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Ship acoustics

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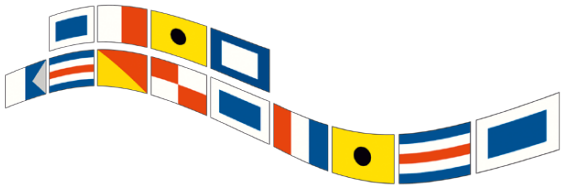
Acoustic optimisation – an indispensable aspect of modern shipbuilding



Safety and comfort

In modern shipbuilding, acoustic optimisation is more than just cosmetic tinkering or an extravagant luxury. In many cases it improves the usability of the vessel and greatly enhances its appreciation by owners and passengers alike. Today's cruise passengers would for example consider it unacceptable for the comfort they expect on a liner to be compromised by irritating noises. Similarly, in cabins on a superyacht all the various built-in systems and equipment must operate unobtrusively to the passenger. On research and navy vessels on the other hand, acoustic optimisation is often actually a fundamental prerequisite for operation at sea. And for safety reasons alone, audibility of alarm signals and speech intelligibility must be ensured everywhere on board.

Complex requirements

The acoustic conditions on board a vessel are extremely complex, with noise and vibration emanating from a number of sources, including diesel motors, cooling compressors, pumps and propulsion systems. Moreover, the typical structure of a ship with its associated ducts and piping systems provides virtually ideal propagation conditions for noise and vibration. At the same time, for reasons of space and weight the scope for abatement measures is usually limited.

Having been involved in all aspects of ship acoustics for over 50 years, our wide range of experience makes Müller-BBM ideally placed to deliver the holistic solutions demanded here. You can therefore rely on our know-how to create added comfort and safety on your ships.

Title page:
Consulting and measurement services for shipbuilders, shipping companies, design offices and suppliers of technical systems for ships.

Diversity is our strength

Tailor-made solutions designed to bring you success

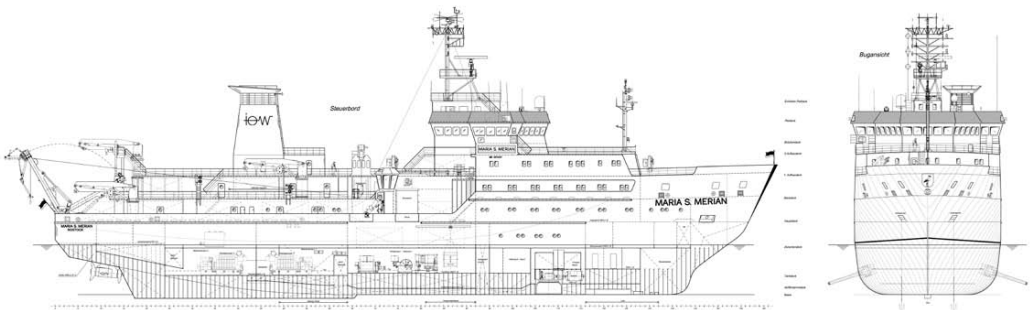
Our services are as diverse as shipping itself and our expertise comprises yachts, cruise liners, cargo ships, research vessels and navy ships. In the definition phase we provide advice on acoustic targets and specifications to shipbuilders, shipping companies, design offices and suppliers of technical systems for ships. During the design and construction phases we also assist with the planning and testing of all noise control measures.

The earlier we are involved, the sooner we can produce airborne sound and vibration predictions for your vessel. And the sooner we can work with you to identify the required abatement measures and determine the most cost-effective overall concept.

Comprehensive consulting in all phases

To ensure that plans are translated into acoustic reality, we offer competent consulting and qualified measurement service throughout the building phase. As well as forming part of ongoing quality control, the capture of airborne and structure-borne noise data from machinery suppliers or from the ship's carcass itself also enables comparison with the input data of the acoustic predictions.

