CASE STUDY

France

Automotive/Community Comfort

PULSE, Transducers, 2260 Investigator

ALSTOM Marine
Sound and Vibration Testing on Ships

In December 2003, the French shipbuilding company ALSTOM Marine delivered the world's largest passenger liner to her new owners, the UK-based shipping company Cunard. At 150 000 tonnes, Queen Mary 2 is the longest, tallest, heaviest and widest passenger ship ever built. Queen Mary 2 will have a crew of 1310 and can accommodate 2620 passengers in over 1400 cabins, suites and apartments.

Brüel & Kjær products are widely used to measure the levels of sound and vibration of Queen Mary 2. For instance, Precision Sound Level Analyzers Type 2260 D are used to measure the acoustic insulation and quietness of the cabins. PULSE™ systems measure on-board vibration levels while Brüel & Kjær hydrophones are used to measure underwater acoustic levels, thus ensuring this huge ship is environmentally friendly underwater and will not disturb wildlife.

Photo by kind permission of ALSTOM Marine, Bernard BIGER

ALSTOM Marine

ALSTOM Marine, via its subsidiary Chantiers de l'Atlantique, and ALSTOM Leroux Naval (subsidiary of Chantiers de l'Atlantique), is a global leader in the building of ships with high added value. Its wide range includes:

- Cruise ships
- Mega yachts
- High-speed ferries
- Naval vessels
- Oil and liquefied natural gas (LNG) tankers
- Container and cargo ships
- Specialised and complex vessels

Long History

Created in 1861 by the Compagnie Générale Transatlantique, Chantiers de l'Atlantique has been a subsidiary of ALSTOM since 1984. The shipyard at St. Nazaire on the French Atlantic coast had a turnover of some 1.8 billion Euros in the 2000/2001 period. Its clients included many of the world's largest ship owners.

The 5000 employees of Chantiers de l'Atlantique, and its 900 naval partners and suppliers have, to a large extent, contributed to the success of the company.

ALSTOM Leroux Naval is a subsidiary of Chantiers de l'Atlantique. Its shipyard at Lorient is highly specialised. With 175 employees, ALSTOM Leroux Naval is a pioneer in the development high-tech, single-hulled, high-speed ferries, coastal patrol boats, tugs, small cruise ships, yachts, and scientific and other specialised vessels from 30 to 140 metres long. The company has tripled its turnover In the last two years.

A further 100% owned Chantiers de l'Atlantique subsidiary, Ateliers de Montoir, specialises in the manufacture of marine furniture including furnishings, doors, teak fittings, and steel/stainless steel equipment.

The Saint-Nazaire Shipyard

Fig. 1
The Saint-Nazaire shipyard covers an area of 108 hectares
Photo by kind permission of ALSTOM Marine

Chantiers de l'Atlantique covers an area of 108 hectares, of which 22 hectares are covered. There is a huge construction dock that enables several hulls to be assembled simultaneously.

The impressive facilities include an assembly platform of 470 m × 66 m, a dry dock of 415 m × 66 m, a pre assembly area of 885 × 45 m, a fitting-out basin of 424 m × 95 m, two fitting-out quays 300 m long, and lifting equipment – gantry cranes of 750 tonnes with a reach of 130 m, and 255 tonnes with a reach of 130 m.

Fig. 2
The shipyard has extensive construction facilities
Photo by kind permission of ALSTOM Marine

The first stage in ship construction is the machining of plates and profiles. Chantiers de l'Atlantique has a raw material storage area, and workshops to produce the initial items required for the assembly and supply of five metal-hull workshops, and numerous contractors.

CAP 21 Project

In April 1998, ALSTOM Marine set itself three ambitious objectives:

- Greatly increase performance, particularly in terms of costs
- Achieve the position of world leader in the cruise ship market
- Considerably improve productivity – in one year to increase production from two to five vessels per year

It was a great success. By April 2001, all of these objectives had been achieved:

- Costs have been effectively reduced by approximately 30%
- Management and workforce organisation has greatly changed – ALSTOM Marine increased its workforce by 1500, and business partners and subcontractors created several thousand more jobs
- Chantiers de l'Atlantique has become the world leader in the cruise ship market

With the new CAP 21+ plan, launched in 2001, ALSTOM Marine will consolidate this success in the long term. It has set a new ambition for future years – to be recognised by its customers as the unifying influence in a world centre of excellence, a creator of complex projects in the maritime sector both today and tomorrow.

