

# CASE STUDY

United States of America

**Link Engineering Company**  
**Brake NVH Testing Systems**

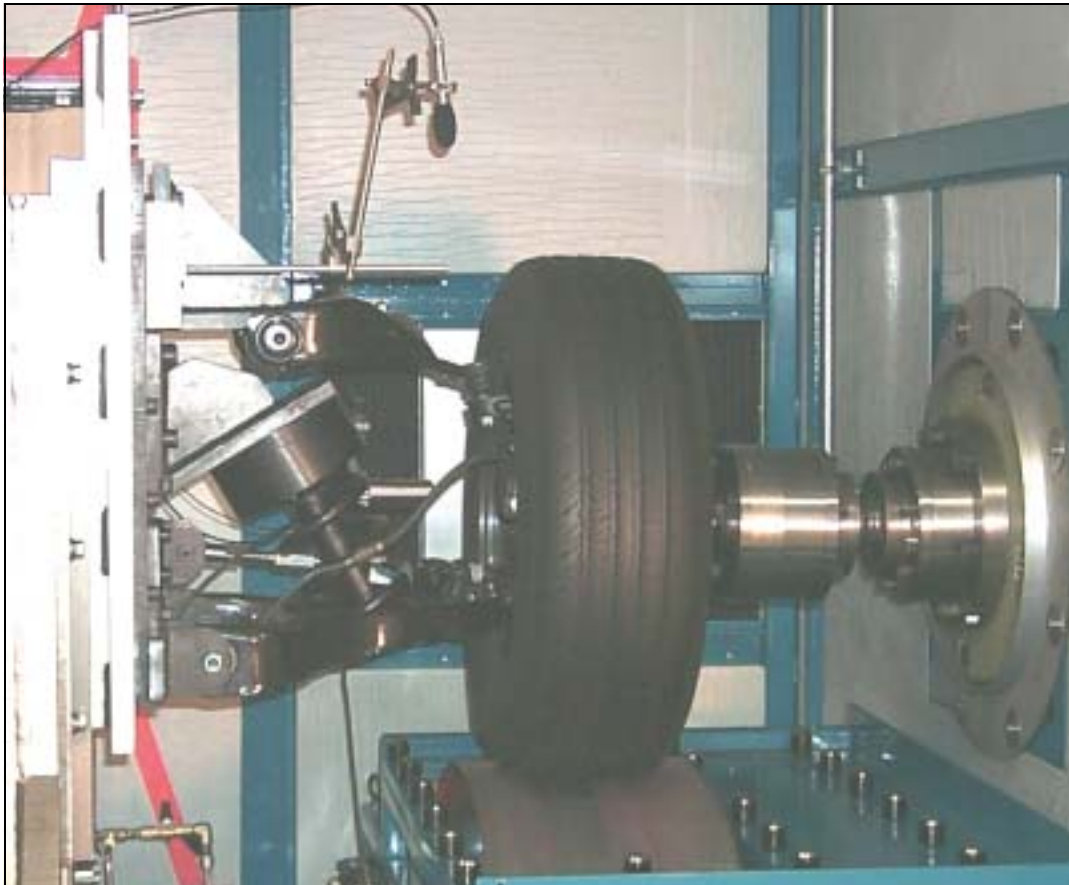
Automotive

PULSE, Transducers



*For 65 years, Link Engineering Company has been deeply involved in the design and manufacture of test systems for the automotive, aerospace, railway and general industries. Its systems are used by major vehicle and component manufacturers throughout the world. Link's experience includes the development and manufacture of a wide range of NVH (Noise, Vibration and Harshness) test systems. The company can deliver complete turnkey projects. Brake NVH testing is one of Link's specialities and it is a world leader in the development of NVH brake test systems and brake analysis.*

*Brüel & Kjær's PULSE™ Multi-analyzer is Link's preferred NVH analyzer platform – some 15 systems have been delivered during the last 18 months.*



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## The Company

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Link Engineering was founded by Mr. Herbert Link in 1935. Throughout its history, the company has focused on the design and manufacture of test systems for the automotive, aerospace, agricultural, railway and general industries. It's a 100% family owned company.

