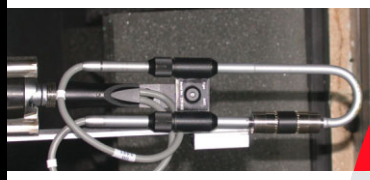


CASE STUDY

University of Southern California Composites Center Testing Advanced Aerospace Materials

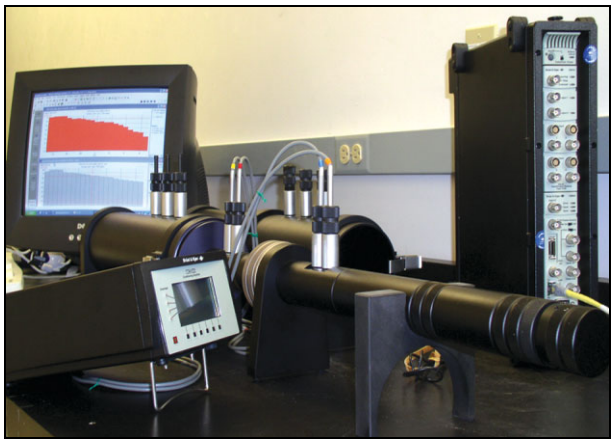
United States of America

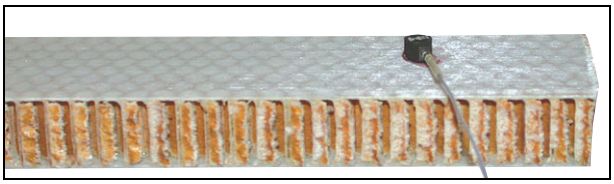
Aerospace

PULSE™, Material Testing, Modal Analysis

The University of Southern California (USC) is one of the world's leading private research universities. Located in the heart of Los Angeles, USC's two campuses are home to the College of Letters, Arts and Sciences and 17 professional schools, as well as one of the largest teaching hospitals in the country.

Within the recently named Viterbi School of Engineering, USC's Composites Center is engaged in cutting edge research on a wide range of new materials. There is a special focus on the development and testing of composites for the aerospace industry. M.C. Gill Corporation, the world's largest manufacturer of aircraft floor and interior panels, funds substantial research projects at USC. A PULSE data acquisition and analysis system is used to determine the mechanical and acoustical properties of composite materials.





125 Years of Excellence

Founded in 1880, USC is Southern California's oldest private research university. Renowned throughout the word, its success can be attributed to excellence in teaching and research, and a strong commitment to public service.

Today, USC's University Park campus, located in the heart of Los Angeles' Downtown Arts and Education Corridor, is home to the USC College of Letters, Arts and Sciences and many professional schools. The Health Sciences campus is home to the Keck School of Medicine of USC, the School of Pharmacy and three major teaching hospitals. USC also has programs and centers in Marina Del Rey, Orange County, Sacramento, Catalina Island, and Alhambra.

With over 30000 students, USC has become world-renowned in the fields of communication and multimedia technologies, has received national acclaim for its innovation, and has strengthened its status as one of the America's leading research universities.

Viterbi School of Engineering

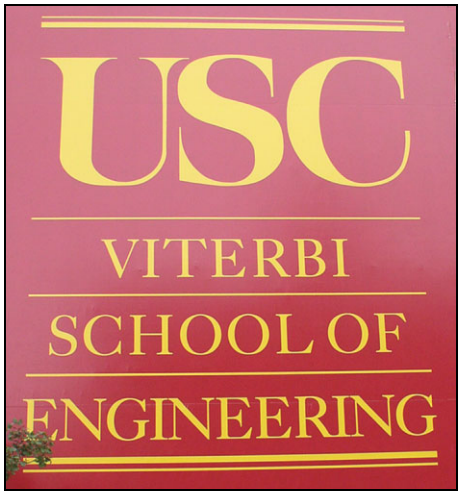


Fig. 1
In March 2004, USC's School of Engineering was renamed 'The Viterbi School of Engineering', following a generation donation by Andrew J. Viterbi and his wife, Erna

In March 2004, the founder of Qualcomm, Andrew J. Viterbi, and his wife, Erna, made a generous gift of $52 million to rename the existing school of engineering. It is USC's largest donation, and will associate USC's engineering school with Andrew Viterbi, an academic, a visionary, an entrepreneur, and a corporate leader in the fields of information technology and communications.

