

CASE STUDY

United States of America

Federal-Mogul Corporation Advanced NVH Testing of Friction Materials

Automotive

PULSE, Transducers

Founded over 100 years ago, Federal-Mogul Corporation is today one of the world's largest suppliers of automotive components and sub-systems serving vehicle manufacturers, and the aftermarket. Its products include friction, powder metal and wiper products, ignition, sealing, lighting, power cylinder and systems protection applications.

There is a core focus on the development and manufacture of friction materials for use in vehicle braking systems. NVH testing of friction materials is carried out at Federal-Mogul's Friction Products US Technical Center at Plymouth, Michigan. The extensive facilities include four brake testing dynamometers. Six PULSE™ multi-analyzer systems, together with Brüel & Kjær transducers, are used for NVH data acquisition and analysis.



History

Federal-Mogul Corporation was founded in 1899 as the Muzzy-Lyon Company. At that time, the founders, J. Howard Muzzy and Edward F. Lyon, sold mill supplies and rubber goods. In the early 1900s, Muzzy and Lyon bought an old printer's type-casting machine and began experimenting with the production of die-cast replaceable bearings for the automotive industry.

Now named Mogul Metal, the Buick 10 was one of the first cars to use parts produced by the company and, in 1910, an order was placed for 10000 connecting-rod bearings for this vehicle.

Throughout its history, Federal-Mogul has made acquisitions and entered into joint ventures to strengthen its manufacturing position within the automotive industry.

Today, Federal-Mogul is a global supplier of automotive components and sub-systems serving the world's vehicle manufacturers, and the aftermarket. Its products include:

- Friction, powder metal and wiper products
- Ignition, sealing, lighting, pistons and power cylinder systems
- Systems protection

The company utilises its engineering and materials expertise, state-of-the-art technology, manufacturing skills, distribution flexibility and marketing power to deliver products, brands and services to its customers throughout the world. With its headquarters in Southfield, Michigan, Federal-Mogul about employs 56 000 people in 24 countries, and has a turnover of over US\$ 6 billion.

Federal-Mogul's global manufacturing facilities are accredited to ISO 9001 and ISO 9002.

Friction Products

Fig. 1
Two of Federal-Mogul's Link Engineering climatic brake testing dynamometers

Friction products are a core business of Federal-Mogul. Its Friction Products Technical Center was first commissioned in 1996. This facility in Livonia, Michigan, extended to some 9000 sq.ft. The demands for NVH testing grew rapidly and as a result, in mid 2002, the company relocated its technical centre to a new 34 000 sq.ft. facility in Plymouth, Michigan. It is close to Federal-Mogul's major US customers, is highly efficient and cost-effective.



There is a technical centre in each country where Federal-Mogul manufactures friction materials, for example, USA, Brazil, Mexico, Czech Republic, Thailand, China, South Africa, Italy, Spain, France, Germany and UK. There is a joint-venture operation in Japan.

Fig. 2
The interior of one of the Link Engineering dynamometers. Brüel & Kjær Microphone Type 4189 is fixed at a specified distance from the face of the brake, disc or pad, being tested

The technical centres are the 'interface' between Federal-Mogul's R&D departments and vehicle and brake manufacturers. The facility in Plymouth is focused on application engineering.

Federal-Mogul's Development Center at Smithville, Tennessee, is the R&D centre where new materials, brakes and systems are developed. Durability testing is also carried out at Smithville.

Federal-Mogul's friction products are used in the manufacture of brake discs and pads for passenger cars up to the largest trucks. The company is a global market leader and supplies friction materials to many of the world's leading brake manufacturers including TRW, Bosch, Continental, PBR, Ferodo, Wagner and Delphi.



When developing friction materials, a large number of parameters must be considered. These include wear, brake life, weight, vehicle inertia, performance, cost, production volume, and especially safety. The Federal Motor Vehicle Safety Standard (FMVSS) specifies the stopping distance for different classes of vehicle.

These factors together affect the choice of materials. Federal-Mogul has a strong focus on the use of environmentally friendly NAO (non-asbestos organic, no metal) materials. Asbestos dust from truck brakes is an ever-increasing environmental issue throughout the world. It is thought that dust from brakes made using asbestos impacts on water supplies and thus passes into the human chain. In addition, Federal-Mogul also develops 'low-met' (metal with no asbestos – used in Europe) and 'semi-met' (metal with no asbestos – used in mainly for truck brakes).

Once the program has been defined, prototype materials are produced and tested for durability and performance at Federal-Mogul's Smithville facility. The NVH characteristics of the materials are then tested and analysed at the Friction Products Technical Center at Plymouth.

NVH Experience

Fig. 3
Murali Venkat is NVH Manager at Federal-Mogul's facility at Plymouth, Michigan



The Plymouth Technical Center has some 25 employees. Murali Venkat is the NVH Manager. He gained his Bachelor's Degree in India. This was followed by an MS in mechanical engineering from Wayne State University. Murali began working at Ford in Dearborn, Michigan, in 1991 and, throughout his career, has focused on NVH analysis while working for major automotive manufacturers.

