

CASE STUDY

Sweden

Automotive, Aerospace

Kungliga Tekniska Högskolan – Royal Institute of Technology
Marcus Wallenberg Laboratory – Sound and Vibration Research

PULSE™, Transducers

Kungliga Tekniska Högskolan (KTH) was founded by Royal Charter in 1827. The University has over 11000 undergraduates, 1500 postgraduate students and a staff of more than 3000. Since 1917, KTH has been housed in central Stockholm, Sweden, in beautiful buildings which today have historical monument status. In addition to providing first class educational facilities, KTH is engaged in cutting-edge research over a broad spectrum – from natural sciences to all branches of technology.

Within KTH, the Marcus Wallenberg Laboratory for sound and vibration research has a wide range of Brüel & Kjær products including transducers, sound level meters and a PULSE system.



Department of Aeronautical and Vehicle Engineering

Within KTH is the Department of Aeronautical and Vehicle Engineering. It consists of nine divisions:

- The Marcus Wallenberg Laboratory (MWL) for Sound and Vibration Research
- Aerodynamics
- Flight Dynamics
- Lightweight Structures
- Naval Systems
- Neuronic Engineering
- Railway Technology
- Underwater Tech.
- Vehicle Dynamics

In addition, there are two centres – one for railway technology and one for road vehicles.

Marcus Wallenberg Laboratory



Fig. 1
Hans Peter Wallin is a senior lecturer and responsible for undergraduate education at the MWL



Established in 1977, MWL is the largest centre for technical acoustics in northern Europe. It focuses on experimental work in the fields of sound, vibration and structural dynamics and the laboratory is specially designed for applications relating to vehicles, machines and processes. The research carried out focuses on vehicle dynamics, safety, comfort, low noise design and environmental impact.

Hans Peter Wallin (known as HP) joined KTH in 1977 and is a senior lecturer and responsible for undergraduate education. He explains, "Today, there are 30 people employed in MWL, and we currently have seventeen Ph.D students".

HP continues, "We train about 550 students each year in basic sound and vibration techniques. My own main task is responsibility for the education of students up to Master Degree level. About 75% of my time is spent teaching. The remaining time is divided between research and other projects. In 2002, our turnover was some 2.8 million Euros".

MWL works with many of the world's leading automotive, aerospace and industrial companies including:

- | | |
|---------------|----------------------|
| ○ Atlas Copco | ○ SAAB |
| ○ Airbus | ○ Scania |
| ○ Bombardier | ○ Electrolux |
| ○ Ericsson | ○ Ford |
| ○ Nokia | ○ Renault |
| ○ Volvo | ○ and many more..... |

In the six years since 1996, MWL has participated in fifteen EC research projects.

Extensive Facilities

In the beginning and middle of the 1990s, one of HP's tasks was to design and commission MWL's state-of-the-art sound and vibration test facilities.

The central part of the laboratory consists of four measurement rooms located in a row:

- anechoic room – 80 Hz cut-off frequency
- reverberation room – 246 m³ volume
- shock and vibration room – 297 m³ volume
- semi-anechoic room – 80 Hz cut-off frequency

All measurement rooms are isolated from the rest of the building in accordance with the 'box in a box' principle to ensure extremely low background noise levels. The rooms are designed to accommodate large objects such as passenger cars, and are equipped with hot and cold water, compressed air, hydraulics, exhaust gas evacuation and refrigeration. The doors between the measurement rooms have openings of 2.4 m × 2.2 m, and are equipped with special frames for quick mounting of different test objects for studying sound generation and transmission in both free and reverberant fields. Cranes

etc., are provided for transporting and hanging test objects up to 5000 kg. The laboratory hall at the entrance floor is designed for larger test objects, such as small aircraft and railway carriages.

Fig. 2
The layout of the MWL laboratory facilities. The four measurement rooms are in a row and have large interconnecting doors

