DEUFRAKO seminar
Railway Noise workshop

FRET Locomotives
Acoustic of Electrical Traction Systems

PROSODIE_PREDICT project_OG 8

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München, 27/10/2010
Summary

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Railway Noise_Acoustics & Freight Electrical Locomotives
Nowadays, ALSTOM Transport FRET Locomotives design has to satisfy more and more constraints:

- High traction power efficiency
- High interoperability
- High flexibility
- High level of reliability and maintainability
- High degree of safety and comfort
- High respect of environment
New generation electrical locomotive made by ALSTOM

Loco PRIMA EL II: BoBo architecture_4U_6400KW

Loco CHINE: CoCo architecture_1U_9600KW,
One of the most powerful electrical locomotive in the world

TSI Noise>>>OK

<table>
<thead>
<tr>
<th>Heavy duty freight</th>
<th>Freight</th>
<th>Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogie configuration</td>
<td>CoCo</td>
<td>BoBo</td>
</tr>
<tr>
<td>Traction power</td>
<td>9 600 kW</td>
<td>6 400 kW</td>
</tr>
<tr>
<td>Speed</td>
<td>120 km/h</td>
<td>140 km/h</td>
</tr>
<tr>
<td>Power supply</td>
<td>25 kV - 15 kV - 1 500 V - 3 000 V</td>
<td></td>
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</table>
Noise sources of loco PRIMA EL II BoBo

- **Rolling noise**
  - Contact rail/wheels (2 bogies with 2 axles for PRIMA EL II BoBo)

- **Traction** and auxiliaries equipments
  - 4 tractions motors with 1 cooling fan per bogie
  - 4 gearboxes
  - 2 tractions boxes with their cooling fan
  - 2 fans to refresh machines room
  - 2 auxiliaries boxes with their cooling fans
  - 1 main transformer with its cooling system
  - 2 braking resistor with their cooling fan
  - 1 air compressor with pneumatic system
  - 1 HVAC system for driver’s cab

Comment: within CoCo architecture, there are 2 bogies with 3 axles, so 2 motors, 2 gearboxes, 1 traction box and 1 compressor are added (compared to BoBo configuration).
Main Traction equipments and noise sources:

**Main Transformer:**
- Cooling unit with fan noise
- Magnetic core with electrical noises

**Intermittent braking resistors:**
- Cooling unit with fan noise
- Resistors with electrical noises

**Traction converter:**
- Cooling unit with fan noise
- Coils/inductors with electrical noises

**Traction motor (PROSODIE project):**
- Fan noise with forced cooling system
- Electrical noises due to magnetic forces

Railway Noise _Acoustics & Freight Electrical Locomotives_
Electrical traction systems are well-known for being noise sources

(rank from SITARE ALSTOM tool:
external noise prediction for loco PRIMA EL II_BoBo)

at standstill _STI limit LpAeq,T<75dBA is respected

<table>
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<tr>
<th>VTMT</th>
<th>VTBM</th>
<th>Bloc aux.</th>
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<tbody>
<tr>
<td>25Hz</td>
<td>25Hz</td>
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</table>
Electrical traction systems are well-known for being noise sources.

(ranking from SITARE ALSTOM tool: external noise prediction for loco PRIMA EL II_BoBo)

- at starting (0->20Km/h) STI limit LpAFmax<85dBA is respected
Electrical traction systems are well-known for being noise sources. (ranking from SITARE ALSTOM tool: external noise prediction for loco PRIMA EL II_BoBo) at low speeds (80Km/h) STI limit LpAeq,Tp<85dBA is respected.
Electrical traction systems contribute to noise pollution.

Development of components with high efficiency lead to important harmonic losses that can create **electrical noises** with high annoying pure tones and require an important cooling airflow (**aeraulic noises** can increase).

