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Dipartimento di Progettazione Aeronautica

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WP E5: Noise from Traction Equipment and Running Gear

WP Leader: **Ansaldobreda**

Partners: Lucchini, Trenitalia, DB, SNCF

SubContractor : UniNa

S. Ferraiuolo , A. Miele
Ansaldobreda SpA
N. Rusciano, M. Viscardi, S. Melchionna
University of Naples "Federico II" – Dept. Of Aeronautical Engineering

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WP E5 Main objectives (TRACTION)

- ✓ ***to identify the state of the art concerning the noise emission due to electric traction.***
- ✓ ***to assess potential prototype solutions, taking into account integration into railway system constraints, global retrofitting feasibility and good cost/benefit ratio also from the maintenance point of view.***
- ✓ ***To provide prototypes of improved components so that noise reduction achieved can be evaluated in an assembled system.***

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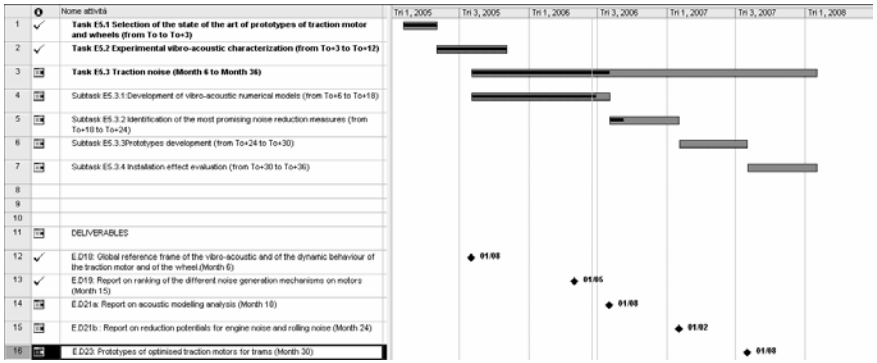
WPE5 GANTT



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Noise sources generalities

WP E5 objective

Tram Main Noise Sources

	External	Interior
•Rolling Noise •Squeal Noise	▪Medium-high speeds ▪Low speeds	▪Medium-high speeds ▪Low speeds
Traction Noise	▪Low speeds ▪Acceleration ▪Deceleration	▪Low speeds ▪Acceleration ▪Deceleration
Auxiliary equipments	Standstill/low speed	Standstill/low speed

State-of-the-art on Traction Noise 1/3

The noise sources related to electrical traction motor can be divided into two fields:

- Electromagnetic noise
- Windage noise

Windage noise is generated by the interaction of the moving parts of the rotor when the cooling air passes through the motor. The primary sources of windage noise in an induction motor are the fans and the rotor bars in the vent areas and at the rotor ends.

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State-of-the-art on Traction Noise 2/3

Magnetic noise has two principal components: constant-level magnetic noise and load related magnetic noise.
The constant-level magnetic noise is a result of the force and vibration that are generated by the interaction of the fundamental magnetic flux wave with the rotating magnetic parts of the rotor. This noise does not change in magnitude with load but can be minimised by the proper slot combination were established.
The load-related magnetic noise is generated when current is induced into the rotor bars under an increasing load. The electric current in the bars create a magnetic fields around the bars that applies an attracting force in the stator teeth. These radial and tangential forces, which are applied to the stator teeth, create vibration and noise.

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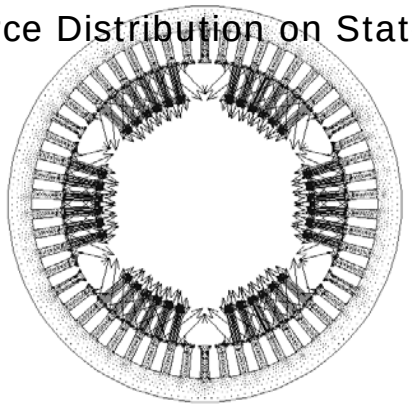
State-of-the-art on Traction Noise 3/3

Force Distribution on Stator



The forces applied to the stator teeth are not evenly distributed to every tooth at any instant in time; they are applied with different magnitudes at different teeth, depending on the relative rotor-stator-tooth location. This results in force waves over the stator circumference that will produce flexural modes *m* of vibration.