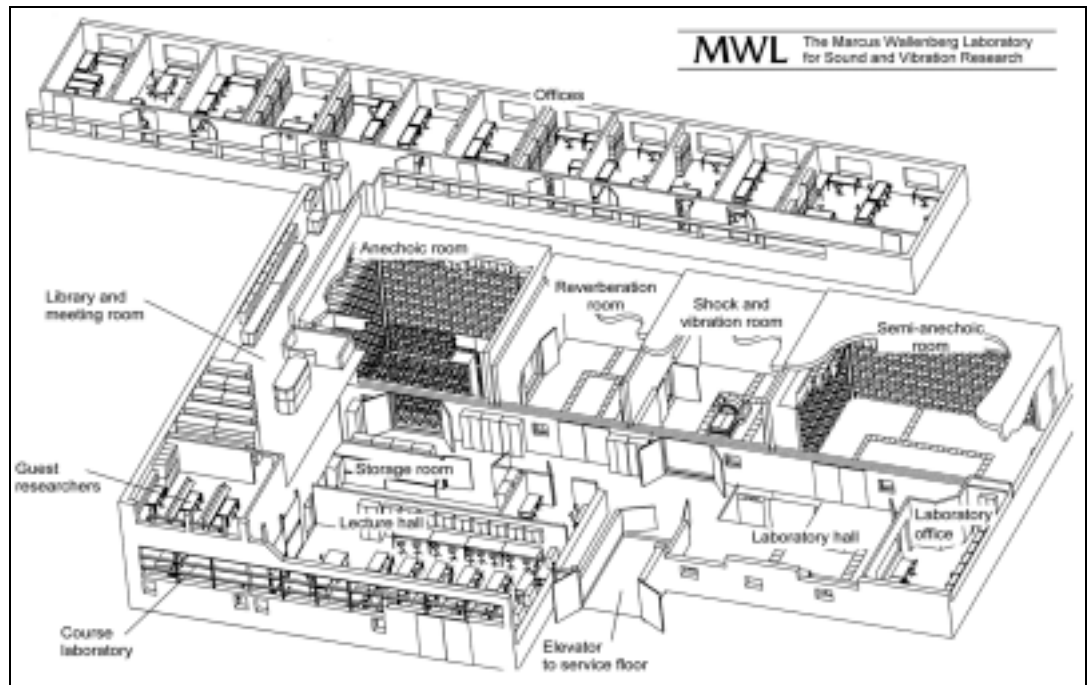
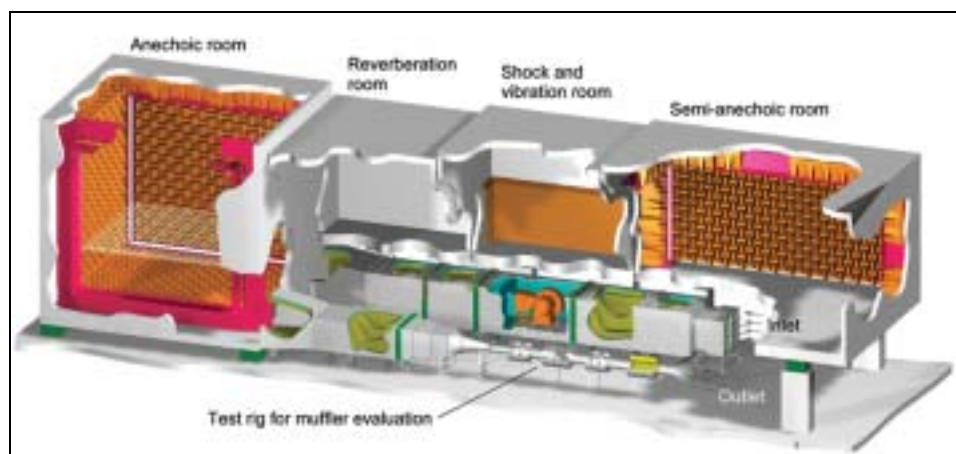


Fig. 3
Measurement of sound power on a handheld pneumatic tool in the semi-anechoic chamber



The unique layout of the test facilities, together with the large laboratory hall and the service floor below, permits all types of measurements to be made. These range from standard measurements such as sound power, sound intensity, sound absorption and sound transmission, to more advanced measurements such as vibration testing, modal analysis, characterisation of mufflers (exhausts) using the flow acoustic test rig, etc.

Fig. 4
The flow acoustic test rig on the service floor uses the anechoic room as a large silencer and settling chamber. The test rig has a very quite airstream with a maximum flow of $10\text{ m}^3/\text{s}$ and pressure up to 10 kPa



The test facilities fulfills a wide range of civilian and military standards.

MWL has its own well equipped workshop to manufacture the part and jigs required when setting up and modifying projects.

Cutting-edge Research

HP says, “Within MWL, we are fortunate to have professors and lecturers that are specialists in particular fields within acoustics and vibration, and the applications that are related to these”.

Some examples of the disciplines that MWL works within are:

- Fluid acoustics – characterisation of sources, interior aeroacoustics and experimental techniques on applications such as fan noise, intake/exhaust systems, mufflers and liners
- Vibroacoustics – dynamic properties of lightweight composite structures and rubber, wave propagation in built-up systems, vibration and sound insulation on applications including interior and exterior noise for vehicles (cars, trucks, trains and interior noise on ships)
- Numerical acoustics – FEM/BEM methods for complex materials, statistical energy analysis etc., for applications such as interior vehicle noise, tyre/road noise and outdoor noise propagation.
- Ultrasonics – development of techniques for non destructive testing and structural properties of components and advanced materials. Applications include the determination of elastic constants for new materials, micro cracks and delamination in composites
- Shock and vibration testing, including temperature and humidity – modal analysis, Kalman filtering and whole body vibration on a wide variety of applications including the detection of mechanical faults

Aerospace

MWL is extensively involved in aeronautical research and works with many of the worlds leading companies. Here are two examples.