Queen Mary 2 – The World's Largest Passenger Ship

Fig. 3
Queen Mary 2 – the main lobby during the final stages of fitting-out
Photo by kind permission of ALSTOM Marine, Bernard BIGER

On 6th November, 2000, the British shipping company, CUNARD, showed its confidence in ALSTOM Marine by granting it the contract for the construction of Queen Mary 2, the world's largest passenger liner. Following the research and design phases, the construction of Queen Mary 2 began on 16th January 2002, when the first steel was cut. Queen Mary 2 was delivered to Cunard at the end of December 2003, and set sail on her maiden voyage in January 2004.

Designed by ALSTOM Marine, the ship is equipped with the latest technology in the fields of propulsion, stabilisers and environmental protection. For ALSTOM Marine, Queen Mary 2 confirms its know-how and cutting-edge technology, and its position as the world leader in the construction of high-added-value ships.

Main Features

- Overall length – 345 metres
- Passengers – 2620
- Passenger accommodation – 1430 deluxe cabins, suites and apartments
- Surface area of the public spaces – 26800 m^2
- Crew – 1310
- Total power – 118000 kW

Even though Queen Mary 2 is powered by two gas turbines and four diesel engines, she will be very quiet, setting new standards of comfort her passengers and crew.

Expertise

Mr. Marek Mazepa is a noise and vibration technician in ALSTOM Marine's Technical Department. Born in Poland, Mr. Mazepa has a Master's degree in metallurgy from the University of Catowice. He studied mechanical engineering at CNAM in Paris.

Mr. Mazepa has worked for the ALSTOM Group for 23 years, originally at Le Bourget Turbines where he specialised in stress and strain measurements on products used in the power plant and nuclear industries. He moved to ALSTOM Marine's Saint-Nazaire Shipyard in 2000.

Mr. Mazepa explains, "I have seven colleagues in our department. Each of us is responsible for testing the acoustics and vibration of one ship. We make a series of predefined standard measurements. In addition, I have responsibility for carrying out special meas-

urements and investigating specific problems on all ships built by ALSTOM Marine. This includes not only the shipyard here in Saint-Nazaire, but also ships built at Lorient".

Fig. 4
Mr. Marek Mazepa is a noise and vibration technician in ALSTOM Marine's Innovation – R&D Department

He continues, "We specially focus on customer service. If a customer has a particular noise or vibration issue on a ship that we have already delivered, then it's my job to investigate the sources, causes and to suggest solutions. It's a very interesting job".

"Our relationship with Brüel & Kjær goes back about 20 years, although I am familiar with them since I was at university. At ALSTOM we use their products to test and analyse the sound and vibration properties of the ships we build, both on-board and underwater. We also test components and materials. We currently have three Precision Sound Level Analyzers Type 2260 D, a 12-channel PULSE system, accelerometers, microphones, hydrophones and calibrators. We also have a number of other analyzers such as a Dual Channel Type 2144 and Vibration Analyzer Type 2515 that are still in use."

PULSE

Mr. Mazepa says, "I have used PULSE for about two years and have become the PULSE "super-user". I spend much of my time using it, but my colleagues also want to use the system and I am teaching them how to make tests and analyse the data, although at the moment I configure and set up PULSE for each type of measurement".

"We can either use the PULSE front-ends separately or stacked together if more channels are needed. One has seven channels and the other five – it's a very flexible arrangement."

Fig. 5
ALSTOM Marine's PULSE system comprises two front-ends – a 5-channel and a 7-channel unit. They can either be used separately, or stacked together

"We either make the measurements and record time data on PULSE for post-processing in the lab, or we can analyse the data in real-time. If more than 12 channels are needed, or if the time data is longer than one hour, we record the data on a Sony DAT recorder. This has an expansion unit that increases the number of channels from 32 to 64. All measurements are dynamic."

He adds, "In my opinion, PULSE is best system available. It's reliable, accurate and well known – it has proved itself. Having the ability to record and analyse at the same time, and on many channels, is a real benefit, and of course, as our testing demands grow, we can easily expand our PULSE system".

"I didn't have any particular PULSE training but used the help functions built in to the software. Once you understand the philosophy, then it's simple. Now I work with PULSE everyday and make my own projects – it's very user-friendly."