Steven B. Sample, USC's President comments, "The Viterbis' gift will serve as a powerful catalyst for bold research and innovation in an engineering school that is experiencing a rapid ascent".

Composites Center

Fig. 2
Steven Nutt is M.C. Gill Professor and Director of the Composites Center. Professor Nutt has unrivalled experience and expertise in the field of composite materials

Steven Nutt is the M.C. Gill Professor and Director of the Composites Center. He joined USC ten years ago and is the first professor of the Composites Center. Before joining USC, Professor Nutt was a Professor of Engineering at Brown University in Providence, Rhode Island. He earned his Ph.D. degree in materials science from the University of Virginia.

Professor Nutt says, "Like Harvard and Stanford, USC is a private university and we receive no state funding. Our funding comes from donations, sponsored research and tuition fees. Within the Viterbi School of Engineering, our major goal is to become a top-five research university".

He continues, "Private universities have greater 'agility' than those that are state funded. About 70% of our funding in the Composites Center is from industry and we proactively offer our services to industry. Some 50% of my own time is spent in research. I teach graduate and undergraduate courses and support over 15 Ph.D. students. It takes a graduate student four to five years to gain his doctorate at USC. The endowment from M.C. Gill is highly important for funding the work of Ph.D students. The graduate students interact with and are mentored by 5 or 6 post-doctoral fellows working within the Center".

M.C. Gill Corporation decided to sponsor advanced R&D on new aerospace materials by exploiting the expertise at USC. Mr. M.C. Gill endowed the Composites Center in 2002 and extensive work on composite aerospace materials is carried out for the company. M.C. Gill Corporation develops new products for commercial aircraft interiors, while USC performs research on the mechanical and acoustical properties of materials.

Research in the Center is also carried out in other areas. An interesting example is the work on the cables used for overhead powerlines. Traditional cables are reinforced by a steel core, and have a number of disadvantages, including thermal expansion and sag at high temperatures. Professor Nutt and his team are working on a new material based on a composite core which can easily resist temperatures up to 180°C with minimal sag. The cost of the new material is competitive with traditional cables, and the new cables carry up to twice the current.

Automotive

Professor Nutt says, "The automotive industry is also becoming increasingly interested in the use of composites. Glass fibre-based materials are already used in trucks and buses as they reduce weight and thus increase payload. We have received initial funding from a major Japanese automotive manufacturer to develop sandwich panels using aluminium/foam, and steel/foam core materials. The goal is to develop panel materials that are lighter in weight and provide noise and vibration damping".

Confidentiality

Professor Nutt adds, "Our policy is that any research work performed by students must go into the public domain, but we are usually able to work with corporate sponsors to protect sensitive or confidential information. This also applies to research work carried out for some government departments, such as the US Navy, and companies in the defence industry. For instance, our work on the use of composite materials for some defence applications is sensitive and requires confidentiality".

M.C. Gill Corporation

Founded in September 1945 by Merwyn C. Gill, M.C Gill Corporation became a principal supplier to Douglas Aircraft, supplying cargo compartment liners for the DC-6, and expanded to supply other replacement parts to commercial airlines. By 1962, its R&D laboratory had developed a polyester-laminate cargo liner for aircraft baggage compartments. It became a best-seller, outperformed all other cargo liners in service, and, for many years, the majority of M.C.Gill business came from replacement and retrofit markets.

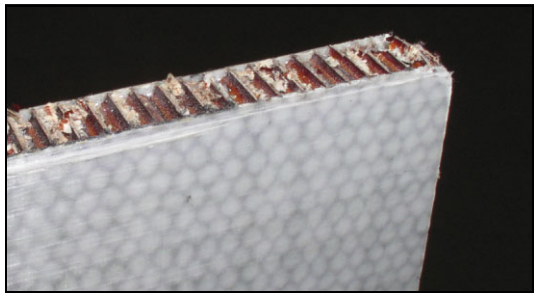


Fig. 3
A composite honeycomb core panel developed by M.C. Gill Corporation for use in the aerospace industry

Today, M.C. Gill's facilities occupy several acres in El Monte, California, and the company is the world's largest manufacturer of original equipment and replacement baggage compartment liners for passenger and freight aircraft.