Based in Plymouth, Michigan, the company employs approximately 250 people. The automotive industry is the core market and brake NVH test and analysis has a special focus – from small brake dynamometers for brake material testing up to 20000 horse power installations for testing aircraft braking systems.

Link designs and manufactures a full range of test systems for laboratory, test-track and on-road vehicle evaluation including, for example:

- Brake, transmission and chassis dynamometers
- Vehicle and aircraft chassis dynamometers
- Material characterisation systems
- Vehicle data acquisition systems and transducers

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## Market Leader

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Link is a market leader and supplies NVH test systems to the world's major automotive manufactures (OEMs), to manufacturers of brakes and braking systems (tier 1), and to manufacturers of brake materials (tier 2). It's a highly vertically integrated company. Individual components are purchased (or built by Link themselves) and fully equipped dynamometers are shipped to all parts of the world. To date, Link has delivered more than 100 vehicle data acquisition systems throughout the world.

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## Testing Laboratory

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With a range of 30 dynamometers and some 135000 square feet of laboratory space, Link Testing Laboratories provides testing facilities to third-party customers. The services offered include:

- Product NVH performance evaluations from components to complex systems – from large scale fleet or customer satisfaction surveys to detailed “cutting-edge” test and analysis
- Root cause investigations to identify sources mechanisms, transmission paths, and subjective response
- Vehicle interior and exterior noise and vibration measurements, including temperature and strain measurements

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## NVH Brake Testing

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*Fig. 1  
Link's new NVH  
dynamometer at  
Link Testing  
Laboratories*



The NVH performance of vehicle braking systems is a critical aspect of the customer's perception of the vehicle. As such, it is crucial that NVH evaluations are able to replicate noise performance on the vehicle. At the same time, brake NVH dynamometers must permit detailed studies of the braking dynamics and noise generation process to provide information necessary for improving performance.

**Fig. 2**  
The operating console of a dynamometer at Link Testing Laboratories

There are few such facilities available for contract use and independent studies. Link has installed a state-of-the-art NVH dynamometer in its Detroit Testing Laboratories. The unit provides the capabilities to perform all current and planned brake NVH test protocols.



### Brake NVH Testing

Performing tests that replicate the NVH performance of braking systems on vehicles is a complex task. It is often necessary to explore a wide array of operating parameters to identify those where noise issues occur. Microphones and accelerometers are used to quantify the brake noise and vibration during such operations.

An enclosure is built around the braking components to permit accurate noise measurements without interference from other noise sources. In addition, these enclosures are designed to represent the on-vehicle environment with a reflecting floor plane and sound absorbent walls to simulate the free-field over a reflecting plane as found on the open road.

### Brake Evaluation Standards

There are two internationally recognised brake noise evaluation standards. One is known as the AK Noise Procedure. This protocol requires over 1000 brake applications and is composed of deceleration and drag segments in an attempt to elicit a wide array of brake noises.



The second major brake NVH test standard is SAE J2521. This procedure is still in draft form, but it is being used around the world for noise evaluations. This protocol utilises a wider array of braking operations and is the product of the latest knowledge on brake noise generation.

Not only can Link's new NVH dynamometer be used for all the above tests, but it can also be used for custom investigative programs. Using its advanced ProLink (Windows® 2000-based) programming environment, custom test protocols can be quickly formulated and implemented. A wide array of control and measurement algorithms can be utilised.

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## Typical Brake NVH Test System Specification

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Link designs and manufactures a wide range of brake NVH dynamometer test systems. The detailed specifications are established according to the customer's individual requirements.