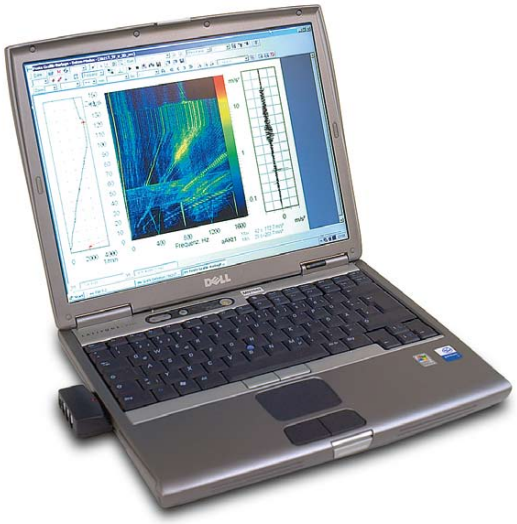
Utilising our many years of experience in evaluating measurement data, we also employ highly specialised analytical tools, in some cases developed in-house, to assess the overall noise characteristics of a vessel or individual aggregates. For example, we use modern numerical techniques such as the Finite Element Method FEM and Statistical Energy Analysis SEA for evaluation at different construction stages.



Measuring, testing and consulting

Well-grounded operational measurements

The cornerstone of our work is the ability to measure and assess all dimensions of acoustic and vibration phenomena through operational measurements. Recording and interpreting airborne, waterborne and structure-borne noise data is therefore one of the core activities of Müller-BBM.



Greater transparency for your decision-making

In many areas in the development, optimisation, evaluation and monitoring of ships, machinery and equipment, the ability to make good decisions rests on a precise knowledge of dynamic system behaviour. Depending on the task at hand, we can measure a regular operating state or a system's response to a defined excitation signal (e.g. impulse hammer, shaker). If wished, it is also possible to extend the relevant airborne, waterborne or structure-borne noise data by simultaneously recording the operating parameters (rpm, temperatures, pressure, etc.). This allows us to find out whether unwanted noise occurs permanently or only in specific operating situations. Our analysis then enables you to assess thesignificance of possible abatement measures.

Seal of approval

From simple measurements of noise pressure levels through to complex investigations involving a large number of measuring points, we have gathered many years of experience in the field of measurement technology and conduct our measurements and calculations objectively and independently. As in many other fields, Müller-BBM is also an accredited testing laboratory for noise and vibrations according to DIN EN ISO/IEC 17025.

Individual investigations

In-house test stands and laboratories

It is not always possible or desirable to conduct measurements during operation. If, for example, the acoustic properties of machinery or components are to be tested under specific conditions or without environmental effects, Müller-BBM can provide advanced test stands and measuring equipment. This enables us to objectively assess the noise emissions of a component in advance and integrate it in the overall analysis.

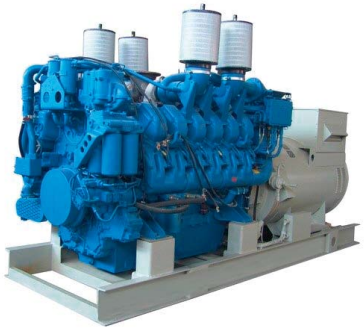
As it is product-specific and does not depend on the acoustic characteristics of the installation site, the sound power level is normally the variable used for the acoustic assessment of a component, machine or system. We perform these measurements in compliance with international standards in anechoic rooms with ultra-minimal external noise or in the diffuse acoustic field of a reverberation chamber.

Interdisciplinary benefits

Grounded in our many years of consulting and testing activities in the field of building acoustics, we maintain our own testing facilities for determine the airborne sound insulation of wall and ceiling elements as well as windows and doors. We can determine the impact sound levels of floorings and deck coverings on our in-house ceiling test facility.

To obtain an overall picture, it is often important to know the acoustic properties of duct linings, air intake and outlet systems or duct elements. On a specially developed test stand, we can measure these at virtually any flow speed without the influence of fan noise. IThe insertion loss of mufflers cane be measured here as well.