The company is a major producer of composite sandwich panels and M.C. Gill floor panels and interior panels are standard OEM and replacement equipment on many aircraft types. Its honeycomb products have a wide range of uses – from engine nacelles to structural components – and it also develops and markets many other types of reinforced plastics including bullet resistant ballistic laminates, interior panels for creating structures such as aircraft galleys and bulkheads. Boeing is a major customer for M.C. Gill products, and the cockpit floor of the new Airbus A380 uses M.C. Gill Corporation materials.

The growth of the M.C. Gill Corporation is based upon its commitment to quality and the continual enhancement of the company's product development and production capabilities.

Acoustic Properties

Professor Nutt explains, "Within the aircraft industry, M.C. Gill's aramid fibre Nomex® honeycomb core material is widely used for aircraft flooring panels, and balsa core panels (with either polyester or aluminium facings), are used for similar applications within aircraft. The Gill Corporation is the largest supplier of replacement flooring panels for commercial airlines

in the world. The company began focusing on the acoustic properties of materials about six years ago. Not only are the acoustical insulation properties increasingly important, but, through our research on the acoustic properties of sandwich panels, we gain additional insight into the mechanical properties of materials".

Testing – Acoustic and Mechanical Properties

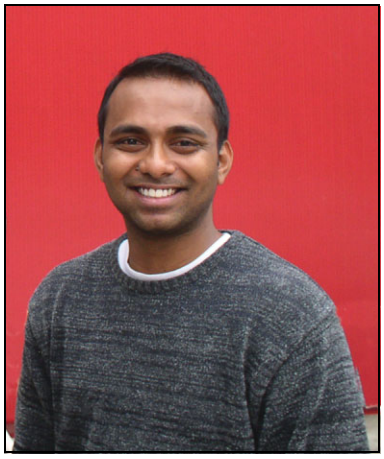


Fig. 4
Shankar Rajaram has been at USC for over four years and will soon gain his Ph.D. in materials science. He gained his first degree in polymer sensor and rubber technology from Cochin University in India

Professor Nutt says, "We use Brüel & Kjær solutions almost exclusively for testing the acoustic and mechanical properties of materials. The company has a reputation as 'The Benchmark' in the industry and a great track record. Another major factor was the fine service and support we get from the local Brüel & Kjær sales engineer, Mark Serridge".

Professor Nutt continues, "The managers and technicians at M.C. Gill Corporation, and other organisations that we work with, appreciate that we use Brüel & Kjær. It gives both of us confidence that the data is completely accurate and reliable. As I just mentioned, we use Brüel & Kjær products almost exclusively within the Composites Center. It's interesting that Qualcomm, founded by Dr. Viterbi, the naming donor for the School of Engineering, also uses Brüel & Kjær equipment extensively".

Shankar Rajaram is working for a Ph.D. degree in materials science. Shankar says. "I have been at USC for over four years and expect to gain my doctorate soon. I work extensively on the testing of composite materials and Professor Nutt is my 'supporter'. But it's much more than an education. It's a platform for self-learning and personal development. I meet many people from industry, both travelling myself and those that visit us, and we experience working in the real-world".