To demonstrate the typical capabilities of a state-of-the-art brake NVH testing system, the following specification refers to the dynamometer installed at Link Testing Laboratories, as shown in Fig.1:

- 0 – 2000 rpm
- Up to 5600 Nm of torque
- Inertia 10 – 200 kg/m<sup>2</sup>
- Air/oil brake apply
- Maximum brake pressure – 200 bar

- Full axle and suspension capability
- Noise chamber – 3.4 × 2.1 × 2.2 m, with thermal and acoustic insulation
- Automated and manual operation
- Torque, pressure, temperature, time and deceleration control
- Drag, full stop and other test sequences

### Acoustic Enclosure

By combining both noise reduction and sound absorption treatments, an acceptably low interior background sound level can be achieved. This permits accurate measurements of all brake noise issues from 500 to 20 000 Hz. In addition, the enclosure is mounted to provide full vibration isolation from the rest of the dynamometer and other mechanical energy sources in the building. Only the noise and vibration that is due to the braking system are measured.

Cooling air is provided in the enclosure to reduce cycle times and to maintain a stable environment in the enclosure. The cooling air speed can be adjusted to maximise cooling and minimise extraneous noise for a given measurement scenario.

### Inverted Tailstock

A key feature of the dynamometer installed at Link Testing Laboratories is the ability to mount a full vehicle corner section or rigid axle. To accurately recreate vehicle noise issues, especially those at lower frequencies, it is necessary to test with the actual vehicle suspension. The dynamometer provides the capability to mount the suspension system with the brake driven from the spindle or the lug side of the rotor.

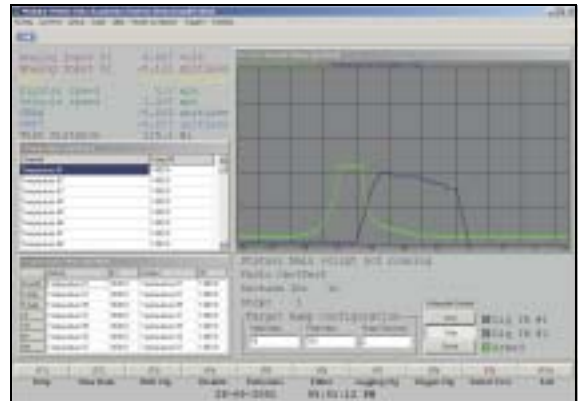
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## Data Acquisition and Analysis System

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**Fig. 4**  
ProLink software provides the intuitive graphical user interface and maximises speed and flexibility in the capture and retention of all relevant test data

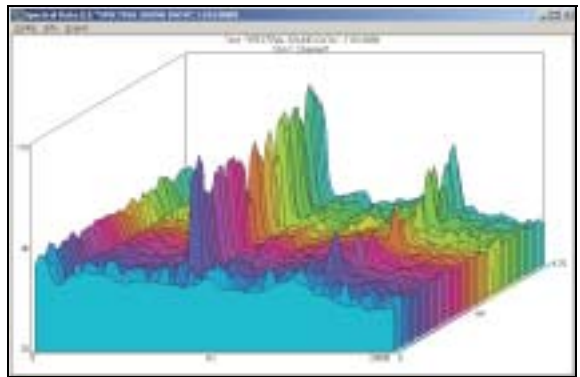
A Brüel & Kjær PULSE Multi-analyzer is dedicated to the dynamometer installed at Link Testing Laboratories. This PC-based noise and vibration measurement system is capable of data acquisition, measurement, post-processing, documentation and analysis with simultaneous measurement of exponential, linear, peak and averaged spectra. The system provides software for noise analysis, time data recording and order tracking.



**Fig. 5**  
A waterfall plot provides a huge amount of information in graphical format

### PULSE Specification

- Eight input channels
- Measurement frequency range – 0 to 25.6 kHz
- PULSE Noise and Vibration Analysis Type 7700 software with throughput to disk option
- Real-time measurements on all channels to 25 kHz
- Microphones and accelerometers to perform all standard tests and more complex investigative studies





A complete state-of-the-art Link Engineering dynamometer control and data acquisition system is a key component in all Link dynamometers. The PULSE software runs in the background and is controlled by Link's ProLink software package running under Windows® 2000. ProLink provides the intuitive graphical user interface and maximises speed and flexibility in the capture and retention of all relevant test data. Monitored parameters include speed, torque, up to eight temperatures, relative humidity, applied pressure and many other parameters.