Specific construction issues



Design of elastic mountings

Reducing the amount of structure-borne sound entering a ship's structure is a key prerequisite for meeting acoustic specifications. Already during the planning phase, therefore, we focus on the correct design of resilient mountings for machinery and equipment.

Using state-of-the-art software tools, we calculate the natural frequencies (coupling frequencies) of the system, taking into consideration the weight and dimensions or moment of inertia of the machinery, as well as the dynamic spring characteristics of the mounting elements provided.

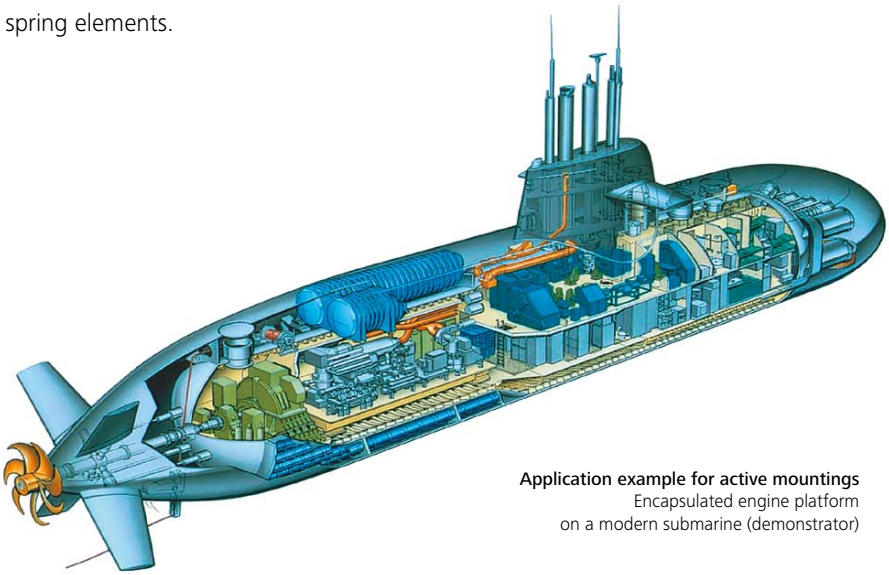
At the same time, we calculate the insulation properties of the planned elastic mountings and the static deformation, if necessary taking into account the drive torque or the given trim and heeling values in order to simulate the effects of swell.

Comprehensive assessment

Knowledge of the dynamic spring characteristics is essential for designing elastic mountings with respect to their vibration and acoustic insulation properties.

Müller-BBM's test stand enables us to determine the dynamic spring characteristics of a bearing with virtually any static preloading and realistic excitation amplitudes for the main axes of the spring elements.

These investigations are based on the laboratory method for measuring the vibro-acoustic transfer properties of resilient elements described in international standard ISO 10846. Based on the fundamental structure and the measurement values, we can then make precise predictions for vibration decoupling in the relevant frequency ranges.



Application example for active mountings
Encapsulated engine platform
on a modern submarine (demonstrator)

The sooner the better

Room acoustic calculations

Shipboard noise often is the result of inadequate or substandard sound insulation measures. Our expertise in acoustics can help you optimise the acoustical concept of your vessel already during the planning phase, sparing you any unpleasant surprises and the need for costly countermeasures at a later date.

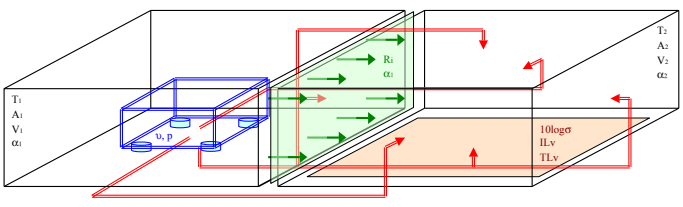
A characteristic feature of our holistic approach is the analysis of all transmission paths in order to reliably predict the sound propagation in rooms. Airborne noise transmission is very important in the immediate vicinity of the noise source, while the impact of structure-borne noise usually dominates at greater distances. However, there are a wide variety of individual factors that determine the sound level in any given room.

