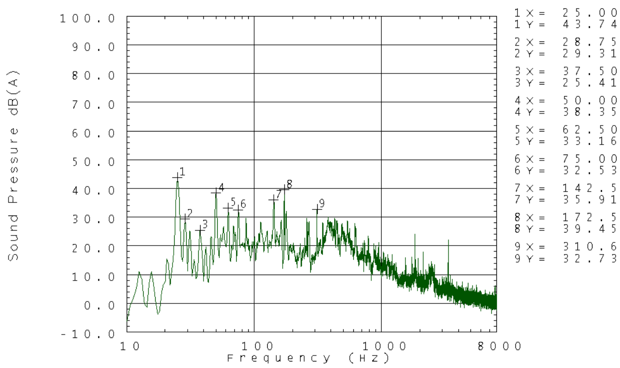


Figure 3: Noise autospectrum in the last row of seats M4 at idle.

The two main noise peaks at 25 Hz and 50, observed in the autospectrum of M4, are due to the vibrations of interior panels like the lateral glass (A7Y) or the lateral panel (A15Y), as shown in Figure 4 and Figure 5. In these figures these frequencies are identified as the main vibration peaks for these surfaces. Due to the size of these panels, the vibrations of these elements radiate noise efficiently to inside the passenger compartment.

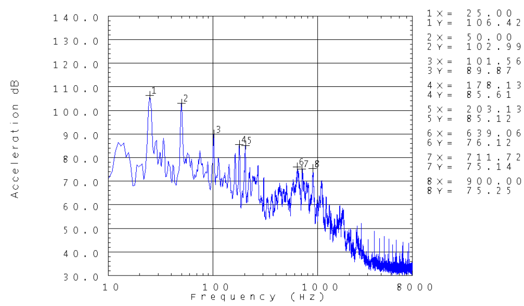


Figure 4: Vibrations in lateral glass A7 in Y at idle.

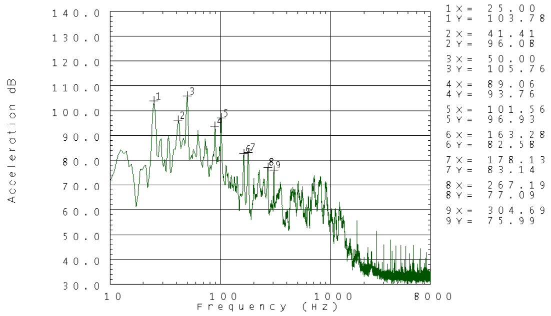


Figure 5: Vibrations in lateral panel A15 in Y at idle.

Finally, it is remarkable that the two vibration main peaks that can be seen on the lateral glass and the panel, Figure 4 and Figure 5, have their origin in the excitation force that the engine exerts on the transversal Y axis of the coach. This fact can be observed in the vibration autospectrum of a point of the chassis close to the engine, A8Y (see Figure 4), where the main peaks at 25 and 50 Hz are identified as the frequencies at which the vibration levels are higher, being these vibrations the source of the noise recorded by M4.

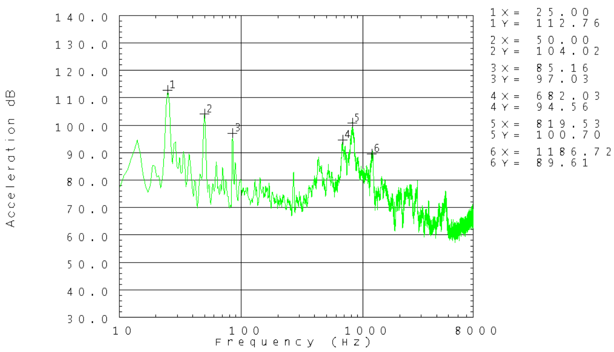


Figure 6: Vibrations in engine A8Y
in transversal axis Y at idle.

The analysis of the measurement at a constant speed of 100 km/h shows that the most important noise peaks inside the coach are present in the band from 100 to 500 Hz, as shown in Figure 7.

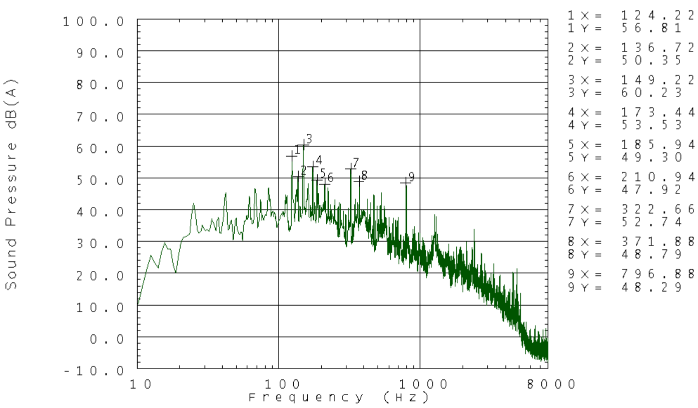


Figure 7: Noise autospectrum in the last row of seats M4
at 100 km/h.

