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The railway noise reductions achieved in the Silence project

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The European project Silence is dedicated to the reduction of railway and roadway noise in urban areas. Within the frame of the subproject E and G, the reduction of the railway noise is addressed. Source ranking of state of the art rolling stocks has been carried out. Then, the Diesel engine, the exhaust, the cooling unit, the electrical engine, the wheels and the track have been optimised by the manufacturers and prototypes have been constructed. The most promising have been selected through laboratory measurement to be installed on the trains and trams. Last measurement campaigns have been carried out to characterise the combination of optimised rolling stocks running on optimised track. Then, relevant reductions of the pass-by noise have been achieved for electrical and Diesel multiple unit trains, freight trains and trams.

In the same time, a software called VAMPPASS has been developed in subproject B to synthesise the time signal of a train pass-by. Using the results of the source characterisation, a Diesel multiple unit has been modelled. The validation of the software has been carried out in terms of indicators and sound quality. Then, a parametric study has been carried out to estimate the potential of pass-by noise reduction of a Diesel multiple unit.

The main results of the Silence project concerning the railway noise are presented in this paper. The source ranking is addressed and also the work carried out to reduce the noise of the main sources. Noise reduction achieved are also presented. At the end, the VAMPPASS software is also mentioned.

1 Introduction

The 6th Framework Programme EU supported SILENCE Integrated Project, aims at developing an integrated system of methods and technologies for an efficient control of urban noise [1]. "Integrated system" means the combined consideration of city authorities, individual traffic (on road) and mass transport (on rail and road) with a holistic treatment of all traffic noise facets : urban noise scenarios identification, individual noise sources (vehicles on infrastructures) reduction, traffic management, noise perception and annoyance. It gathers 45 partners including cities authorities, car and railway industry manufacturers, public transport operators, road technology laboratories and universities. It started on February 1st, 2005 for a duration of three years. The general approach chosen was the following :

- Assessment of urban noise situations from noise maps,
- Definition of typical urban noise scenarios for each mode, which form the reference working basis for the project,
- Identification, for each noise scenario of the noise abatement priorities and noise reduction potentials.

A global target of 10dB(A) in reducing most critical urban noise situations was set for the project. The rail situations considered in the project include light and heavy rail (trams, metros in open air and trains).

The results of the application of the general approach to rail scenarios are described with an emphasis on the reduction of the main noise sources. Testing methods used or developed to identify precisely and rank acoustical sources on rail vehicles have been already presented in [2]. The global noise reduction achieved for heavy rail is presented. A paragraph is dedicated to the modeling of a train pass-by using the VAMPPASS software developed within the frame of the Silence project.

2 Freight trains

The validation platform concept of the Silence project is presented in [2]. From a hot spot analysis, typical cases are selected from noise maps, which form the basic scenarios for rail. For each scenario, a validation platform is defined

consisting in state-of-the-art vehicle running on a state-of-the-art track. Pass-by tests have been carried out at the beginning of the project to assess the reference situation and enable identification of the most prominent sources. For the most prominent identified individual source, the noise reduction potential has been investigated. Attention will be given, not only to the global noise level reduction, but also to getting an improvement in perception of the component noise, through identification of the most annoying characteristics of the component noise (subproject A). At the end of the project, the most promising solutions developed to reduce the noise of the main sources have been tested on vehicles.

The validation platform for freight trains was organised by DB in Gersthofen in Germany. Pass by measurements using an antenna of microphones over a broad range of speeds between 20 km/h and 80 km/h with an increment of 20 km/h were carried out in order to identify possible resonances of the superstructures or of the brake-riggings. In addition, measurements were performed at the maximum speed of 120 km/h as specified in the technical specification for interoperability (TSI) "Noise". Results have confirmed that the rolling noise remains the main source of freight wagons even with K brake blocks. Then, mitigation measures to reduce the rolling noise have been developed by Corus for the track contribution and by Lucchini for the wheel one.

2.1 Rail dampers

Rail dampers developed by Corus (Silent Track™) have been optimised within subproject G concerning infrastructure. The Corus rail damper is composed of two masses embedded into an elastomer (see Fig. 1).

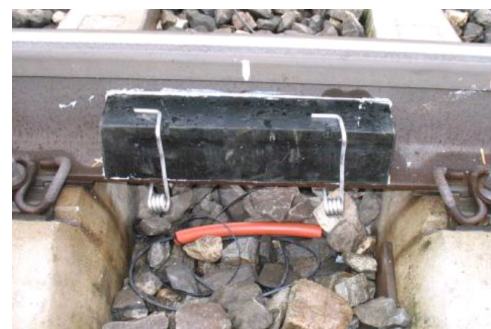


Fig. 1 Corus rail damper (Silent Track™).