For instance, the structureborne noise is reduced as a function of the elastic mountings of the engine, the length of the propagation path, the ship's structure and the properties of the insulation measures adopted.

In addition, the absorption characteristics of the rooms themselves influence the resulting noise level. Depending on the size of the room, wall construction and furnishings, the incident sound can be amplified by reflection or reduced by absorption.

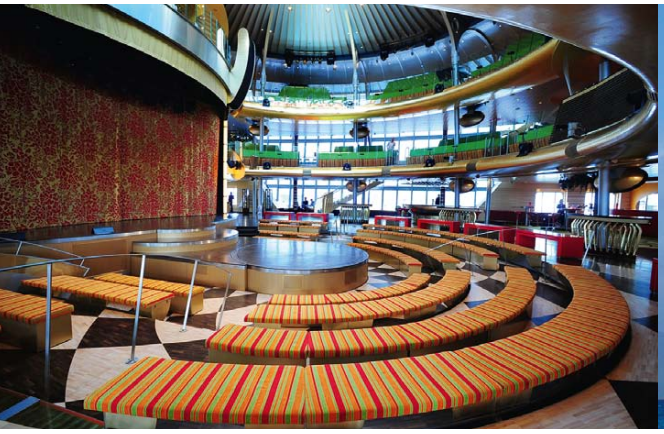
If the source levels, the properties of the insulation material and the structural parameters of the ship are known, the sound transferred into the receiving room can be calculated for each transmission path. The energetic addition of all transmission paths then gives the noise level in the room.

Thanks to our many years of work in this field and the comprehensive database on noise sources and insulating materials we have compiled, we can quickly produce reliable predictions for sound propagation in the rooms of your vessel.



Transmission paths between transmitting and receiving room
Reliable sound propagation prediction

Well-founded information for safety and comfort



Sound propagation calculations

Not only do acoustics play an important role in comfort and safety of passengers and crew in the interior of vessels, noise levels are a key factor in external areas. Besides the need for quiet relaxation, there are also safety aspects to consider. It must be ensured, for instance, that voice instructions and alarm signals can be heard and understood at all times.

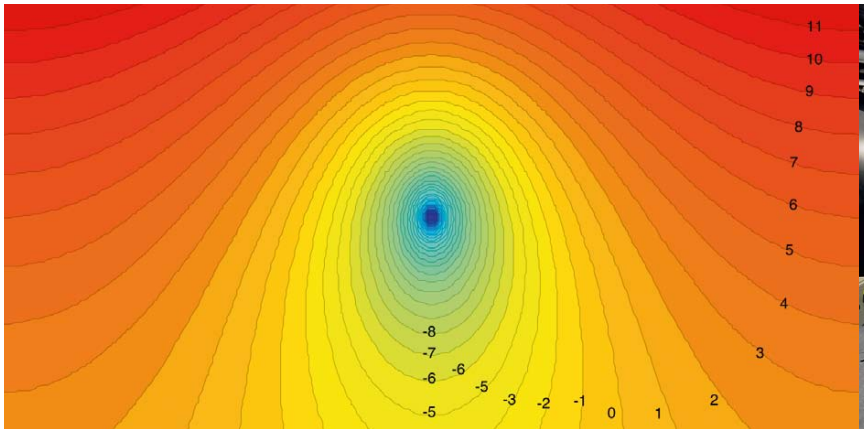
Simulations and calculations

Numeric propagation models enable us to generate detailed sound maps for specific sections or entire decks from the given noise data for ventilation grilles, exhaust gas stacks or machinery set up in exterior areas. The great benefit of these sound maps is that critical areas can be identified at a glance, and you can readily monitor the success of any changes implemented.

The methods we use to calculate sound emissions and propagation are specified in the latest directives and standards. Three-dimensional modelling of deck sections and incorporation of the reflection and absorption characteristics of the elements used affords an exact mapping of the acoustic conditions. The shielding, reflecting , superpositioning and bending effects prevailing on board are factored into the calculations so that noise abatement measures can already be optimised during the planning phase, before building even commences.

