OPS Master Plan for Spanish Ports Project. Study of potential acoustic benefits of on-shore power supply at berth

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Summary
The “OPS Master Plan for Spanish Ports” project aims at drafting a Master Plan for the supply of electric power to ships at berth in Spanish Ports. In addition to the development of pilot cases that will provide electrical equipment in some ports and the adaptation of the ships that dock there, the project includes series of technical studies to identify the environmental benefits linked to the implementation of this new technology. This framework has supported the development of an analysis of the potential reduction of acoustic impact from ships at berth if power is supplied from the electric grid instead of using auxiliary engines generators. This issue has been already studied and it is known that there are other sources of noise from ships at berth (ventilation inlets/outlets from engines room and cargo decks, and reefers) that continue operating and could reduce the potential acoustic benefits.
The communication presents results achieved in this study, considering only the noise coming from the ships and excluding the loading and unloading activities or other installation at port. Noise measurements were conducted in the Bilbao Port to estimate the sound power of relevant noise sources of three types of ships: container, Ro-Ro and cruiser. An estimation of the acoustic benefits of the OPS is developed and although the number of ships measured cannot be considered representative, it is discussed how these types of ships could be classified to predict the acoustic benefits of OPS implemented in a port.

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1. Introduction

This paper presents results of a project carried out to estimate the acoustic benefit of the Cold Ironing system in ports. This study is part of “OPS Master Plan for Spanish Ports” project that is funded by the European Union through financial instrument Connecting Europe Facility (CEF) and coordinated by PUERTOS DEL ESTADO. This benefit is added to the elimination of onboard emissions (air pollution) at berth; resulting from ships being connected to the electrical grid as they can switch off their auxiliary engines used to provide the power needed on board during their stay in port.
The study has covered the following tasks:

• Analysis of the State of the Art. A documentation search was carried out in several sources, mainly focused on:
  - knowledge of the ship’s noise sources with acoustic emission in dock.
  - methodology for performing the measurements and, wherever possible.
  - estimation of acoustic benefits of Cold Ironing system.

• Definition of methodology for assessing the acoustic benefit of OPS.

• Measurement campaign on auxiliary engines noise differentiated from other on-board noise sources, in three representative types of berthed ships and, avoiding side-effect of noise generated from port activity.

- Creating database of the acoustic power from ships while at berth for various fleets by extrapolation of noise samples taken at site.
- Development of a simplified simulator to estimate the sound levels generated by berthed ships at user-defined reception points by applying a defined algorithm to specific data incorporate by user and those included in database referred above.
- Sampling of noise levels for two weeks in representative location within port area, applying the algorithm mentioned above, and validating noise simulator.

2. Methodology applied

An estimate of the Cold Ironing system benefit was made by first characterizing the emission of noise

Table I. Ships sampled and corresponding acoustic emission results obtained in the campaign

Type	*Year*	*Size (GT)*	*Auxiliary engine power (kW)*	*Operating conditions (kW)*	*Auxiliary Engine*		*Additional source: ventilation*	
					Sound Power Level (dBA)	*Tonal components / Low frequency (dB)*	*Sound Power Level (dBA)*	*Tonal components / low frequency (dB)*
Ro-Ro passengers	2003	22382	4200	900	109,3	6/0	113,2	6/0
Ro-Ro cargo	1999	12076	2x980 kW	400	107,5	3/3	109	6/0

Type	*Year*	*Size (GT)*	*Size (TEU)*	*Refrigerated Container (TEU)*	*Power auxiliary engine (KW)*	*Operating conditions (kW)*	*Auxiliary Engine*		*Additional source: refrigerated container*	
							Sound Power Level (dBA)	*Tonal components / Low frequency (dB)*	*Sound Power Level (dBA)*	*Tonal components / low frequency (dB)*
Containers	2002	14241	1129	153	-	-	97,4	3/6	-	-
	2008	7702	798	150	2x750	1x750	95,1	0/3	-	-
	2007	8971	917	200	2x469	1x469	95,0	3/3	-	-
	2009	10585	1036	---	-	-	90,2	0/3	92,3	3