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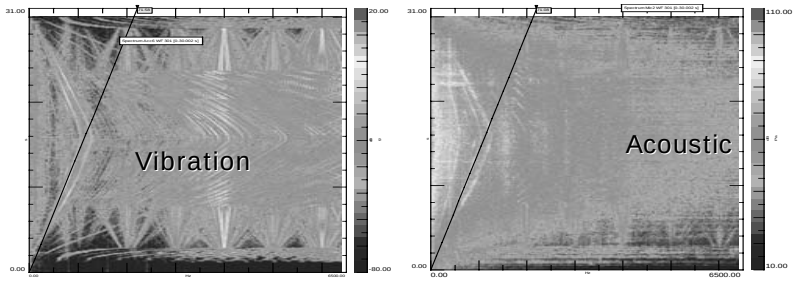
Vibro-Acoustic Measurement on the traction motor

Acoustics		Vibrations	
Sound intensity	Status	Modal Analysis	Status
	Completed		Completed
Beamforming	Status	Laser Vibrometry	Status
	Completed		Completed
		Vibration characterization of the motor on the vehicle	Status
			Completed

Vibro-Acoustic Measurement
On board acquisition



Detail of accelerometer acquisition (left) and acoustic one (right)

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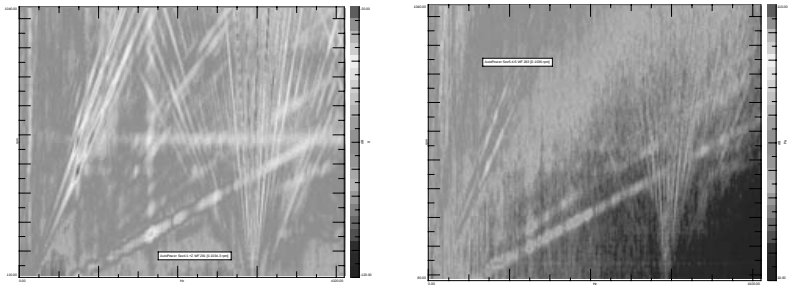
Vibro-Acoustic Measurement
Laboratory acquisition



Detail of accelerometer acquisition (left) and acoustic one (right)

silence

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Preliminary results

Measurements show a good level of correlation between acoustic and vibration behaviour; in every measurement engine first order was at about 75 Hz. The highest order at about 3 kHz are related to the electrical supplier, these order are less important from the acoustic point of view.

Comparing these measurements to those made in field campaign arises a good correlation between two condition test.

The preliminary test campaign described above has underlined a good accomplishment between their results, so a deeply engine vibro-acoustic investigation was planned trough laboratory test campaign by sound intensity and laser vibrometry acquisition.

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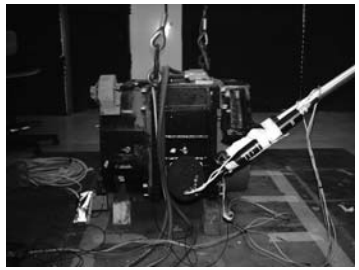
ENGINE SOUND INTENSITY MEASUREMENTS ISO 9614-1

To simulate different loading condition, power supply was given at various step of current frequency supplying; measurements were performed with 6 frequency alimentation: 15, 20, 25, 30, 35 and 38 Hz.



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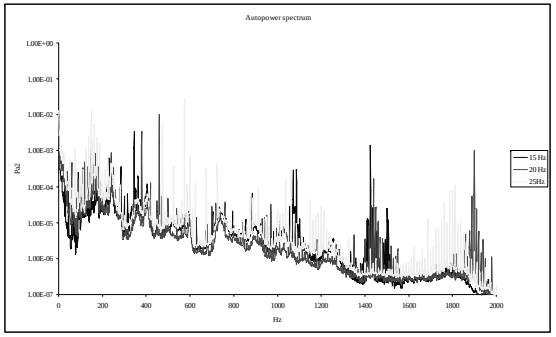
ENGINE SOUND INTENSITY MEASUREMENTS



Autopower spectrum as function of speed

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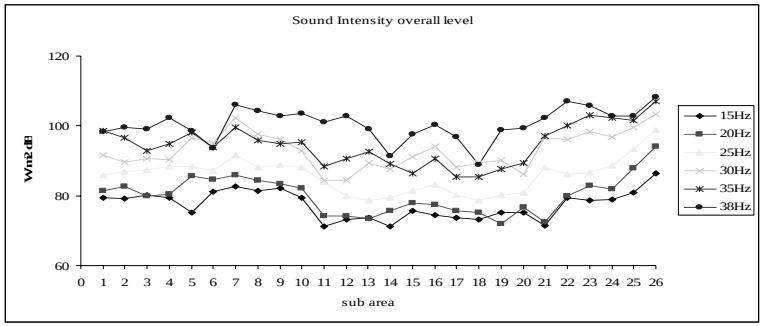
ENGINE SOUND INTENSITY MEASUREMENTS

