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VIBRO ACOUSTIC CHARACTERIZATION OF A LIGHT METRO RAIL TRACTION SYSTEM

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Abstract

The vibro-acoustic characterization of a light rail vehicle is presented. Object of the study is the "SIRIO" platform, ANSALDOBREDA's proposal for city transport on rails. The approach followed can be distinguished in two different moments: on board measurements and pass by measurements. Both measurements were performed in order to separate traction noise (most relevant sources at low speed) from rolling noise.

INTRODUCTION

In recent years the abatement of adverse effects of noise on communities has become one of the most important and urgent tasks of transportation engineering. Exposure to noise has increased mainly along road traffic routes in cities and as a result the impact of road traffic on the environment is a persistent problem in contemporary society. Belonging to the necessity of reducing transportation system noise impact on urban and sub urban areas, AnsaldoBreda has planned a series of research activities together with the Department of Aeronautical Engineering focussed on different step of vibro-acoustic characterization of the transport vehicle. In a first phase the vehicle has been analyzed from a global point of view in order to asses its global acoustic behaviour, this step should include the evaluation of the role of the on board equipments, and the role of wheel-rail rolling noise on tram’s global noise levels emitted at the operative urban working condition. The relative measurement campaigns were performed in operative test rail in Milan. The second phase of measurements were performed in AnsaldoBreda factory test track in Pistoia, and were addressed to best distinguish the relative contribution of traction equipment and of wheel-rail interaction noise.

THE SIRIO PLATFORM

The Sirio platform is ANSALDOBREDA's proposal for city transport on rails. The technological and system concepts of the vehicle meet customer request through the aggregation of few elements. Thanks to the possibility of personalization, vehicles can reflect the image of the urban community in which they will operate. Sirio is a family of tram vehicles with continuous low floor to be operated on separate or shared line, its floor height is 350 mm from top of rail, its power supply is overhead or embedded power line. Minimum curve radius: 15 m. Wheel arrangement: possibility of 10 motor boogies. Rail gauge: standard or metric. Traction equipment: IGBT inverter. Body width: from 2.3 - 2.65 m.

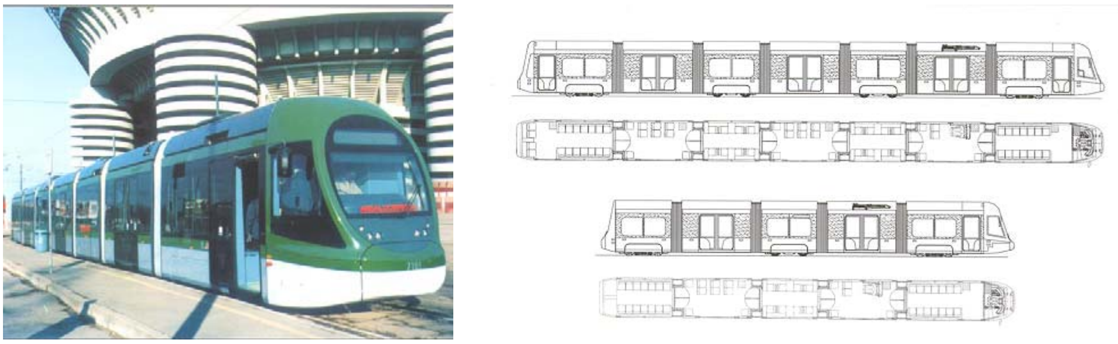

figure 1- Sirio Platform

METHODOLOGICAL APPROACH AND RESULTS

As already mentioned this work is based on two different measurement campaigns, the first one in Milan was made to characterize Sirio platform in order to detect its global acoustical behaviour and underline the most relevant noise sources; a second series of measurement campaign in AnsaldoBreda's factory test track in Pistoia where the attention was focused on traction noise equipment .

Global acoustic characterization

In this measurements campaign, held in Milan (figure 2a), microphones were positioned at standard distance of 25 m from the rail centre line (pass by location) and onboard , outside the vehicle, close to the inverter, near the conversion unit**,** near the motor boogie (see some details in figure 3a and 3b) and the trailing boogie (to distinguish the traction motor noise from the wheel-rail contact emission trough a noise spectra comparison relative to specific track condition). Different measurements were performed with the one and all auxiliary systems switched on and the tram stopped. Successively the vehicle runs at different operative speed and traction condition (acceleration, coasting and braking).