Type	*Year*	*Size (GT)*	*Auxiliary engine power (kW)*	*Auxiliary Engine*		*Additional source: ventilation*	
				Sound Power Level (dBA)	*Tonal components / low frequency (dB)*	*Sound Power Level (dBA)*	*Tonal components / low frequency (dB)*
Cruise liners	1973	28372	2200	111,1	3/6	103,2	3/6
	2000	30277	-	104,2	0/6	94,7	0/6
	2016	55254	-	101,6	3/6	97,5	3/6
	2002	139570	-	105,3	3/6	98,7	3/6
	2008	154407	-	104,5	0/6	96,2	0/6

sources generated by ships at berth of these three fleets:

- Ro-Ro/Ferries
- Container ships
- Cruise liners

In the theoretical scenario where there is no power being generated in the ship, the corresponding noise source disappear. Noise sources from ships not only include those which will be attenuated or eliminate whenever the ship uses shore supplied power instead of the auxiliary engines, but other sources include ventilation systems and container refrigeration systems. The late category will keep emitting despite auxiliary engines were switch off.
Noise sources were characterized following a procedure based on a simplified implementation of standard ISO 3746.
The locations and the time of the day when measurements were taken were decided to prevent side-effects of potential noise caused by activity being carried out in the surroundings. Therefore, as far as the berthed ships allowed it, measurements were taken during the night-time.
Ro-Ro ships noise samples were taken on board to control the emission conditions of each source. Thus, contribution of ventilation and engine to the overall noise generated by the moored ship was more accurately characterized.
After processing noise samples, it was possible to calculate by using sound pressure values $L_{Aeq,T}$, both the sound power L_{WA}, in third octave spectrum, and the overall level of the noise sources linked to the systems installed in the measured vessels that emit to the outside.
The measurements were performed in Bilbao Port in Spain between September and November 2017.

Figure 1. Location of the measurement points. Bilbao Port. Spain.

Ships whose acoustic emission was measured are described by type, dimensions, age and auxiliary engine specifications, provided that the information was available.
Ships sampled and corresponding acoustic emission results obtained in the campaign are presented in Table I, above.

3. Repeatability test to verify the procedure to characterize the acoustic emission of moored ships

The result of a repeatability test of the characterization procedure of moored ships used in this project is presented in this section. During the measurement campaign, the emission of the same container ship docked in the same dock was characterized in separate days, although in a different location. This double exercise allows us to analyze the consistency of the established characterization procedure, both to perform the measurement and to calculate the emission of the noise source.
This is the Max Carrier ship, which was docked at the port on the nights of October 4th and 20th in 2017.

Max Carrier: October 4th

Max Carrier: October 20th

Figure 2. Location of the Max Carrier on the nights of October 4th and 20th in 2017.

Table II. Result of the Repeatability test: sound power level dBA. (Container Ship)

IMO	*Measurement date*	*Sound power level (dBA)*
9236597	4/10/2017	97,9
9236597	20/10/2017	97,4

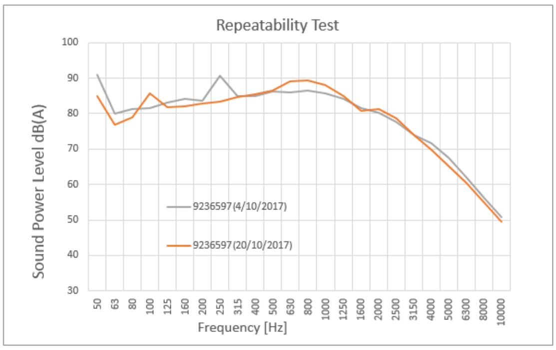


Figure 3. Graph of the sound power spectra in dBA (Container Ship). L_{WA}.

The difference in the overall emission levels of the auxiliary engine calculated from the measurements taken on both days is less than 1 dBA.