Modal Analysis of Aircraft Structure and Control Surfaces

Fig. 5
Experimental structural dynamics – modal analysis is made on the structure of a glider. In the foreground, note the accelerometer fixed to the end of the wing



Members of KTH's Flight Dynamics Division together with MWL recently made a study of aeroelastic phenomena which often represent crucial problems in aircraft design. A ground vibration test using shaker excitation was performed on an ASK-21 glider aircraft. The objective of the test was to obtain the modal parameters, such as resonance frequencies, mode shapes, damping and generalized masses of the aircraft structure and control system. The goal was to validate and improve a finite element model of the aircraft. The modal investigation of the aircraft was performed in two parts. First, the whole structure including wings, fuselage and tail was investigated, with the control surfaces (rudder, elevators, etc.) locked in place. Second, the modal parameters of the control system were investigated where the wings, fuselage and tail were fixed but leaving the control surfaces free. The test data was analysed using I-DEAS TestTM and MATLAB[®].

Effects of Vibration on Military Helicopter Pilots

Fig. 6
Marcus Thuresson investigates the activities of the neck and shoulder muscles of a military helicopter pilot when exposed to vibration



Fig. 7
Tests are made under a variety of conditions. These include the wearing of night vision equipment. A triaxial accelerometer is placed on the top of the pilot's helmet



Fig. 8
A single axis accelerometer is mounted on the frame for the pilot's seat



Karolinska Institutet is one of Europe's largest medical universities. It is also Sweden's largest centre for medical training and research, accounting for 30% of the medical training and 40% of the medical academic research that is conducted in Sweden. In cooperation with MWL, and using its test facilities, Marcus Thuresson of Karolinska Institutet, Neurotec Department, Division of Physiotherapy is engaged on cutting-edge research into the effects of vibration on Swedish military helicopter pilots. The project is a cooperation between Karolinska Institutet and MWL

Marcus, a qualified physiotherapist and Ph.D student, explains, "The test setup consists of a helicopter pilots seat, complete with dummy pedals and controls, mounted on a frame that is excited by a large electodynamic shaker. Vibration in helicopters is at very low frequencies and the shaker is driven with a swept sine wave from 2.5 Hz to 30 Hz."

Marcus continues, "We want to investigate the effects of vibration on the shoulder and neck muscles of real pilots with different helmet weights, some of which include night vision equipment. We use Brüel & Kjær accelerometers – a seat accelerometer, a triaxial accelerometer on the helmet, and other single-axis accelerometers placed on the mounting frame".

A Long Relationship

Fig. 9
Vibration testing on a part of a railway carriage using PULSE



HP says, "We began buying products from Brüel & Kjær in 1977 and have a wide variety of their equipment including transducers, sound level meters, etc. The local service and support is excellent. Some of the original items, now more than 25 years old, are still in everyday use. In fact, we regard our relationship with Brüel & Kjær as a close partnership".

PULSE

HP continues, "Based on our long experience of working with Brüel & Kjær, when we decided a few months ago to buy a new analyser for general noise and vibration data acquisition, we chose a PULSE system. It's important for us to have a Windows®-based real-time system, especially during the test setup on projects. PULSE has proved to be highly flexible and easy-to-use".

Fig. 10
Senior researcher
Per-Olof Berglund
makes
measurements in
the anechoic room
using PULSE and a
sound intensity
probe



Per-Olof Berglund, one of MWL's most experienced PULSE users says, "It took me about four hours to learn and configure the PULSE system for measurement and that's fast compared to other systems I have used. The short setup time is mainly due to intuitive menus and the excellent help provided in PULSE. As a researcher, I need to have full control over the ongoing measurement and also to be able to easily export the test data from the measurement system. PULSE fulfills these requirements very well".

Key Facts

- Kungliga Tekniska Högskolan (KTH) was founded by Royal Charter in 1827
- The University currently has over 11 000 undergraduates, 1500 postgraduate students and a staff of more than 3000 employees
- KTH is engaged in cutting-edge research over a broad spectrum of disciplines
- Within KTH is the Department of Aeronautical and Vehicle Engineering
- MWL started as the Department of Technical Acoustics in 1977 – it took its new name, The Marcus Wallenberg Laboratory for Sound and Vibration Research, in connection with the inauguration of the new laboratory building in the middle of the 1990s
- MWL is the largest centre for technical acoustics in northern Europe.
- MWL focuses on experimental work in the fields of sound, vibration and structural dynamics and the laboratory is specially designed for applications relating to vehicles, machines and processes
- MWL works with many of the world's leading automotive, aerospace and industrial companies including
- In the six years since 1996, MWL has participated in fifteen EC research projects
- The research carried out focuses on vehicle dynamics, safety, comfort, low noise design and environmental impact
- MWL has state-of-the-art sound and vibration test facilities
- The test facilities are certified to a wide range of civilian and military standards
- MWL has its own workshop to manufacture part and jigs required when testing
- MWL is extensively involved in automotive and aeronautical research
- KTH's relationship with Brüel & Kjær dates back to the 1970s
- MWL has a wide variety of Brüel & Kjær equipment
- "Based on our long experience of working with Brüel & Kjær, when we decided a few months ago to buy a new analyser for general noise and vibration data acquisition, we chose a PULSE system"
- "We regard our relationship with Brüel & Kjær as a close partnership"