10ème Congrès Français d'Acoustique
Lyon, 12-16 avril 2010

FPSO Noise Control
From initial design to launch of the vessel

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Floating Production Storage and Offloading (FPSO) vessels are commonly used in Oil & Gas projects for deep offshore production. They are constituted of a production plant (Topsides & Hull Machinery space) and Living Quarters.

Concentration and proximity of noisy equipment to the Living Quarters increases the risk of unacceptable noise levels. Moreover, offshore workers' comfort and safety are an increasing concern for major Oil & Gas companies.

As it is nearly impossible to reduce noise on operating production units, noise control must be part of design philosophy. Therefore, a global methodology applicable from the early design stage and able to control noise on the whole FPSO is carried out. It is based on a mixed approach:
- Database built from previous projects,
- High performance Finite Element Model (FEM) calculations,
- Air-borne noise computations,
- Development of specific hybrid methods to estimate structure-borne noise.

This methodology was developed in parallel to project requirements as follows:
- Preliminary design: noisy equipment identification, preliminary noise studies (including expertise and feasibility analysis), project noise specifications.
- Detailed design:
  - Noise and vibration specifications for each critical equipment package;
  - Numerical acoustic FPSO models for computation of topside noise maps;
  - Air-borne and structure-borne noise calculation in machinery space and living quarters;
  - Design modification definition and validation, experimental validation (Noise and Vibration measurements) on critical equipment packages;
  - On-site validation: noise measurements in the machinery space and living quarters during yard commissioning, noise measurements on topsides during offshore tests.

After the main steps are clearly detailed, different project applications and example results will be evoked and illustrated.

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1 Introduction

1.1 Background

Floating Production Storage and Offloading (FPSO) vessels are commonly used in Oil & Gas projects for deep offshore production. They are constituted of a production plant (Topsides & Hull Machinery space) and Living Quarters.

The noise and vibration exposition of offshore workers and their comfort inside the accommodation is an increasing concern for major Oil & Gas companies. The implementation of solutions to reduce noise and vibration when necessary on a production unit in operating conditions is very delicate or even impossible. Consequently, noise and vibration control is part of the design philosophy. A global and efficient methodology should be carried out from the early design stage in order to control noise throughout the FPSO.

1.2 Global control methodology

First step is to identify the potential noisy equipment at the beginning of the project. Noise specifications are issued and noise emitted by those pieces of equipment is controlled throughout the design process.

Different computation models are built:

- External noise computation for the factory part (Topsides),
- Statistical Energetic Analysis (SEA) model for air-borne noise computation in the Living Quarters,
- Hybrid model to analyse structure-borne noise induced by major noisy pieces of equipment.

The critical areas (for Topsides) and rooms (for Living Quarters) are then highlighted. Design modifications are computed and remedial actions proposed.

At the end of the project, measurements are performed to control the conformity of the whole plant with specifications.

2 Noisy equipment control

During the first stage of the project, the potential noisy pieces of equipment are listed (such as turbo-generators, turbo-pumps and turbo-compressors, Diesel generators, reciprocating pumps and compressors, …).

Their planned locations on-site are studied, and preliminary computations are performed as early as possible. Critical areas are highlighted and an acoustic specification is issued for each noisy package, taking into account its localisation and the feasibility for the vendors to respect the limit.

An exchange process is then set up with equipment vendors: assistance and review of equipment acoustic design are provided and technical notes presenting the equipment sound power level computation are reviewed and commented.

Acoustic behaviours of the noisy pieces of equipment are validated during their factory acceptance test on the vendor bench (intensimetry measurements).

This process is summed up in Table 1.

NOISY EQUIPMENT LIST

Selection of noisy equipment

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NOISY EQUIPMENT

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SPECIFICATION (NDS)

Issue of Noise Data and Studies (NDS)
Including definition of acceptance criteria

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ASSISTANCE & REVIEW

- Clarifications of noise requirements to equipment suppliers.
- Follow up and analysis of NDS and calculation notes (including acoustic treatment) provided by equipment suppliers

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EQUIPMENT NOISE MEASUREMENT

Noise measurements and control on supplier test bench during Factory Acceptance Test (FAT)

Table 1 : Noisy equipment control methodology

3 Noise computation & analysis

3.1 Factory (Topsides)

The aim of this part of the study is to assess the noise levels to which workers will be exposed during their shifts in the plant.