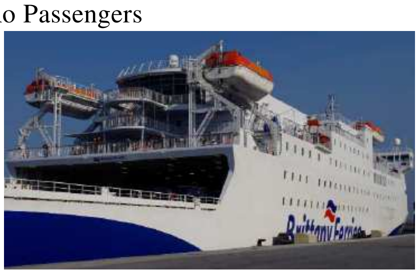
4. Database proposal of acoustic emissions

From the analysis of results of the samples taken during this project, an acoustic grouping was proposed. Ships groups consider acoustic power based on their characteristics.

4.1 Ro-Ro

The characterization of two different Ro-Ro (Roll on Roll off) ships was carried out: Passengers and general cargo.

Ro-Ro Passengers



Ro-Ro General Cargo

Figure 4. Ro-Ro moored

The main noise sources on a Ro-Ro ships are: the exhaust from the auxiliary engines with the ventilation associated to the machine room, and the ventilation of the cargo/passenger's deck.

It is assumed that when applying OPS, emissions from auxiliary engines are eliminated, but the ventilation of the cargo/passenger's deck is working.

The following figure shows the sound power levels for each type of Ro-Ro, defined in both scenarios, current and theoretical with Cold Ironing System.

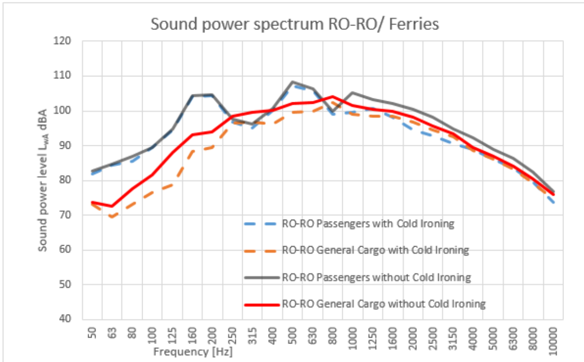


Figure 5. Graph of the sound power spectra in dBA (Ro-Ro with / without Cold Ironing system). LwA.

Table III. Sound power level dBA. (Ro-Ro)

	Sound Power Levels L_{WA} dBA		
	Auxiliary engines + Ventilation	*Ventilation (only)*	*dBA reduction (using OPS)*
Ro-Ro Passengers	115	113	1,5
Ro-Ro General Cargo	111	109	2,2

4.2 Containers

The main noise sources on a Container ships are: the exhaust from the auxiliary engines with the ventilation associated to the machine room, and the reefers (Cooled containers).

The following figure shows the sound power levels for each type of containers, defined in both scenarios, current and theoretical with Cold Ironing System.

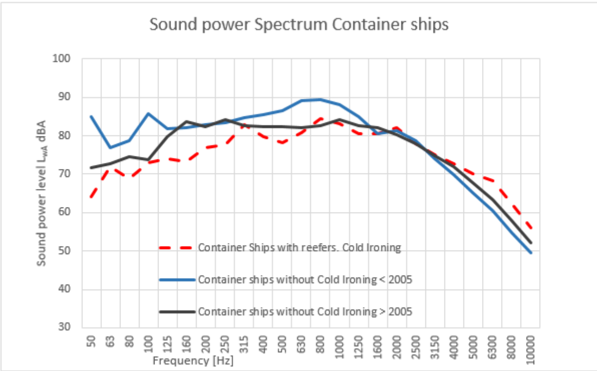


Figure 5. Graph of the sound power spectra in dBA (Container Ship with / without Cold Ironing system). LwA.

Table IV. Sound power level dBA. (Containers)

	Sound Power Levels L_{WA} dBA		
	Auxiliary engines +Reefers	*Reefers (only)*	*dBA reduction (using OPS)*
Year of Construction < 2005	97	92	5,1
Year of Construction > 2005	94	92	1,7

4.3 Cruisers

The main noise sources on cruisers are: the exhaust from the auxiliary engines with the ventilation associated to the machine room, and the mode of operation of their ventilation and refrigeration equipment. The following figure shows the sound power levels for each type of cruiser, defined in both scenarios, current and theoretical with Cold Ironing System.