**So more power needs more cooling and it can mean more NOISE !**
ALSTOM Transport Eco-Design policy

For ALSTOM Transport, to reduce the environmental impact of rail transports and to improve passenger’s comfort are very important objectives. Environmental parameters are strongly incorporated into ALSTOM products from design phases. **Actions against noise pollution** (PROSODIE project evidence) are real strategy points and research efforts enable ALSTOM Transport to:

- satisfy a stronger society's requirements,
- answer in easier way to standards, European directives (TSI Noise), and customers requirements that are more and more restricting,
- increase technology advances compared to competitors,
PROSODIE project
Focus on electrical noises from traction motor
PROSODIE is a R&D PREDIT 3 project OG 8
PROSODIE means in french: “PROPulsion Silencieuse Optimisée et DImensionnée pour l’Environnement”

2 research axis: Electrical and Aeraulic Noises

- To improve again the acoustic performances of traction equipments (traction motors, traction & auxiliaries converters)
- To develop new tools and new methodologies to progress in acoustic design
- To find solutions, new technologies to reduce electrical noises and aeraulic noises
- To validate improvements in real conditions with prototypes Scale 1:1
Acoustics of traction motors

The main noise sources on a traction motor are:

✓ **Aeraulic noise** due to cooling systems (very annoying at medium and high speeds for self-cooled motor)

✓ **Electrical noises** (very perceptible at low speeds and during acceleration phases) characterized by unpleasant high tonalities and audible by travelers (inside and outside) and by the people who live along the track

✓ **Mechanical noises** from gears and bearings

Electrical noises come from magnetic vibrations due to magnetic forces.

For traction motor, **air-gap Maxwell forces** are the main contributor of audible magnetic noises.
Electrical noise motor analysis

To understand the audible magnetic noises radiated by the association motor+inverter

ALSTOM Traction motor (250KW) asynchronous PWM at 1280 Hz (Zr=36, Zs=48, p=2)
Electrical noise motor analysis

To understand the audible magnetic noises radiated by the association motor+inverter

**EXCITING FORCES**

- Motor geometry (Zr, Zs, materials, eccentricities, ...)
- PWM strategy
- Winding

\[ B_n \propto iN\Lambda = (\Lambda_0 + \Lambda_h)(i_0 + i_n)(N_0 + N_h) \]

Magnetic forces (i.e. generated by currents):
Maxwell (+magnetostriiction)

\[ F_n \propto \frac{\Lambda_0^2 i_0^2 N_0^2}{\text{fundamental bobinage}} + \frac{2\Lambda_0^2 i_0^2 N_0 N_h}{\text{denture}} + \frac{2\Lambda_0 \Lambda_h i_0^2 N_0^2}{\text{MLI}} + \frac{2\Lambda_0 \Lambda_h i_n N_0^2}{\text{modifed natural frequencies and associated deflection modes}} \]

characterized by exciting frequencies associated to spatial orders

**EXCITED STRUCTURE**

- Motor geometry and materials
- Stator+frame structure characterized by natural frequencies and associated deflection modes
- Motor environment (mounting and coupling)

Coupled structures with **modified** natural frequencies and associated deflection modes
Railway Noise_PROSODIE project

Electrical noise motor analysis

To develop and to validate at different stages (electrical, mechanical and acoustics field) a numerical tool that enables to predict magnetic noises.
**Electrical noise motor analysis**

To design low-noise motors fulfilling specified traction characteristics

Slotting phenomena

Sound pressure level at 1m from initial motor and 2 prototypes in on-load case (with resistive effort on rotor shaft)

New motors are 15 dB quieter than the actual motor at some speeds

No significant resonance due to slotting or saturation occurred with new 2 rotor prototypes
The maximum sound pressure level is obtained when the PWM vibrations near twice the switching frequency enter in resonance with 0 and 2p stator modes near to 3000Hz, that’s to say for $f_c=1500Hz$

Switching frequency has a 15 dB impact on starting noise
**Electrical noise motor analysis**

Within PROSODIE project, ALSTOM Transport has developed a vibro-acoustic simulation tool that predicts correctly main magnetic noises, and helps ALSTOM engineers to design low-noise motors, and diagnosing magnetic noise problems.

ALSTOM Transport continues to launch R&D projects in acoustics field to reduce more noise levels of its products.
Thank you for your attention

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