The mass-spring system has been optimised to improve the damping and enlarge the bandwidth of vertical track decay rate increase. Results of the last measurement campaign carried out in Germany are presented in Table 1.

Train speed (km/h)	Effect of wheel dampers	Effect of rail dampers	Combined effect rail and wheel dampers
40	-0.7	1.6	-
80	0.9	3.5	4.2
100	1.4	3.1	4.6
120	1.6	2.9	4.3

Table 1 Noise reduction provided by rail and wheel dampers

The global noise reduction provided by rail dampers has been increased from 2 to 3.5 dB(A) on a TSI compliant German track.

2.2 Wheel dampers

Due to the high temperature of the wheel during the braking phase of freight wagons, elastomer are not well suited to be used for wheel dampers. Then, a new concept has been proposed by Lucchini Sidermeca in subproject E5. The damping is provided by friction between two plates, one fixed on the rim and the other one fixed on the hub. Both plates are in contact with rivets (see Fig. 2).

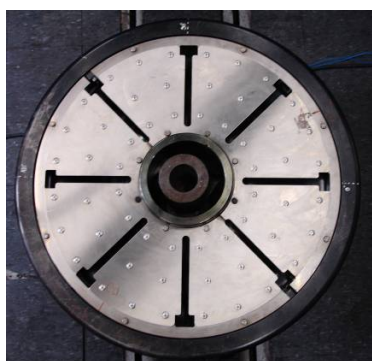


Fig. 2 Hypno[®] wheel damper from Lucchini Sidermeca.

The noise reduction provided by the Hypno[®] wheel damper has been estimated using FEM and TWINS simulation software. A noise reduction between 2 and 3 dB(A) could be expected. A prototype has been built and test carried out on breaking test bench from Trenitalia to homologate Hypno[®]. Then, 12 wheelsets have been equipped with Hypno[®] and mounted on a test train. Results of the measurement campaign carried out in normal operating conditions on the German validation platform are presented in Table 1. The Hypno[®] wheel damper provides a global noise reduction of 2 dB(A). In association with rail dampers, a global noise reduction of 4.6 dB(A) can be reached on a German TSI compliant track (see Table 1).

3 Suburban trains

Within subprojects E3 and E4 of Silence, the noise reduction of Diesel and electric suburban trains running at

low speed (from 30km/h to 80 km/h) has been considered. A validation platform has been selected in France, in Maison-Alfort near Paris and in Italy near Genova. Two Diesel/electric multiple unit trains (D/EMU) have been selected : AGC train from Bombardier and Minuetto train from Alstom. Pass-by measurement campaigns using antenna of microphones have shown that noise sources are numerous and their contribution to the pass-by noise depends on the configuration of the train during the pass-by. Then, a new post-processing has been developed to estimate the contribution of each noise source to the global pass-by noise by using results of the antenna measurements. An example is presented in Fig. 3.

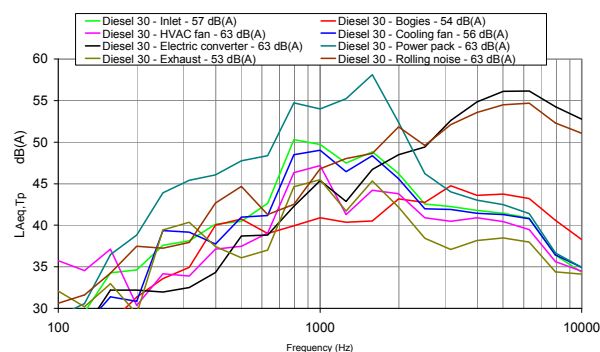


Fig.3 Contribution of the main sources to the pass-by noise of an AGC train running in Diesel mode at 30km/h.

In urban conditions, at low speed (30km/h), the Diesel engine, its cooling unit and the exhaust are the main sources. Around 80 km/h, the rolling noise becomes the main one.

3.1 Diesel engine

The noise of the Diesel engine can be treated by using damping material (sandwich plates) onto the rocker cover, the inlet manifold, the oil sump (see Fig.4) and also by modifying the pre-injection low of the engine. Tests carried out by the engine supplier show that the global reduction achieved is between 2 dB(A) and 4 dB(A).