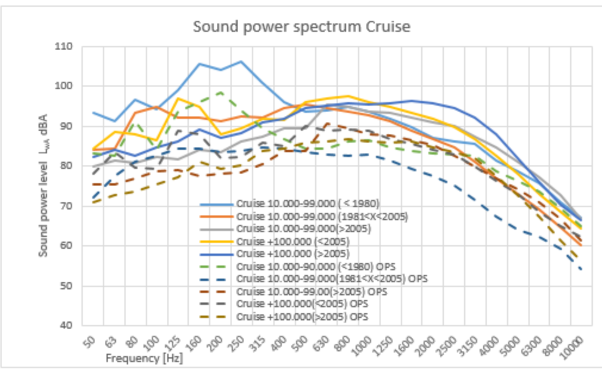


Figure 6. Graph of the sound power spectra in dBA (Cruisers with / without Cold Ironing system). LwA.

Table V. Sound power level dBA. (Cruisers)

		Sound Power Levels L_{WA} dBA		
	Year of construction	*Auxiliary engines + Other noise sources*	*Other noise sources (only)*	*dBA reduction (using OPS)*
Capacity 10,000/ 99,000	< 1980	112	103	8,6
	1981< X < 2005	105	95	9,9
	> 2005	103	98	5,5
Capacity +100.000	< 2005	106	99	7,4
	> 2005	106	96	9,3

5. Noise level simulator of moored ships: SIMNOISESHIP TECNALIA

In the framework of this project Tecnalia has developed a simulator, called SIMNOISESHIP. Its aim is to show acoustic benefit of the Cold Ironing system offered to moored ships, by estimating sound pressure levels at certain distances from the ship; this is graphically represented as well.

Algorithm uses acoustic emissions database proposed for each ship type, which resulted from the measurement campaigns carried out throughout the project.

The Algorithm was defined following the sound propagation method of calculation described in ISO 9613. It should be noted that this is the official method defined by the current legislation for performing industrial noise assessments.

The use of this simulator is conditioned to limitations of mentioned ships' database, and also to assumed hypothesis of considering a direct propagation from the ship to the reception point with an average propagation height of 10 m above the ground level.

The formulation of the simplified model was validated, developing the following tasks:

- the data of noise level measurements was taken over two weeks at the representative point of a potential sensitive receiver at a container terminal; measurement periods were selected with no noise other than that generated by the ship, that is, during certain times at night;
- the data of noise for each case was estimated using the simulator where number and type of container

ships at berth were considered together with respective distances to microphone.

Home screen:

First request for information from the user:

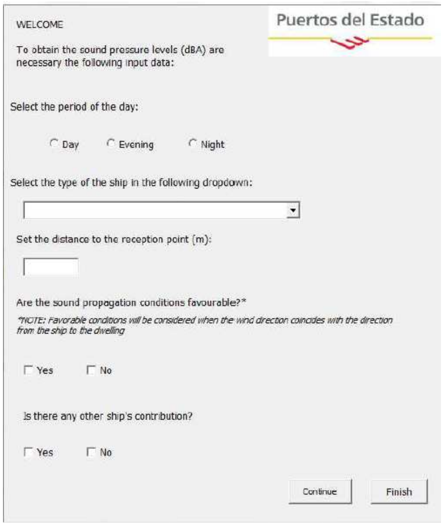


Figure 7. Simulator Simnoiseship Tecnalia

The values obtained in the proposed simplified model for the three assessments performed are shown below:

Table VI. Differences between simulator Simnoiseship and acoustic measurement.

Assessment	*Ship Selected*	*Activity Summary*	*Differences dBA*
1	Container ship age > 2005	1 Container ship from 23:30 to 7:00	-0,1
2	Container ship age < 2005	1 Container ship from 23:00 to 06:40	1,4
3	3 Container ships age < 2005	3 Container ships from 23:00 to 7:00	-1,1

Results of this validation procedure shows slight differences amounting 2 dBA when compared the simplified model to the measurements from the continuous recording. This validation is considered satisfactory.