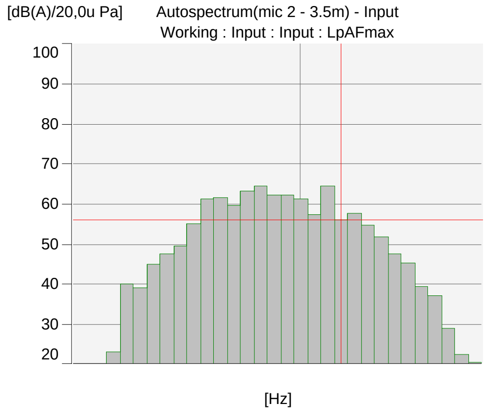

figure 2 Details of Milan measurement site(a) and an example of pass-by spectra (b)

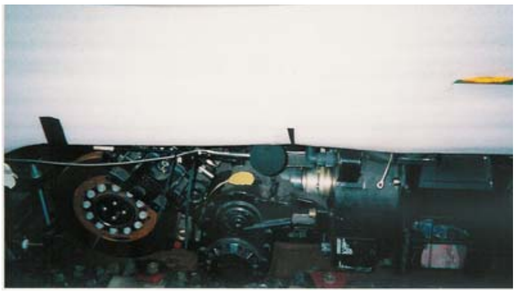

figure 3 Details of measurements device near the inverter (a) and the traction equipment(b)

As mentioned, tests were addressed to identify Sirio most relevant noise sources, so the attention was focussed on the electrical equipment on the roof (inverter and conversion unit), on traction equipment, the wheel-track interaction noise contribution was evaluated through the inspection of the trailing boogie noise emission.

First Phase Experimental Results

In figure 2a, a typical spectra, as measured at stand location, is reported. This picture gives some information regarding the overall level, but no information may be derived for what concern the noise sources ranking.
The comparison of results from on-board microphones, may, on the other hand, give useful informations about single sources levels and typical spectra.
In the next pictures are reported the results in 1/3 octave (20-20.000 Hz) band of the most relevant noise sources.
The inverter noise level is about 82dB(A) at various speed , the conversion unit noise level is about 83dB(A) at various speed.
These levels are much lower than the rolling noise (if referred at speed higher than 30 Km/h) and moreover of the electrical motor noise as shown in the next picture 4.

The comparison between motored boogie noise emissions and the trailing boogie noise emissions, as reported in the next figure 5, give evidence of such a circumstance.
As shown in the picture the overall level measured near the motored boogie is about 96 dB(A), and about 85 dB(A) near the trailing boogie.

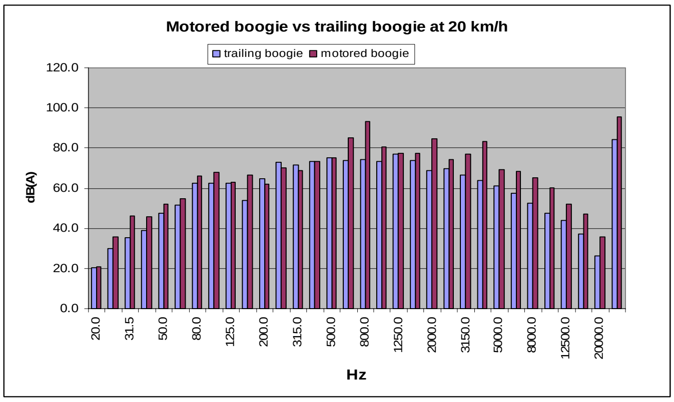

Figure 4 traction equipment vs rolling noise emission at 20 Km/h

As a result of this first measurement campaign it was so assessed that most relevant noise sources is represented by the traction equipment, whose noise spectrum is characterized by relevant emission in the 800 Hz 1/3 octave band.
The rolling noise also represent a relevant source, if we refer at speed higher than 30 Km/h; it will be also better investigated, even if the operative profile of the tram determine the low speed being the most critical conditions.

Second Phase, local acoustic characterization: Traction equipment and rolling noise

In the second phase of measurements, the attention was pointed out on traction and rolling noise in order to evaluate their contribution on the global noise emitted levels.

figure 4 Setup measurements detail in the motored boogie area

Measurements were performed on two separate step: the on board one and pass by one. For the on board measurements were used both microphones and accelerometers sensors displaced along the vehicle. Inside the vehicle 2 microphones and 2 accelerometers on the floor. Outside the vehicle, in the motored boogie area (figure 6) 2 microphones, 1 accelerometer on the boogie structure, 5 accelerometers on the engine. In the trailing boogie area (figure 7): 2 microphones, 1 accelerometer on the boogie structure, in next pictures is shown setup detail.