Fig.4 Modified rocker cover and oil sump using sandwich plates and stiffener.

3.2 Diesel engine encapsulation

In case of state of the art DMU, the Diesel engine and the gearbox are encapsulated. A fan is used to blow up fresh air in the compartment. If the DMU is driven by electrical engine, then the power-pack composed of the Diesel engine and the electric generator can be encapsulated more easily due to the fact that the Diesel engine and wheels are not

mechanically linked. Two methods have been developed within Silence to design shielding of the engines. One is based on FEM/BEM approach and the other one is based on an analogy between heat transfer and acoustic transfer.

Three solutions of shielding have been modelled :

- complete encapsulation of the Diesel engine with chicane for heat transfer
- screening and damping materials very close to the engine skin in a retrofit case
- screening and damping materials very close to the engine skin in a pre-project case

A four days stand still measurement campaign has been carried out on a Minuetto train to valid the first solution (see Fig. 5).



Fig.5 complete encapsulation of the Diesel engine.

Results show that a noise reduction of the powerpack of 8 dB(A) can be reached with and without a complete encapsulation with chicanes.

3.3 Exhaust of the Diesel engine

First, a one dimensional approach was used to design new mufflers. Some validations have been carried out on a test bench using a scale model. The most promising solutions have been tested by the Diesel engine supplier at standstill. Expansion chambers and Helmholtz resonators (Fig. 6) are relevant solutions.

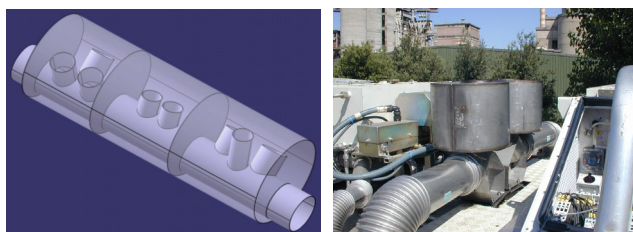


Fig.6 exhausts with expansion chambers or Helmholtz resonators.

The noise reduction is effective in low frequency range (< 200 Hz) for dedicated pure tones which can reduce annoyance but not the global pass-by noise (see Table 2) expressed in dB(A).

3.4 Cooling unit of the Diesel engine

One of the most important source of DMU is the cooling unit. The classical architecture of the unit is presented Fig. 7.

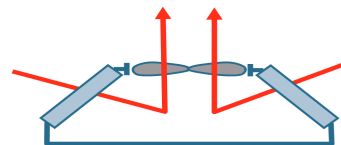


Fig.7 classical architecture of a cooling unit.

A complete change of the architecture has been proposed and 14 improvements or combinations of improvement tested :

- axial fan upside down (reversed flow)
- gap between blades and stator filled in
- hub covered
- damping material inside
- damping material outside
- guide vanes

The most efficient combination of improvements leads to a noise reduction of 8 dB(A). A higher noise reduction (9 dB(A) to 10 dB(A)) including the removing of the pure tones can be reached by using radial fans in place of axial ones. A prototype of such a cooling unit has been build (see Fig. 8) to be mounted on an AGC train.

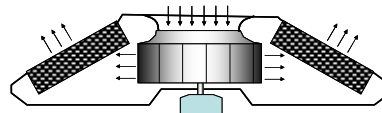


Fig.8 prototype of a new design of cooling unit.

Noise reduction provided by optimising axial fans of the cooling unit is compared to the reduction providing by using radial fans Fig.9.

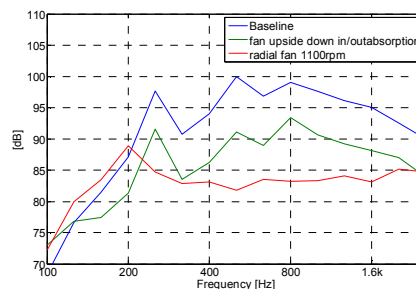


Fig.9 Power spectra of the noise radiated by the cooling unit (laboratory measurement)

A pass-by measurement campaign has been carried out with an AGC train equipped with the prototype of the cooling unit. Preliminary results show a noise reduction of 7 dB(A) onto the global pass-by noise at 30 km/h between the power car equipped with the standard cooling and the optimised one.