Figure 8 and Figure 9 show that both the seats floor and the corridor have the highest vibration level at middle frequencies, from 100 to 500 Hz, and the main peaks coincide with the main noise peaks identified in Figure 7. Therefore, it can be concluded that the high vibration levels at middle frequencies detected in different zones of the floor of the coach, determines the interior noise in such frequency band.

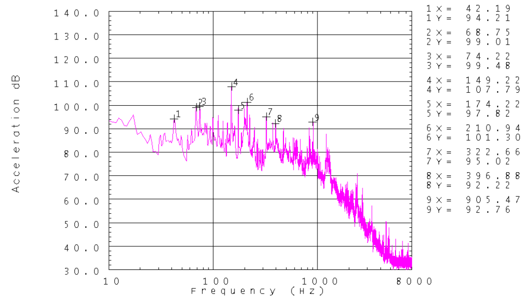


Figure 8: Vibrations in seats floor A6 at 100 km/h.

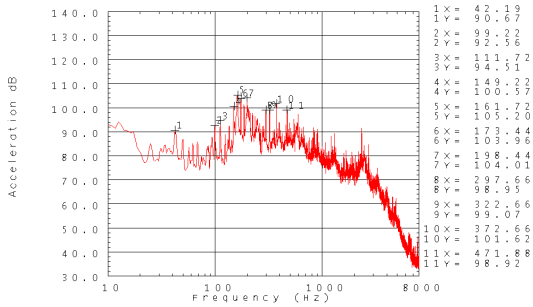


Figure 9: Vibrations in corridor floor A11
at 100 km/h.

Another fact which confirms that the vibrations of the floor of the coach contribute significantly to the interior noise, is the comparison between the results obtained in the measurements at 100 km/h and idling at 100 km/h. In idling at 100 km/h the noise and vibration of the engine and the transmission group is greatly reduced, so vibration of the seats floor at middle frequencies decrease. This fact affects the noise inside, as shown in Figure 11. Thus, while noise at low frequencies does not vary between the two operating conditions, at middle frequencies there is a decrease in the level of noise inside the coach.

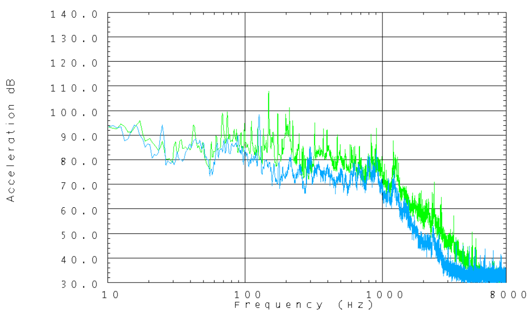


Figure 10: Vibrations in seats floor A6 at 100 km/h (-----)
and idling at 100 km/h (-----).

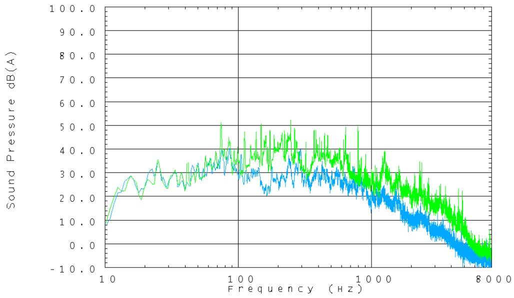


Figure 11: Noise in the interior M3 at 100 km/h (-----) and idling at 100 km/h (-----).

4 Conclusion

A vibroacoustic measurement and analysis procedure has been established for coaches. This methodology allows all tests to have a reference and makes it possible to carry out comparisons between different models and configurations of the coach.

The detailed analysis of noise and vibration autospectra has empowered to identify the source of the most important noise peaks inside the passenger compartment. In addition, how the sources of noise inside the coach change with the different operating conditions have been identified.

At present the project is being continued on the identification of airborne and structural noise and vibration transmission paths generated by the engine, the gearbox, the transmission group, the rolling motion and the aerodynamics of the coach.

Acknowledgments

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References

[1] Sang-Kwon Lee, "Objective evaluation of interior sound quality in passenger cars during acceleration ", *Journal of Sound and Vibration 310*, 149-168 (2008)

[2] Jeffrey S. Williams, Glen C. Steyer, "Experimental noise path analysis for problem identification in automobiles "

[3] AECOR, “Métodos de evaluación del ruido de rodadura” (12-2007)

[4] ISO 5128-1980: “Measurement of noise inside motor vehicles”.