Result of a sound propagation calculation
Deck area of a cruise liner with tenders (plan view)

Research and development at Müller-BBM

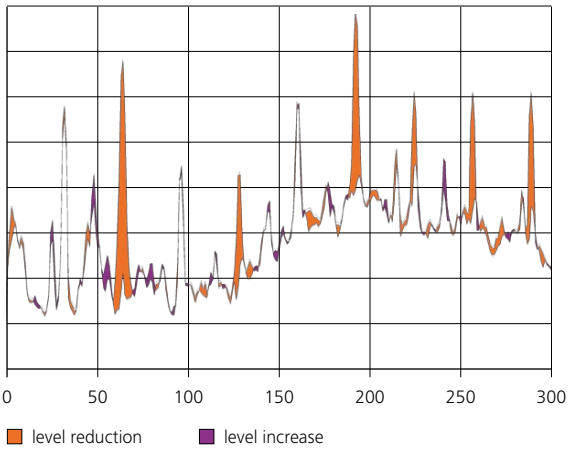


Methods for active noise reduction

It is not always possible to resolve complicated acoustic problems with the technology currently available. At Müller-BBM we therefore research and develop new measurement and calculation methods along with solutions for the shipbuilding industry. One current example are methods for active noise reduction.

All airborne and structure-borne noise on a ship is ultimately attributable to oscillations in the ship's structure in the acoustic frequency range and can be described as waves. Independent waves are superimposed and if, given two otherwise identical waves, the peaks and troughs always line up exactly, they cancel each other out. This is the simple idea behind active noise reduction methods which are frequently referred to somewhat loosely as »anti-noise«. However, practical implementation is not always quite as straightforward since it is necessary to generate the anti-noise at all the desired points and at all times with a very high degree of precision and a 180° phase offset. The graphic shows the relatively narrow range within which this phase cancellation delivers the best results. Owing to the relatively narrow tolerances involved, practical solutions are usually limited to »acoustically simple« problems. This includes, for example, tonal structure-borne noise excitations of rotating machines which, transmitted over the engine mounts, can often be heard throughout the ship. Active systems can improve the passive mounts with respect to the unwanted tones here. We have already succeeded in showing the benefits of active mountings in a variety of demonstration systems.

Fundamental frequency 30 Hz
active system on 2., 4., 6. – 9. harmonic



Active mounting application
Structure-borne sound levels with and without active mountings to reduce selected harmonics of an engine in a large shipbuilding demonstrator

Acoustic status and signature monitoring

In critical cases, permanent monitoring and analysis of the acoustic status of a vessel or individual machinery may be expedient or necessary. Müller-BBM develops and implements methods and systems for monitoring individual machines or entire vessels during operation on the basis of the airborne and structure-borne noise data captured.

Implementing a monitoring system involves a wide variety of tasks:

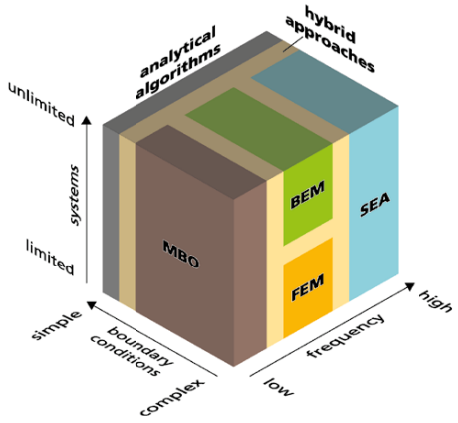
- Selection and positioning of sensors
- Definition and adaptation of the signal analysis to the particular problem
- Producing the monitoring software with a custom user interface
- Definition of alert and intervention limits
- Creation of user-oriented functions such as data recording and visualization, current status monitoring and data storage.