Sub areas 1, 2, 3, 4 are in the rotor side
Sub areas 5, 6, 7, 8, 9, 10 are in the front side
Sub areas 11, 12, 13, 14 are in the opposite rotor side
Sub areas 15, 16, 17, 18, 19, 20 are in the rear side
Sub areas 21, 22, 23, 24, 25, 26 are in upper side of the engine



Sound power as function of sub areas

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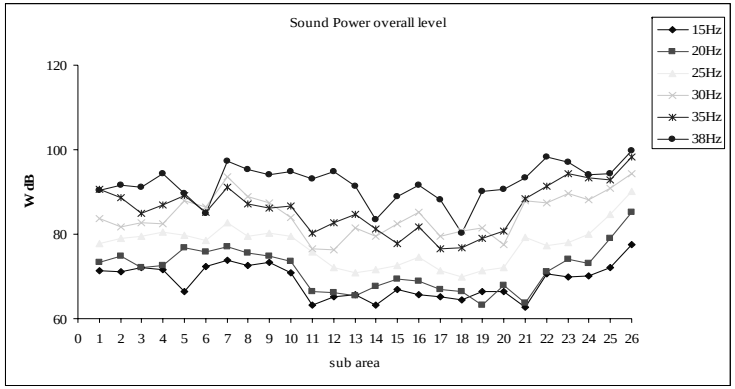
ENGINE SOUND INTENSITY MEASUREMENTS



Sound power as function of sub areas

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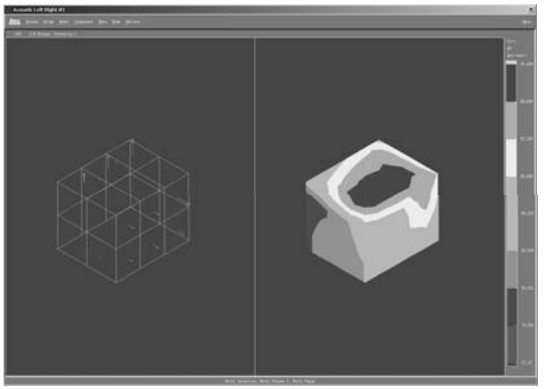
ENGINE SOUND INTENSITY MEASUREMENTS



200Hz 1/3 octave band Intensity emission

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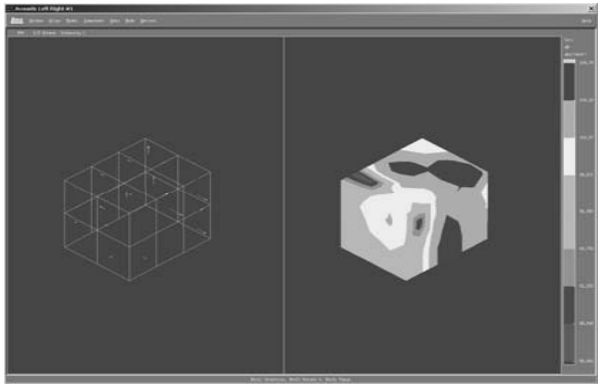
ENGINE SOUND INTENSITY MEASUREMENTS



800Hz 1/3 octave band Intensity emission

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Preliminary results

The most critical intensity emissions are in 800Hz 1/3 octave band; as showed the engine most critical area are represented by sub areas 7, 8, 9, 10 in the front side, and by sub area 22 and 23 in the upper side.

The intensity mapping referred to the real installing position of the engine on the vehicle shows that sub areas 7, 8, 9, 10 are the most critical for the landscape noise emission, the intensity vector is oriented to the vehicle normal lateral side.

Emission from sub areas 22 and 23 are oriented to the vehicle floor, so them are critical for inside vehicle acoustic environment.

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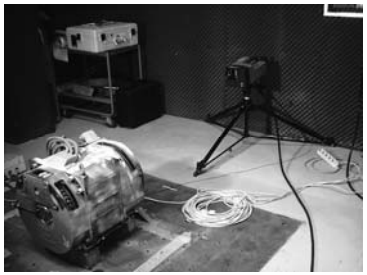
LASER VIBROMETER MEASUREMENTS

the engine was supplied by the lab inverter with an alimentation frequency from 20 to 40 Hz step 5 Hz, also considering the most critical condition at 38 Hz, and the upper 50 and 60 Hz.