This computation concerns external noise, using ray-tracing software such as CadnaA [1]. A geometrical model of the plant is developed including main acoustic sources (valves, pipes and packages: see paragraph 2), defined by their sound power level in octave band, and main obstacles (technical buildings, tanks, scrubbers, …).

Sound pressure level maps are computed for each deck in normal operating conditions. These maps are updated throughout the project with the following acoustic data as it becomes available:

- Acoustic specifications,
- Results of vendor package noise computation notes,
- Measured sound power level of each pieces of equipment, acquired during FAT on vendor test bench.

For each step, critical areas (Lp>85 dBA) are identified and design modifications are proposed:

- On critical equipment (e.g. enclosure),
- On critical piping and valves (e.g. thermal and acoustic cladding),
- On the installation itself (e.g. shielding system).

The final computation is used to define the restricted areas where workers must wear hearing protections.

Maps in emergency conditions (with flare operating: Lw > 140 dB, …) are also computed, to define where emergency speakers and rotating lights shall be located. Audibility in emergency muster points is also studied.

3.2 Accommodations (Living Quarters)

A noise limit is set at the beginning of the project for each room in the Living Quarters depending on the type of room: cabin, office, dining room, …

The overall noise levels in the rooms are the sum of 4 components:

1. <u>Air-borne noise from external equipment</u>: estimated during the previous step (topside noise computation) and applied on the external walls of the building.
2. <u>Air-borne noise from internal machines:</u> radiated by the main machines located in the hull and acoustically transmitted through the partitions.
3. <u>Structure-borne noise from internal machines:</u> related to the floor and partition vibration levels induced by the vibration excitations generated by the machines. Structure-borne

noise transmission is unlikely to produce noise levels above 60 to 70 dB(A), but its contribution should be studied in areas where low noise levels are required.

4. <u>Heating, Ventilation, Air Conditioning system (HVAC) noise</u>: directly radiated in rooms by the HVAC system (openings). This component is estimated and provided by the HVAC supplier.

In order to be able to control the noisy components separately, noise allocations are defined. The overall noise limit (Lp) in each room is split into 3 limits:

- A first limit to control external and internal air-borne noise from acoustic sources (components 1 and 2),
- A second limit to control structure borne-noise from vibrating equipment (component 3),
- A third limit for HVAC noise.

The overall noise limit in each area is split as follows:

- Allocation for air-borne components: Lp – 3 dB,
- Allocation for HVAC: Lp – 5 dB,
- Allocation for structure-borne component: Lp – 7 dB.

The air-borne noise model is composed of:

- A geometrical model, representative of the building size and connection between rooms (see Figure 1),

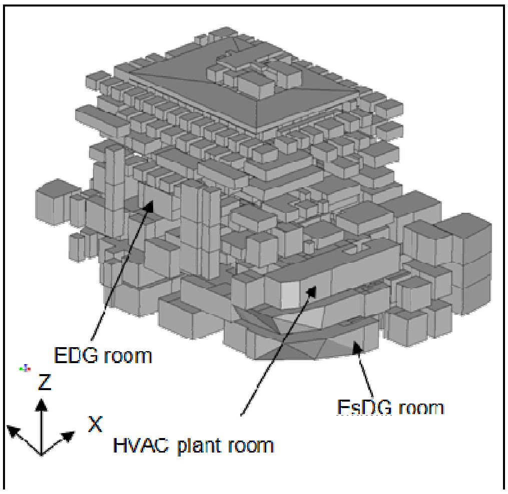

Figure 1: Geometrical model for air-borne noise computation

- Input data: absorption coefficient and transmission loss of panels; main sources' sound power levels.

This computation is based on SEA hypotheses for diffuse fields. It is used to identify critical rooms and panels and to propose local or global design modifications if necessary.