The benefits for you are clear: by tailoring the hardware and software to your various requirements, you gain both the optimum results and maximum safety. Systems for monitoring the cavitation of ship's propellers, the wheel quality of trams or vibrations within a heat exchanger are just some examples of systems created by Müller-BBM.

We employ state-of-the-art methods to improve the performance of monitoring systems. One example is the description of sound propagation in complex technical systems using Transfer Path Analysis (TPA) with crosstalk cancellation.

This is also used in systems for estimating the acoustic radiation of navy vessels. The waterborne noise in the far field, i.e. the acoustic signature, is predicted from structure-borne sound measurement data. The method was integrated in a real-time structure-borne sound monitoring system that has already seen successful deployment.

Numeric simulation: FEM, BEM and SEA

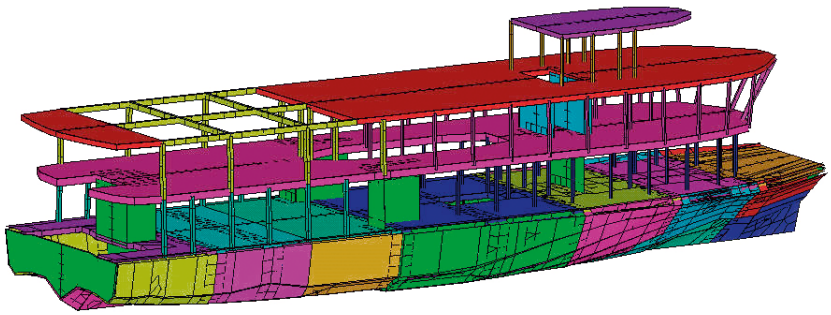


Certain problems require the use of numerical methods for calculating the vibration properties of local or global structures. These include, for instance, the calculation of propeller-excited pressure fluctuations on the outer skin of a vessel or design of the intermediate mass of an elastic mounting system.

Müller-BBM employs the Finite Element Method (FEM) and the Boundary Element Method (BEM) to simulate a wide variety of technical scenarios. In structural dynamics and acoustics, these two techniques are important above all in the lower frequency ranges. Problems in the higher frequencies are resolved with the aid of statistical methods such as Statistical Energy Analysis (SEA).

In the case of FEM, the exact definition of the structural elements with respect to material, geometry and boundary conditions is crucial in order to obtain correct calculations. We create a simulation model on the basis of the steel structure plans for the ship or detailed drawings of components.

With the aid of the analyses, improvements can be made promptly and cost-effectively to the structure in question according to criteria such as, for example, transmission behaviour, natural frequencies, radiated sound power, dimensions or strength. Modifications can therefore be evaluated quickly in order to identify the optimum design.



FEM overall model of hull structure

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Müller-BBM Industry Solutions GmbH is a subsidiary of Müller-BBM AG, with headquarters in Planegg near Munich. Since 1962 Müller-BBM has been advising clients nationally and internationally and is now one of the world's leading engineering firms. More than 350 highly qualified employees form an interdisciplinary team of scientists and engineers in the most diverse specialist fields. The company currently has twelve offices in Germany as well as a branch office in Austria.

Notifications
Müller-BBM Industry Solutions GmbH is notified as an expert authority in accordance with § 29b of the German Federal Pollution Control Act (BImSchG).

The notification comprises
- determining emissions and immissions of air pollutants, noise and vibration
- verifying the correct installation and function in addition to the calibration of continuous emission measurement systems (CEMS)
- checking combustion conditions

Accreditations
Our testing and calibration laboratories are accredited according to DIN EN ISO/IEC 17025:
- Test laboratory for sound and vibration, electromagnetic fields and light, air pollution control, measurement of hazardous sustances
- Calibration laboratory for acceleration and acoustical quantities

Müller-BBM Industry Solutions GmbH has a significant number of employees with competency certificates that were awarded to them on an individual basis. They include publicly appointed and sworn experts, state-recognised experts and otherwise appointed and notified experts.

Detailed information on the scope of our accreditation, its international validity and the corresponding certificates can be found on http://www.mbbm-ind.com/about-us/quality

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