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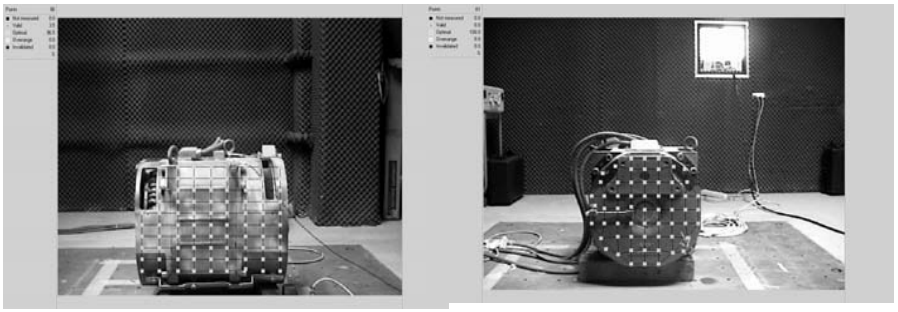
LASER VIBROMETER MEASUREMENTS

The engine was divided into 5 scan areas, 4 lateral (front, rear, rotor and opposite rotor side) and the upper one, on every area the acquisitions were performed for each of the above mentioned frequency supply conditions.



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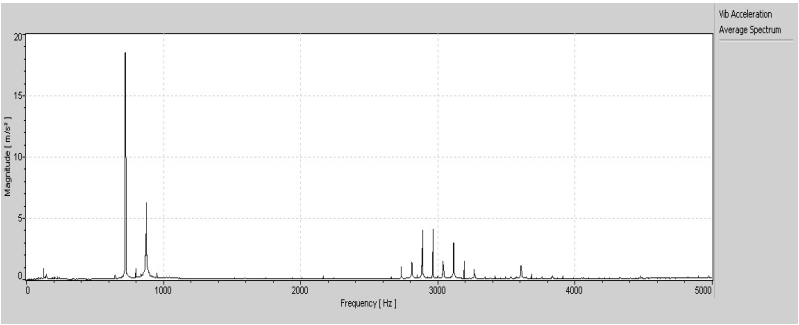
LASER VIBROMETER MEASUREMENTS



averaged vibration levels at 38 Hz supply condition

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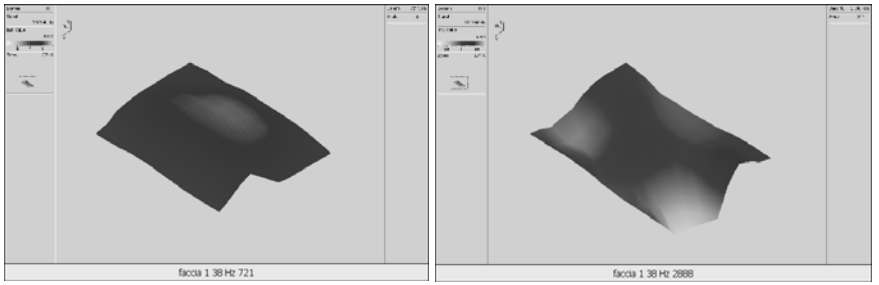
LASER VIBROMETER MEASUREMENTS



Deformed shapes at 38 Hz supply condition

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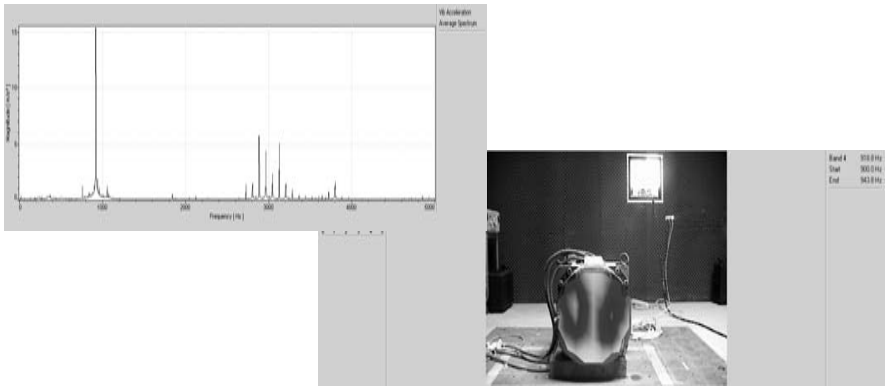
LASER VIBROMETER MEASUREMENTS



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CONCLUSIONS AND REMARKS

From comparison of field and laboratory tests, it appear a very similar behaviour of the engine both under the vibrational and the acoustic point of view.

Starting from this consideration, it should be possible to assess the best technological solutions for noise source reduction in lab and eventually test it on the vehicle, later on.

Taking into account the main genesis of noise, two main solutions are actually under preliminary assessment and shall be object of the future work:

- At source level: developing innovative feeding strategies
- On the propagation path: using advanced shielding (hybrid active-passive skin panels).