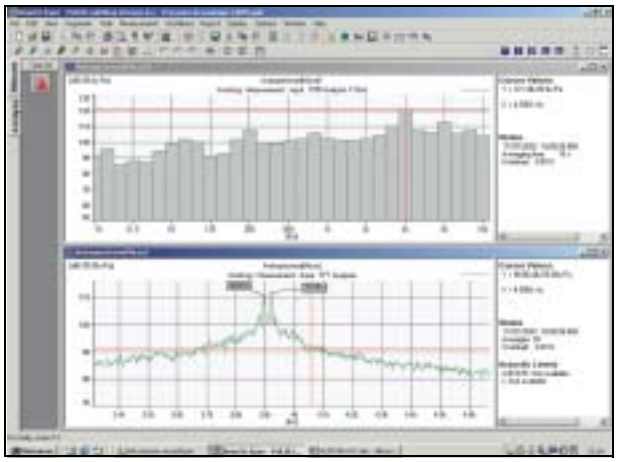

Fig. 6
A typical PULSE display showing the sound pressure spectrum of the ship and FFT narrow-band analysis with the peaks annotated

The test parameters that are carried out on a ship are determined by Mr. Mazepa, his colleagues and the manager of the R&D department.

Mr. Mazepa explains, "There are three factors that we want to correlate. These are, vibration, acoustics and the dynamic pressure of the propellers – measured using a sensor through a small hole in the hull. These measurements go into a database and are used when drawing up provisional specifications of a ship".

"As an example, on the Queen Mary 2, we measured the vibration level on the fourth deck. We used the two PULSE front-ends stacked together to give us 12-channels. We placed single-axis accelerometers all over the ship, at predetermined positions, which required about five kilometres of cables".

"We measured the natural frequency of the ship, excited by the waves. Typically, the frequency of the waves is about 0.1 Hz. Queen Mary 2 has two gas turbines and also four diesel engines, so we measured the effect of these different propulsion systems running at a wide range of speeds. Using FFT analysis, the frequency range of interest is from 0.1 Hz to 5 kHz."

Fig. 7
Mr. Mazepa in his laboratory at ALSTOM Marine's Saint-Nazaire shipyard

To check conformity with agreed specifications, Mr. Mazepa also makes measurements on components such as gearboxes, bearings, motors, pumps, air conditioning, the efficiency of rubber mountings and even washing machines – in fact everything that affects the vibration of the ship's structure. The natural resonant frequency of the ship is also measured. The result is used to validate the mathematical model calculation and to confirm the rigidity of the ship's structure.

Modal Analysis

Modal analysis is carried out while the ship is moving. 32-channels are normally used with the accelerometers placed at 160 predetermined measurement points on three or four decks. The data is currently recorded on the Sony DAT recorder and post-processed using PULSE in the lab, but soon PULSE will also be used to also acquire the data.

Mr. Mazepa comments, "We also carry out modal analysis on individual parts of the ship's structure. For this work we use impact hammers and a range of shakers. These range from a 10 N shaker up to a 2000 N unbalanced, variable-speed shaker that can exert a force of up to 20 tonnes to 30 Hz. Many of our shakers are made by Brüel & Kjær".

Comfort Measurements

Comfort measurements are made using both PULSE and Precision Sound Level Analyzers Type 2260 D. The acquired data is A-weighted to correspond with noise as perceived by an average person.

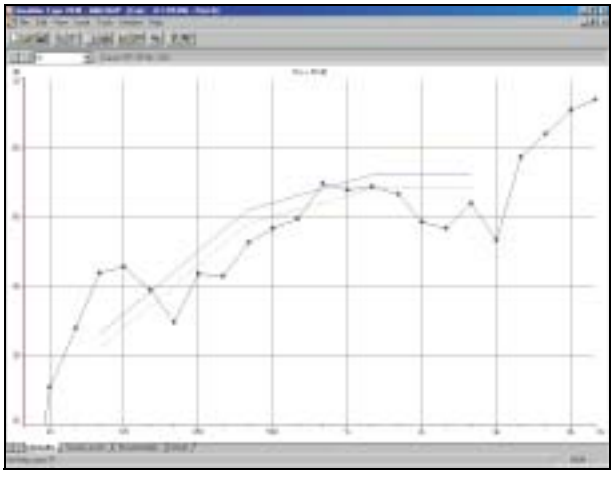

Fig. 8
Airborne noise insulation, indicated by R'_w (ISO 717), is measured with 2260 D and reported with Qualifier Type 7830

Mr. Mazepa says. "We measure the acoustics levels in all parts of the ship. The measurements are made to check conformance with the specified levels and also to test the effectiveness of insulation materials and to develop new sound-proofing solutions. We use Brüel & Kjær Sound Source Type 4224, BZ 7204 Building Acoustics software on 2260 Investigator, and Qualifier Type 7830. We also made tests for impact noise using a Brüel & Kjær Tapping Machine Type 3207".