He joined Federal-Mogul in 2002 and is especially interested in mathematical modelling using CAE technology. Murali explains, "Together with our customers, we design unique brake material for each vehicle program."

He continues, "Brake squeal is one of the biggest warranty issues in the US and automotive manufactures put great focus on this. The NVH specifications are getting constantly tighter, and are ultimately driven by vehicle customers. R&D check the performance and make durability tests on new brakes. The brakes, both disc and drum, then come to us for detailed NVH evaluation".

The technical centre at Plymouth currently has four brake-testing dynamometers. Each dynamometer runs 24 hours a day, 365 days a year. The dynamometer tests are defined by SAE J2521, AKNoise, etc.

Murali adds, "An average NVH test takes 24 hours while the full evaluation process generally lasts from two to four weeks. Of course we also make benchmark tests on our competitors products".

A routine noise test uses one microphone channel although special investigations may use up to eight. The frequency range of interest is between 1 kHz and 15 kHz. The test data is A-weighted and so removes the low frequencies. Murali says, "A squeal above about 70 dB(A) is critical – this equates to about 50 dB(A) measured in the vehicle".

PULSE

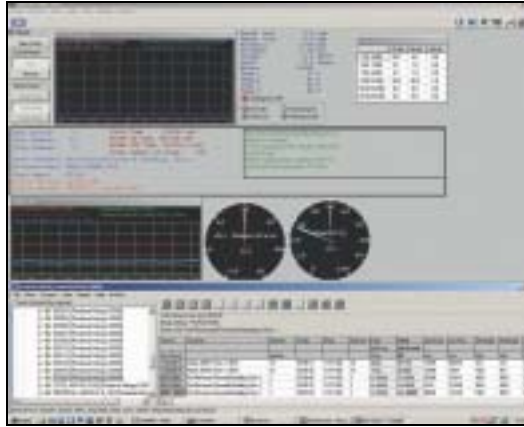
Murali says, "I first used Brüel & Kjær products at university, and I have been using them ever since. We currently have six PULSE front-ends".

Fig. 4
The spacious control room for the four brake testing dynamometers



“Each of the four brake-testing dynamometers is equipped with a PULSE system for data acquisition and analysis. We also have a further 8-channel PULSE system comprising two 4-channel front-ends. This is dedicated to modal analysis work. Our Link 3501 in-vehicle test system is also equipped with PULSE for data acquisition.”

Fig. 5
The PULSE software runs in the background. The operator interface at each of the four dynamometer control stations is provided by Link Engineering’s ProLink software



“We have standardised on PULSE so that all NVH test data is totally compatible. It’s a powerful system, intuitive, and easy to set up and use. It also very useful to be able to stack a number of PULSE units together if a higher number of channels are needed for a particular test. We can also split the modal analysis system into two separate units if needed. It’s flexible, efficient and convenient”, says Murali.

Federal-Mogul’s R&D centre at Smithville also has PULSE. Therefore, test data can easily be exchanged between this facility and the friction products technical centre. Every PULSE system runs under Windows® 2000.

All microphones are Brüel & Kjær Type 4189. These are calibrated before each test using a Brüel & Kjær Sound Level Calibrator Type 4231. The accelerometers used for modal testing are Type 4293, also from Brüel & Kjær.

Link Engineering

Fig. 6
Each of the four brake testing dynamometers has its own Link Engineering control station



Three of Federal-Mogul’s brake testing dynamometers are manufactured by Link Engineering, the most recent being commissioned in March 2003. But each of the four dynamometers is controlled by its own Link control station, and uses ProLink software. The PULSE software, installed in each PULSE data acquisition system, runs in the background.

Murali continues, “There is a very high demand for NVH testing and each of the dynamometers runs seven days a week, 365 days a year. Therefore, reliability is essential and Link is our dedicated dynamometer platform. The dynamometers at Smithville also use Link control and data acquisition systems and a project has started to provide these facilities at the Federal-Mogul sites in France and the UK”.

In-vehicle Testing

Although much of the NVH analysis work carried out at the technical centre, Federal-Mogul also acquires large amounts of test data from in-vehicle testing under practical road conditions.

For in-vehicle data acquisition, Federal-Mogul uses a Link 3501 system. This is also equipped with its own PULSE front-end.

Fig. 7
Federal-Mogul uses a Link Engineering 3501 in-vehicle test system.

A 4-channel PULSE multi-analyzer acquires the data

“Murali explains, “The Detroit Suburban Traffic Test (DST) and Detroit City Test (DCT) tests are performed as specified by ‘the big three’ (Ford, General Motors and DaimlerChrysler). They each also have their own internal standard procedures”.