Structure-borne noise is assessed thanks to a hybrid model developed by Vibratec. This method is a simplified version of the FEA-SEA approach, developed in [2]. Input data can be obtained for example thanks to the inverse methods detailed in [3]. The frequency range of interest is from 63 Hz to 250 Hz octave bands.

The principle is detailed in Table 2:

Step 1: Vibration level on vibrating equipment supporting floor <V²>

↓ Transfer function (measured or computed)

Step 2: Average vibration level in critical room floor <V²>

↓ Transfer function (database)

Step 3: Average sound pressure level in room (Lp structure-borne noise)

Table 2 : Synopsis of structure-borne noise computation

Finite Element Computation enables the computation of a mean vibration level inside the rooms containing the main pieces of vibrating equipment. Transfer functions between this mean vibration level and the average vibration level in critical rooms has been estimated, either by computation (FE model) or by on-site measurements on similar installations.

An empirical transfer function (1) between floor vibrations and structure-borne noise contribution is then used to obtain the sound pressure level in the room. This equation was obtained by adapting results of [4] according to Vibratec measurement database.

$$Lp = 20 * \log(V) + CORR \qquad (1)$$

<u>Lp :</u> sound pressure level in the room (dB)

<u>V :</u> floor vibration mean velocity (mm/s RMS) in octave band or 1/3 octave band

<u>CORR</u> is a correction factor, representing the radiation efficiency of the floor in the frequency range of interest. This factor is based on Vibratec experience and is illustrated in Figure 2

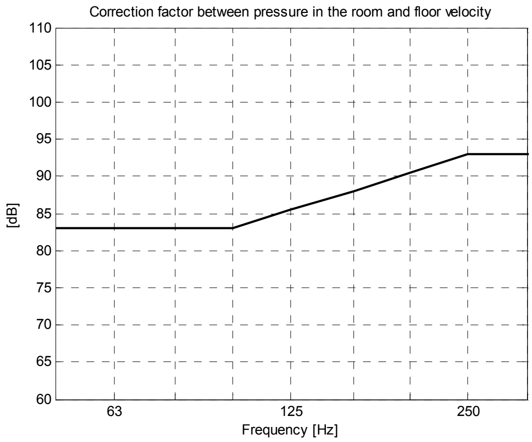

Figure 2: Correction factor used for structure-borne noise estimation.

Figure 3 compares measured and computed structure-borne noise in a room (air-borne and HVAC components are negligible in this room).

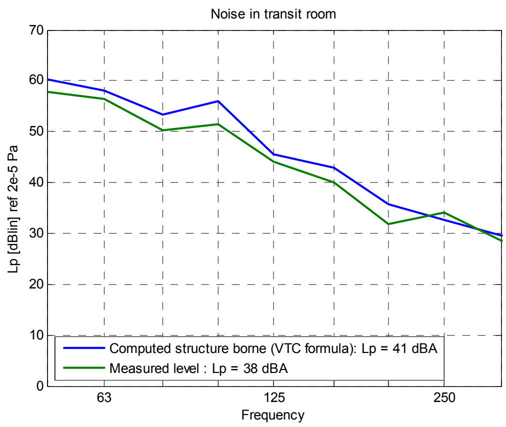

Figure 3: Illustration of computed and measured structure-borne noise

Spectral recomposition is satisfactory and global noise is over-estimated by 3 dB: this estimation highlights critical rooms during the design phase. Appropriate remedies, such as floating floors, can be considered early in the project.

4 Noise commissioning

Once the vessel is built, a first commissioning stage can be performed: noise and vibration measurements inside the accommodations. These measurements are used to verify operational noise level in the rooms, as well as the quality of the insulation between them.

Equipment packages located in the hull are started and loud-speakers are used outside to simulate the factory noise on the accommodation walls.

Once the vessel and the factory are on-site and operating normally, a noise map is measured to assess the effective noise throughout the topsides. Results are compared with requirements in terms of workers' exposure to noise.

5 Conclusion

This global methodology goes from the earliest stage of the design to the production launch of the vessel. It enables the estimation of noise levels to which offshore workers will be exposed, and identifies potential critical areas for which design modifications are necessary as early as possible in the project.

Références

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