Fig. 5
The asymmetric source chamber of the transmission loss suite contains Rotating Microphone Boom Type 3923, ½-inch Microphone Type 4192 C and OmniPower™ Sound Source Type 4296

Shankar was extensively involved in the design and construction of the Composite Center's transmission loss facility. Using the sound intensity method, it comprises:

- Asymmetric source chamber – 15 m^3 with a tiled interior, RT_{30} – 1.5 s
- Anechoic receiver chamber – 20 m^3. By removing the floor, the chamber becomes semi-anechoic with a cut-off frequency of 200 Hz
- Rotating Microphone Boom Type 3923
- ½-inch Microphone Type 4192 C
- OmniPower™ Sound Source Type 4296
- Audio Power Amplifier 100 W Stereo Type 2716 C
- Sound Intensity Probe Kit Type 3599 with a traverse system and remote control facility

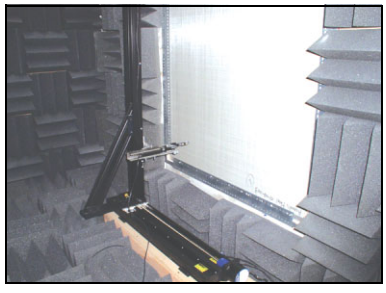


Fig. 6
Inside the anechoic chamber, a Sound Intensity Probe Kit Type 3599 is mounted on a traverse system

Shankar says, "We use the transmission loss suite to test the acoustic loss of honeycomb and balsa-core materials used in aircraft floors. It's very important because noise is transported by air and by vibration of the aircraft structure. Noise caused by turbulence, engine noise and the boundary layer of the fuselage are all transmitted by the interior panels, which act like the cone of a loudspeaker".

Pink noise is always used as the sound source because it most closely resembles real aircraft noise. Pink noise is accepted by the aircraft industry as the source to use for noise measurements. Shankar says, "We generally use about 90 dB. This can be heard outside the suite. We measure for 10 seconds at each point on an 11 × 11 reference grid. The total sample size is 42 × 42 inches (1.07 × 1.07 m). The sound intensity probe is mounted in a traverse system and the probe moves automatically to the next point on the grid after each measurement. The system is used every day".

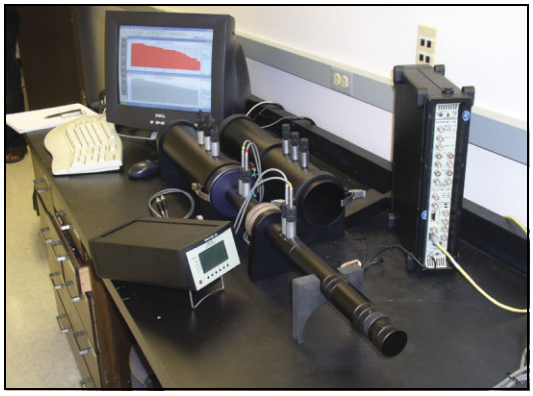


Fig. 7
The Composite Center's material testing facility comprising a PULSE data acquisition system, PULSE Material Testing Type 7758, Audio Power Amplifier 100 W Stereo Type 2716 C and Impedance Tube Kit Type 4206

He continues, "Repeatability and reproducibility are good above 200 Hz and the measured transmission loss equates to predicted values over the entire frequency range, for both honeycomb and balsa core panels".

Calibration of the transmission loss suite is made in accordance with ISO 3741.

Material Testing

Shankar adds, "With our PULSE-based material testing setup, we can measure over a frequency range from 50 Hz to 6.4 kHz. It's easy to prepare the samples and the system enables us to test large numbers of samples very quickly".

Reporting

The PULSE hardware platform and software solutions run under Microsoft® Windows® XP.

Following a test, the data is immediately exported to Excel. The graphs are produced and pasted into the Composite Center's own template. Professor Nutt, Shankar, and other members of the Center travel to the M.C. Gill Corporation about every six weeks to present their reports, discuss the findings of the research, collect new materials and discuss the parameters that should be tested.

Shankar says, "They are great people to work with and our relationship is a successful partnership".

The Future

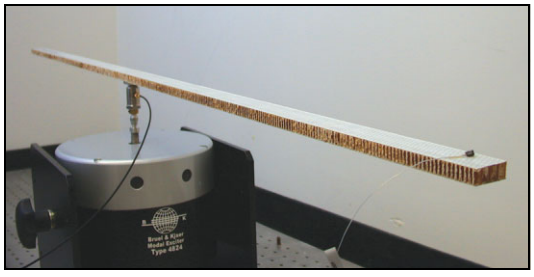


Fig. 8
Modal Testing. Brüel & Kjær Modal Exciter Type 4824 driven with pink noise from the generator in the PULSE front-end, excites the test sample. An accelerometer with very low mass measures the response

Professor Nutt explains, "There is a huge future for composite materials in the aerospace and other industries. The aim is to find ways to use composite materials to make structures more efficient. In our research on sandwich structures, we want to further investigate the effect of shear waves and bending waves inside panels".