“Brake noise events are recorded using a Brüel & Kjær microphone located close to each brake-disc or pad. We measure a number of other parameters including the brake-pedal pressure (measured on the hydraulic brake-line), the temperature of each pad/disc, vehicle speed, etc. There is also the Los Angeles City Traffic Test (LACT). This is a test for both noise and durability.”



For NVH testing under extreme conditions, Federal-Mogul makes high ambient temperature tests in Arizona during the summer, in Minneapolis during the winter, and in Colorado to test the effects of high altitude. The Link 3501 system is compact and therefore very convenient for transportation.

Data Handling and Reporting

Fig. 8
Frequency response functions (FRFs) can be measured in a climatic chamber.

The temperature is accurately controlled from – 65 °C to + 175 °C. The data is acquired and analysed using two stacked 4-channel PULSE front-ends

Murali says, “We have a frequent need to compare data. We plan to acquire PULSE Data Manager and this will prove to be an excellent tool for the archiving, retrieval and comparison of data”.

For reporting, a CSV file from the ProLink software is pasted into Excel and detailed a six page report is created. The test data is saved on a database on a central server and placed on Federal-Mogul's intranet so it is available to the R&D departments, technical centres, and manufacturing facilities throughout the world.



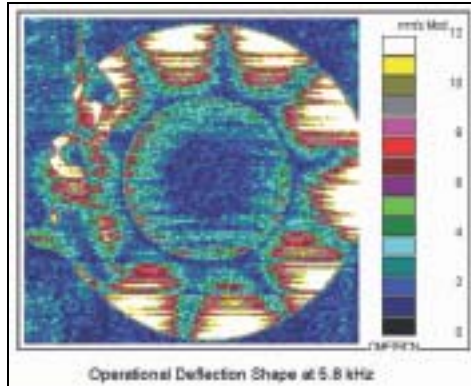
The Future

Murali says, “We are continuing to make very substantial investments in our test facility here at Plymouth. The result is that our testing efficiency is increasing, we save time and money for our customers, and we are very close to the market. In 2004, we expect to purchase a new laser doppler vibrometer to replace our existing Ometron unit. This will be used to investigate noise sources both in a dynamometer and in the vehicle test area”.

The laser doppler vibrometer can determine vibrations in the 1 kHz to 6 kHz frequency range.

Fig. 9

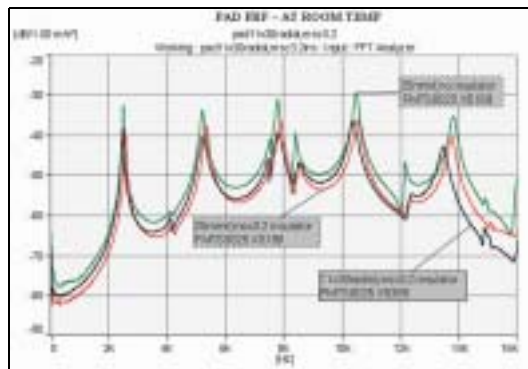
Left: An Ometron laser doppler vibrometer is used to investigate the causes of noise. The illustration shows the Operational Deflection Shape (ODS) of a brake disc at 5.8kHz
Right: There is a well equipped vehicle test area complete with hoists and exhaust extraction system



“We we will also start to use Modal Test Consultant™ Type 7753 and ME'ScopeVES™ Type 7754. Together, these new applications will greatly help with the expanding use of modal analysis techniques. There will also be an increasing use of mathematical modelling using predictive software programs, and this will reduce the amount of initial testing required during development.”

Fig. 10

A typical frequency response function display from a brake pad tested at room temperature. FRFs can also be measured in a climatic chamber



“For instance, we measure the actual frequency response functions (FRFs) to ensure compliance and to improve our modelling predictions. I spend much of my time working in this area. But there will be no substitute for practical testing to detect and measure brake-squeal, both using dynamometers and under real driving conditions.”

Murali concludes, “The service and support from Brüel & Kjær’s local office in Livonia is excellent – we regard them as our friends, our partners, and not just as suppliers.”

Key Facts

- Federal-Mogul is a global supplier of automotive components and sub-systems
- There is a core focus on the development and manufacture of friction materials for use in vehicle braking systems
- NVH testing of friction materials is carried out at Federal-Mogul’s Friction Products US Technical Center at Plymouth, Michigan
- The facilities include four brake testing dynamometers and Seven PULSE systems
- “Brake squeal is one of the biggest warranty issues in the US
- “NVH specifications are getting constantly tighter, ultimately driven by customers”
- “We have standardised on PULSE so that all NVH test data is totally compatible”
- Each dynamometer is controlled by a Link control station, using ProLink software
- “Reliability is essential and Link is our dedicated dynamometer platform”
- “PULSE Data Manager is proving to be an excellent tool for the archiving, retrieval and comparison of data”
- “The service and support from Brüel & Kjær’s local office in Livonia is excellent – we regard them as our friends, our partners, and not just as suppliers”