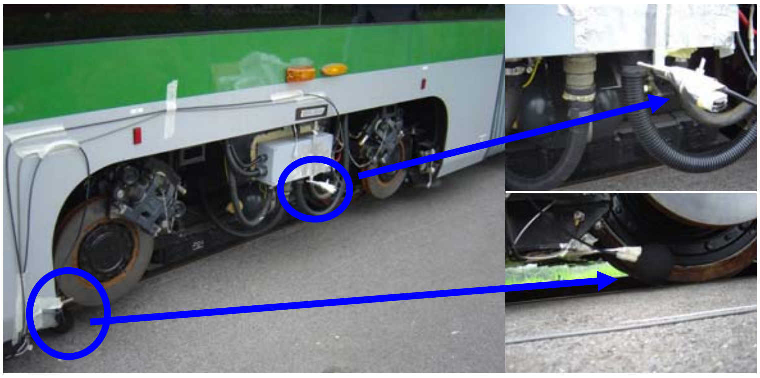

figure 5 Setup measurements detail in the trailing boogie area

Pass by measurements setup was composed by Microphone's "antenna" (3 sensors, horizontal/vertical alligned), Beamforming system: 42 channels (wheel array), 1 microphone's monitor station (7,5 mt from the center line), optical dual trigger system; next picture shows setup detail.

figure 6Pass by measurement setup

Second Phase Experimental Results: on board measurements

The accelerometers displaced on the engine are used to separate its different working condition in order to distinguish traction phase from coasting phase. Next figure shows the acceleration (**g**) measured by the sensor at the different phases.

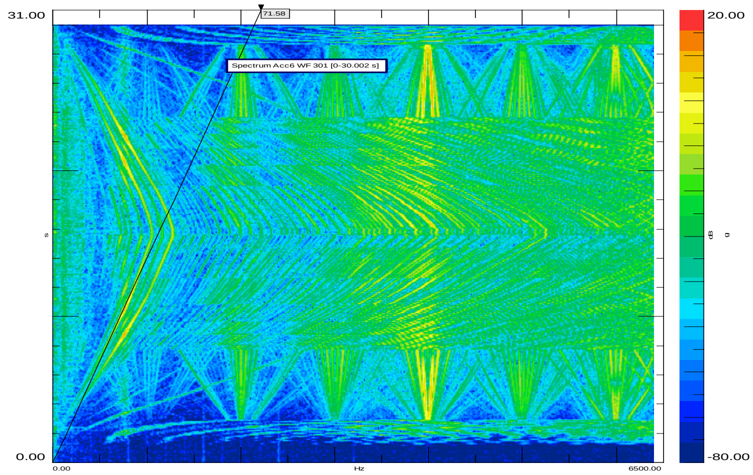

figure 7 vibrational level on the engine

In the following figures 8 and 9 are reported noise sonograms measured near motored and trailing boogie respectively; it appears clear the differences between the typical spectra, in terms of harmonics related to the electrical motor working conditions.

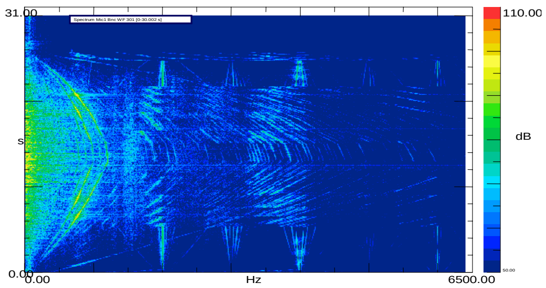

figure 8 detail of motored boogie microphone measurements

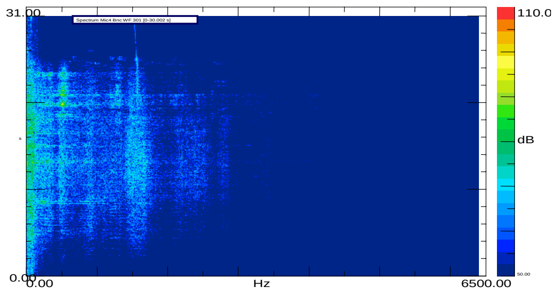

figure 9 detail of trailing boogie microphone measurements

The same comparison is reported in next figures 10 and 11 in terms of 1/3 octave noise spectra (details of sensor are showed in previous figures 6 and 7).