Emission levels are typically between 90 and 100 dB(A), and receptions levels are dependant on where the measurements are made. The two spectra are measured consecutively, not simultaneously.

Mr. Mazepa continues, "The 2260 is really easy to use. It's completely portable and allows us to make accurate measurements anywhere. We can see the results in real-time but can also post-process the data using the Qualifier software".

Underwater Measurements – Environmental Factors

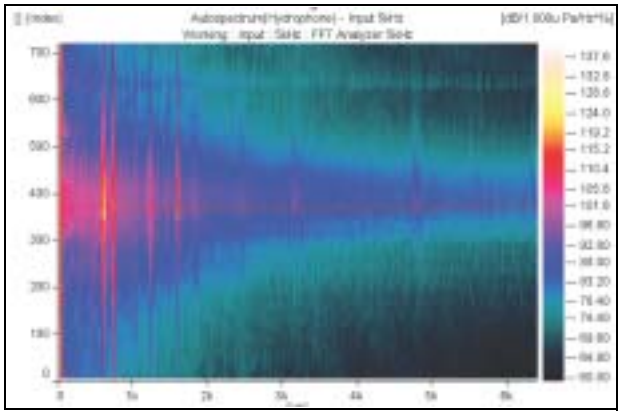

Fig. 9
A typical contour plot from an underwater pass-by measurement on a ship using PULSE and two hydrophones

There are tight specifications on the underwater noise of oceanographic ships built specifically for scientific and survey work. Today, many cruise ships visit protected areas of scientific interest and include activities such as whale watching.

Mr. Mazepa explains, "Our cruise ships do not have to conform to these underwater noise emission levels but, in the future, we expect them to be adopted as an international standard. They form part of the vessels specification".

Pass-by

The test used to check conformity is similar to the type of testing carried out on naval vessels. PULSE is placed in a small boat. Two hydrophones, each 30 to 40 metres deep are connected and the ship passes by, to port and starboard at different speeds. Using

GPS, the navigation has to be accurate as the distance from the ship to the hydrophones must carefully calculated. Using extrapolation, this distance is then used to calculate the underwater sound pressure at a distance of one metre from the propeller pods and shafts. The result also allows us to compare the noise levels produced by different propulsion designs."

Data Management and Reporting

Using the Report Organiser in PULSE with standard reports, the test data is automatically exported to Microsoft® Word or Excel. Non-standard reports are created using "cut-and-paste" procedures.

Mr. Mazepa says, "These reports are printed on paper and sent, as required, to my colleagues in R&D, customer service, our technical and engineering departments, to certifying authorities such as Lloyds, and to our end customers. The test data is all archived on CDROM and on a central server."

"We often compare data using Excel and therefore, the provision of PULSE Data Manager Type 7767 in PULSE version 8.0 will be very useful."

Key Facts

- ALSTOM Marine, via its subsidiary Chantiers de l'Atlantique, and ALSTOM Leroux Naval (subsidiary of Chantiers de l'Atlantique), is a global leader in the building of ships with high added value
- ALSTOM Marine's shipyard, located at Saint-Nazaire, on the French Atlantic coast, has 5000 employees
- In November 2000, the British shipping company, CUNARD, showed its confidence in ALSTOM Marine by granting it the contract for the construction of Queen Mary 2, the world's largest passenger liner
- The company's relationship with Brüel & Kjær goes back about 20 years,
- Brüel & Kjær products are used to test a ship's sound and vibration parameters
- ALSTOM Marine currently use Precision Sound Level Analyzers Type 2260 D, 12-channel PULSE system, accelerometers, microphones, hydrophones and calibrators
- "In my opinion, PULSE is best system available. It's reliable, accurate and well known – it has proved itself"
- "There are three factors that we want to correlate. – vibration, acoustics and the dynamic pressure of the propellers"
- "The 2260 is really easy to use. It's completely portable and allows us to make accurate measurements anywhere. We can see the results in real-time but can also post-process the data using the Qualifier software"

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