He continues, "Using our PULSE system and ME'scopeVES™ Modal and Structural Analysis Type 7754 software, we currently use conventional modal analysis techniques measuring first one dimension and then two dimensions. For this work we use a Modal Exciter Type 4824, force transducers, Impedance Head Type 8001 and micro accelerometers with very low mass, all supplied by Brüel & Kjær". We plan to invest in Brüel & Kjær's Operational Modal Analysis Type 7760. This is the way the industry is going. We believe that OMA, used in controlled laboratory conditions, will enable us to design the next generation of composite sandwich panels with improved acoustic performance."

Professor Nutt concludes, “Our investment in PULSE and software applications has proved to be the right decision, and has fully justified our belief in Brüel & Kjær as a supplier of noise and vibration solutions. It has taken testing to new levels of accuracy and efficiency, and we look forward to continuing our close association with the company in the future”.

Key Facts

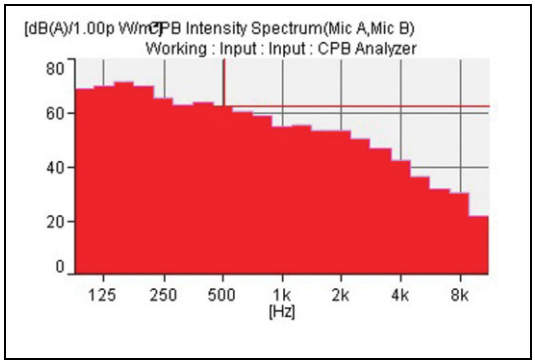


Fig. 9
A typical report automatically generated by PULSE. Following material testing, the CPB intensity spectrum is displayed relative to frequency

- The University of Southern California is one of the world’s leading private research universities
- Within the recently named Viterbi School of Engineering, USC’s Composites Center is engaged in cutting edge research on a wide range of new materials
- There is special focus on the development and testing of composites for the aerospace industry
- M.C. Gill Corporation, the world’s largest manufacturer of aircraft floor and interior panels, funds substantial research projects at USC
- “The automotive industry is also becoming increasingly interested in the use of composites”
- Boeing is a major customer for M.C. Gill products
- The cockpit floor of the new Airbus A380 uses M.C. Gill Corporation materials
- M.C. Gill Corporation began focusing on the acoustic properties of materials about six years ago
- “By using acoustics within the range of human hearing, we get a better insight into the mechanical properties of materials”
- “We use Brüel & Kjær solutions almost exclusively for testing the acoustic and mechanical properties of materials”
- “Brüel & Kjær has a reputation as ‘The Benchmark’ in its industry and a great track record”
- “The managers and technicians at M.C. Gill Corporation, and other organisations that we work with, appreciate that we use Brüel & Kjær. It gives both us and them confidence that the data is completely accurate and reliable”
- Qualcomm, founded by Dr. Viterbi, also extensively uses Brüel & Kjær equipment
- “Noise caused by turbulence, engine noise and the boundary layer of the fuselage are all transmitted by the interior panels which act like the cone of a loudspeaker”
- “With our PULSE-based material testing setup, we can measure over a frequency range from 50 Hz to 6.4 kHz”
- “It’s easy to prepare the samples and the system enables us to test large numbers of samples very quickly”
- “There is a huge future for composite materials in the aerospace and other industries”
- “We plan to invest in Brüel & Kjær’s Operational Modal Analysis Type 7760”
- “Our investment in PULSE and software applications has proved to be the right decision, and has fully justified our belief in Brüel & Kjær as a supplier of noise and vibration solutions. It has taken testing to new levels of accuracy and efficiency, and we look forward to continuing our close association with the company in the future”

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