3.5 Rolling noise

The rolling noise remains one of the most important sources when the train speed is higher than 80 km/h. As the AGC is equipped with disk brakes mounted on the wheels, there is very few possibility to add wheel dampers to tackle the rolling noise. Then, a dedicated ring damper DAAVAC has been designed by Pinta-Enac to be inserted between the wheel and the disk. A small groove (depth = 2 mm) manufactured in the inner part of the wheel retains the damper. A measurement campaign has been carried out to run the train equipped with DAAVAC onto the track equipped with rail dampers (Silent Track™ from Corus). The pass-by noise reduction is between 4 and 5 dB(A) at 80 km/h in electric mode (with only half of the bogies equipped with wheel dampers).

4 VAMPPASS software

The improvement of the comfort (HVAC in cabs, in coaches, 220V power supply, ...) leads to an increase of the inboard equipments. All these devices are able to rise up the noise of the train pass-by. The noise reduction in operating conditions becomes a new challenge : which source(s) must be optimised to reduce the pass-by noise ?

4.1 Description and validation

Within the frame of the subproject B, a software called VAMPPASS has been developed to simulate the pass-by noise of a train or a car. It provides sound pressure levels, spectra, time history, ... and also the sound sample of the pass-by in audio-3D (see Fig.10 the output interface of the software).

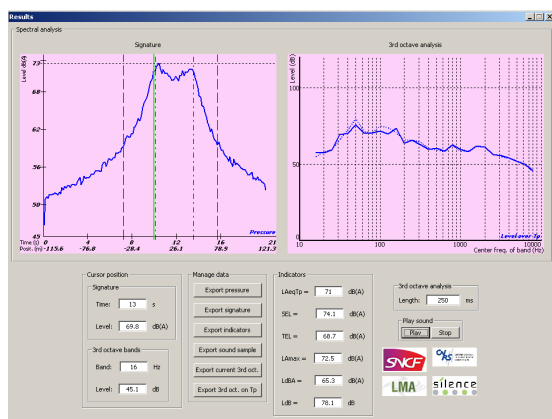


Fig.10 : output interface of the VAMPPASS software

A validation of the outputs of the software has been carried out. With appropriate definitions of the sources, the accuracy of the pass-by noise prediction is ± 1 dB(A) and ± 3 dB in each third octave band. Two perceptive studies carried out using, on one side, measured sound samples, and, on the other side, synthetised sound samples, lead to the same results which confirm the relevancy of sound samples provided by VAMPPASS.

4.2 Example of application

An application to the reduction of the pass-by noise of an EMU/DMU has been carried out using VAMPPASS. Twenty one sources characterised within sub-project E have been used to define the train. According to the results presented in paragraph 2, optimised sources have been defined with laboratory measurement, scale model measurement, numerical models, ... Pass-by noise of the existing train has been validated with pass-by measurement. Then, a parametric study has been conducted by combining the optimised sources in different operating conditions. Main results are presented in Table 2.

CONFIGURATIONS	LeqTp(A) (dB(A))
30kph diesel mode	
standard case	68,7
noisy case (regular powerpack compartment)	69,8
exhaust optimisation	68,6
cooling optimisation	67,5
rolling noise optimisation	
rail dampers	68,4
rail and wheel dampers	68
global optimisation	67
80kph diesel mode	
standard case	76,2
noisy case (regular powerpack compartment)	77,1
exhaust optimisation	76,4
cooling optimisation	74,9
rolling noise optimisation	
rail dampers	75,2
rail and wheel dampers	74,7
global optimisation	72,9
30kph electric mode	
standard case	61,9
rolling noise optimisation	
rail dampers	58,2
rail and wheel dampers	57,3
80kph electric mode	
standard case	72,2
rolling noise optimisation	
rail dampers	68,9
rail and wheel dampers	67,4

Table 2 results of the parametric study carried out with VAMPPASS to reduce the pass-by noise of a DMU/EMU

Results show that pass-by noise reduction of such a train running in operating conditions is not an easy task. The parametric study allows to focus onto the main important sources to be treated as a priority.

5 Conclusion

Main results of the sub-projects B and E of the European Integrated Project Silence have been presented in this paper. For the freight wagons, a new concept of wheel damper has been developed and validated in operating conditions. In combination with optimised rail dampers, a pass-by noise reduction of 5 dB(A) is reached. This reduction is validated with another concept of wheel damper tested on a EMU/DMU. An optimised cooling unit, using radial fans instead of axial ones, leads to a pass-by noise reduction of 7 dB(A). Noise reduction onto the Diesel engine provides also 2 or 3 dB(A) more. By combining the developed solutions, the target of a pass-by noise reduction of 10 dB(A) at the source is reached.

Acknowledgments

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