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## Engineering Expertise

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**Fig. 6**  
*Jim Thompson, Ph.D, PE, is Link's NVH Sales and Marketing Executive Director*



Jim Thompson, Ph.D, PE, is Link's NVH Sales and Marketing Executive Director – he is an NVH expert.

Jim gained a Bachelor's degree from Virginia Polytechnic Institute and State University. This was followed by a Master's degree in Mechanical Engineering, and then a Doctorate from Purdue University. His thesis was on "Noise in small engines".

Jim has worked at Link for three years and, in addition to heading NVH, sales, and marketing, is responsible for Link's state-of-the-art engineering technology.

Jim says, "Brake noise is a leading warranty issue in the U.S. Complaints representing hundreds of millions of dollars are received by the automotive OEMs". Jim explains, "Our test systems are used in R&D applications. In addition to brake, clutch and transmission testing, we are expanding our solutions to include a wide range of other automotive components including steering assemblies, alternators, starter motors, etc".

"We work in one of two ways – either a manufacturer will give us a detailed specification of the parameters that are to be tested, or, especially with noise issues, we will be asked to advise on the testing that's needed and then write a detailed specification for the test system. Very often we are involved right from the initial concept through to delivery of the turnkey system, including training the operators."

Jim continues, "Our users are not generally NVH experts and so we aim to make our test systems as automated as possible. A really great development is TEDS (Transducer Electronic Data Sheet) equipped transducers. It's a major plus for customers with little or no NVH experience. TEDS transducers reduce the setup time and there are far less errors because the transducer sensitivity is entered into the system automatically".

**Fig. 7**  
*In-vehicle testing – Link's 3501 system installed in a truck cab*



"There is an increasing trend towards in-vehicle testing for troubleshooting applications. A typical system will comprise a 6/1-channel PULSE system. Four accelerometers are used, one on each brake and a microphone is placed inside the cabin to detect brake squeal", says Jim.

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## Accreditation

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Link is accredited to ISO 90001 and by QOS (this is a standard used by automotive companies in the USA – it exceeds the ISO demands).

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## Brüel & Kjær

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**Fig. 8**  
*This dynamometer tests the properties of materials used in aircraft braking systems*



Jim says, “In the past we had a number of options concerning analyzers. But we decided to work with Brüel & Kjær and they are our preferred supplier, not only for analyzers but also for transducers and calibration equipment. Brüel & Kjær’s name stands for outstanding quality, reliability and accuracy. PULSE is a PC-based solution and this is the way we wanted to go. The decision has proved to be correct and we get excellent back-up, service and support from their local office in Livonia, Detroit”.

Jim continues, “We also use a 6/1-channel PULSE system in our own test lab. Together with transducers, it’s extensively used to check the performance of our test systems before delivery to a customer, and for general investigative work and troubleshooting”.

### Fifteen-plus PULSE Systems

Since the cooperation started in the beginning of 2001, Link has ordered in excess of fifteen PULSE systems from Brüel & Kjær. Jim concludes, “This is positive proof of the success of both our companies and, of course, our customers favour PULSE as the standard analyzer installed in our NVH test systems. In addition, they appreciate that they get an analyzer for a wide range of NVH test applications”.

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## Key Facts

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- Link is based in Plymouth, Michigan – it employs approximately 250 people
- The automotive industry is the core market and brake NVH test and analysis has a special focus
- Link is a market leader and supplies NVH test systems to the world’s major automotive OEMs, and to tier 1 and tier 2 automotive sub-suppliers
- Link has delivered more than 100 vehicle data acquisition systems
- Link Testing Laboratories provides testing facilities to third-party customers
- “Brake noise is a leading warranty issue in the U.S. Complaints representing hundreds of millions of dollars are received by the automotive OEMs”
- Link is accredited to ISO 90001 and by QOS
- Brüel & Kjær is Link’s preferred supplier – for analyzers, transducers and calibrators
- Link gets excellent back-up, service and support from Brüel & Kjær’s local office
- Link has ordered in excess of fifteen PULSE systems from Brüel & Kjær