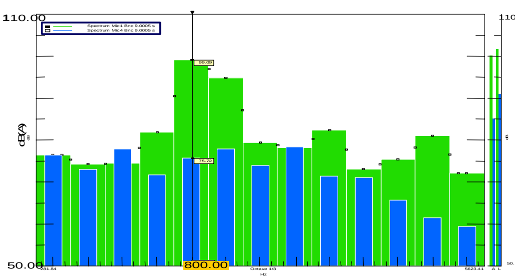

figure 10 acceleration phase1/3octave spectrum motored boogie(green) vs trailing boogie (blue)

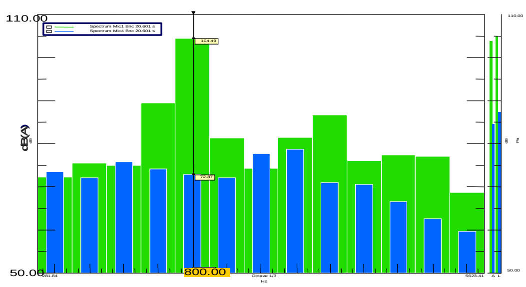

figure 11 breaking phase1/3octave spectrum motored boogie(green) vs trailing boogie (blue)

The comparison underline the differences between rolling noise and traction noise: the overall level measured by the sensor in trailing boogie area is about 15 dB less than measured in the motored boogie one in acceleration, traction equipment most relevant 1/3 octave band are represented by 800 Hz.
Noise overall level differences between boogies sound emission increases in breaking, also in this case 800Hz is traction equipment most relevant 1/3 octave band.

Second Phase Experimental Results: Pass by measurements

The following pictures 11 give a summary of the pass by measurement results. They confirm the evidence of the noise differences between the motored and trailing boogie (both in terms of level and spectra) .

figure 11 Pass by measurement summary

An "acoustic picture" as reported in figure 12 give a confirmation of these differences, being clear the harmonic contribution of the motor characteristic of the overall noise.

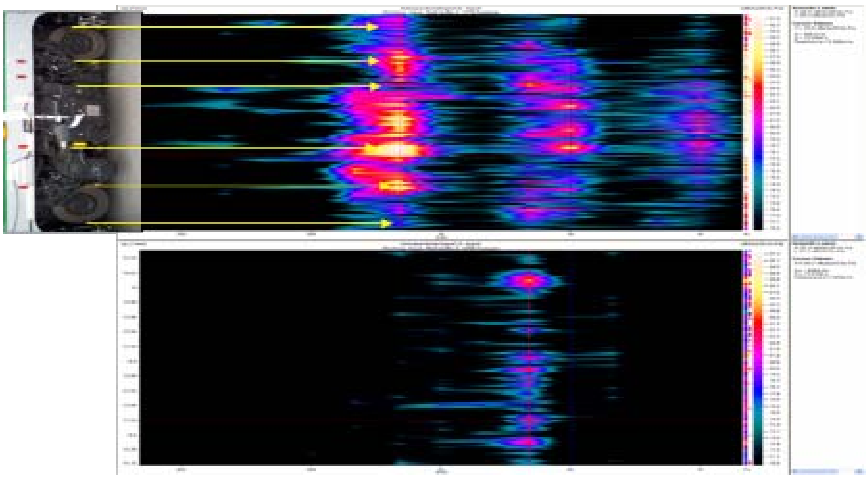

figure 12 Acoustic picture of the motored and trailing boogie area

CONCLUSIONS

As a conclusion of the activity it can be stated that a characterization of the exterior noise field of the SIRIO platform, has been assessed with particular attention to low speed regimes.
The parallel measurement of “pass-by” and on-board noise levels and spectra has permitted to point out a noise ranking and a single noise characterisation.
Among the different sources, it has been verified that the electrical motor represent the more noisy one, whose spectra is deeply characterised by the harmonic component of the electrical driving signal.
The results of this activity will so represent the input for successive activities devoted to the study and development of noise limitation strategies to be applied.

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