6. Conclusions

Noise levels emitted by berthed ships using the Cold Ironing system can be significantly reduced depending on the type of vessel.
This benefit can be perceived at night and at locations close to the port; in other cases, it may be masked by the port activity or other surrounding noise sources.
The most relevant conclusions are the following:

1. This project provides data on noise emitted by berthed ships to be added to referred bibliography, albeit necessary caution due to:
   - limited number of sampled ships.
   - limited number of fleets sampled: containers, Ro-Ro and cruisers.
   - samples were taken in one port only.
2. An important contribution of this project is that ships’ dominant noise sources being auxiliary engines have been differentiated as far as possible from other sources such as ventilation vents and refrigerated container systems.

3. A ship classification is proposed according to their noise emissions by using the results of those measurements.

4. An additional parameter was considered necessary for the assessment that is the ship's age, showing a logical relationship in the interpretation of the ships noise measured. This approach might be interesting for the analysis of other measurements performed by other research groups given that, in the literature consulted, it was observed that ship capacity does not necessarily determine its noise emission.

5. The procedure for characterizing the noise emission of berthed ships, while being a simplification of those referred to in the literature, is considered valid and in line with the aim of the project, and was checked with a repeatability test in which very positive results were obtained.

6. The acoustic benefit would be remarkable in the absence of other sources such as traffic, and where no loading, unloading or other noisy activities are being performed that is at night; indeed, at that time population has greater sensitivity to noise and, therefore, most demanding legal acoustic limits are imposed.

7. The project provides a Noise Simulator or calculator tool which allows the noise levels from the ships berthed alongside the quay to be quantified at any reception point defined by the user; this is made according to categories established in the project itself.
In addition to quantifying the effect of the noise generated by the ships and emitted into the port environment near ship's berth, also the simulator can calculate the acoustic benefit of making use of on shore power supply or Cold Ironing system as simulator considers other ship noise sources.
The tool is based on algorithms which follow a simplified calculation method included in currently in force ISO 9613.
This simulator has been validated very positively in a real case study, comparing the estimated values using the simulator with actual measurements.

8. The results of the theoretical estimation of the acoustic benefit of the Cold Ironing system are the following, which coincide with the consulted literature:

- Ro-Ro type ships, apart from the auxiliary engines, have an additional source of noise: the acoustic emission of the ventilation systems, which have a significant contribution and cannot be avoided by Cold Ironing system. Data collected in this project quantify acoustic benefit of using Cold Ironing in about a 2 dB reduction, which may not be significant in terms of perception. This reduction coincides with data measured in the port of Rotterdam[1].

- Container ships have also an additional noise source: the refrigeration of the containers loaded in the ship which directly emit to the outside surroundings. This source should be quantified in each container ship since it is not possible to estimate for all cases generally. Although this variable is not set, the data collected during this project quantified a reduction of between 2 and 6 dB by the Cold Ironing system.

- Cruise ships can profit acoustic benefits of between 6 and 10 dB of reduction depending of cruisier type when applying the new technology. It should be noted that these vessels present the largest uncertainty in terms of power of their auxiliary engines and mode of operation of their ventilation and refrigeration equipment; the latter is directly related, among other factors, with activities being carried out at the time of the measurement and with the number of passengers on board.

All this noise reduction at source -ship berth position- results in an increase of comfort both for inhabitants settled down near the port and for crew members themselves.

Given that the acoustic benefit provided by the Cold Ironing system can be very relevant, it is concluded that each Plan and / or Project for the implementation of this system in ports should include an acoustic study in which the typology of ships, the presence of additional noise sources others than auxiliary engines, the propagation of sound from the berths to sensitive areas, as well as the presence of other sources of noise. Thus, the Plans and / or Projects for the implementation of this system in ports may consider the benefit it provides in terms of reducing noise levels in sensitive areas of the surroundings.

Acknowledgement

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