Controlling Automotive Power and Emissions

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ENGINEERING FOCUS

THE DEPARTMENT OF ENGINEERING AT THE

Engineers everywhere in the World are competing to build more economical and less polluting cars. At the same time they are improving the way the vehicle obeys driver commands to deliver power from the engine to the wheels. To meet these challenges, engineers are deploying more and more advanced technologies using novel engine designs and cars containing powerful computer controllers.

Only a few years ago it used to be possible for the average driver to explain the working mechanisms under the car bonnet. Now the modern engine is computer controlled using many sensors and actuators, such as the mass-air-flow sensor and the exhaust-gas recirculation valve, complicating but vastly improving the performance of the engine system.

To make all these latest power-maximising and fuel-minimising technologies today's automotive engineer needs carefully measured data to build 'mathematical models' of the engine and transmission. The most basic of these measurements include the torque and the rotational-velocity (often more simply if less accurately called speed) at the engine shaft and at the vehicle wheels.

Once accurate models are obtained, the engineer must use these to design feedback and feedforward controllers to implement in the engine control computer in hardware and software referred to as the Engine Management System.

Measuring vehicle performance on the Liverpool Rolling-road Dynamometer

The Engine Management System in the car has many jobs. Amongst the most important of these is to turn the fuel injectors on and off at precisely the right time. This must be done very exactly. If too much fuel is allowed to enter the cylinders, not only does fuel consumption go up, but the catalytic converter quickly becomes inefficient, and nasty hydrocarbon pollutants come out of the exhaust pipe. Similarly if too little fuel is injected, excessive nitrous oxides and carbon monoxide is produced.

The control strategy is finally tested using computer monitoring equipment on the rolling road dynamometer. For these tests the 125kW Liverpool Rolling Road Dynamometer with its huge 35kW vehicle cooling fan can mimic 120mph motion and airflow, whilst the test vehicle is connected to sophisticated monitoring equipment in a sound-proofed control room.

The Liverpool Rolling-road Dynamometer Measuring the Torque and Speed at the Wheel

Another job for the car's control computer is to time the sparking of the spark-plugs. Because the time taken for combustion of the air-fuel mixture in the cylinder is troublesomely random so called filtering techniques must be used to get good average results at the expense of worse fuel consumption. Exciting new research in the Engineering Department of the University of Liverpool is now looking at over-coming this problem by replacing the spark-plugs and their electrical leads with a laser ignition system using optical fibres connected to the engine cylinders.

Although internal combustion (Petrol and Diesel) engines have been around a long time (and the Ford Model T has just had its hundredth birthday!) the engine control computer has given it a new lease of life, and the automotive engineer some exciting new possibilities!

The Power **P** in units W delivered by a rotational element like the engine crankshaft of the vehicle wheel is related by the equation **P=T w** where **T** is the torque in units Nm and **w** is the rotational velocity (speed) in rad/s. As an example a Ford Mondeo might develop maximum power at 600 rad/s at which point the torque produced is 100Nm. The power developed is correspondingly **P**=100. 600 N m rad/s =60000W=60kW. In public advertisements these figures are often expressed in HP. Using 1HP=745.7W what would the power of the Mondeo be in HP?

Dr Tom Shenton
Mechanical Engineering

Inside this issue

Issue 3

A word from the Editor

The third issue of Engineering Focus concentrates on two sensitive environmental issues in car design: Control of power and emissions and brake noise reduction. In the modern automotive industry the need for engineers having skills that transcend the boundaries of the traditional engineering disciplines (such as Mechanical, Electrical, Materials etc) is growing ever more strongly. Dr Tim Bullough in his article on 'Integrated Engineering' describes the opportunities and advantages of an inter- and multi-disciplinary engineering education and Dr Cheryl Anderson talks about a problem-based learning exercise on the design of a Jaguar car door.

It won't have escaped your attention this summer that Liverpool's bid to become the European Capital of Culture for 2008 was successful. The Head of Department, Professor Peter Goodhew, describes the wonderful opportunities opening up for Liverpool as a city and the students of this university and department in particular. Just as we go to press the Department has received confirmation of its successful bid for over £16M for the building of a new undergraduate project laboratory and extensive refurbishment of its existing buildings. There will be much more on this exciting development in forthcoming issues of Engineering Focus.

Don't forget to look at articles by former student, Andy Moore, now a pilot with bmi, and on industrial placements for students of Integrated Engineering. I hope you enjoy reading this issue of Engineering Focus.

Professor John Mottershead
Alexander Elder Professor
of Applied Mechanics

My Career in Engineering...

Andy Moore – bmi Pilot

It has to be one of the best parts of my day's work, the feeling of the sunlight streaming into the flightdeck as we punch through the clouds into the unblemished blue sky.

Once we're cruising at 39,000ft the views of the countryside unfolding below disguise the massive feat of engineering keeping our 89 tonnes of aircraft aloft.

That modern air travel is faster, safer and cheaper than ever before is taken for granted by the majority of us who fly. These achievements have been hard won over the last 100 years since the Wright brothers first accomplished powered flight and the aerospace industry was born. Today's advanced jet airliners cost tens of millions of pounds to buy and are the result of years of testing and research.

It's no surprise that aerospace engineering is at the cutting edge of modern technology, the environment in which we operate provides challenges like no other. Whilst our passengers are enjoying the ice in their drinks, few realise that the temperature outside is around –56°C, and that the gentle rumble we find inconvenient as light turbulence could be because of wind speeds of up to 200 miles per hour at our cruising altitude.

Everyday that I fly I am surrounded by engineering, every part of the aircraft from the wing to the cup holders have been carefully designed to be more efficient, cheaper to produce and lighter in weight. Many of my friends who graduated with me now work to design and produce the components that cumulate in millions of successful flights each year; and my background in aerospace engineering from Liverpool helped achieve my ambition of flying commercially (of the eight people selected to be on the year long sponsored training course, five had an engineering background).

I couldn't imagine a job further removed from a 9-5 office environment.

Varying destinations, weather conditions and the people I work with all combine to make my work so enjoyable and each day different from the last one.

Andy Moore graduated in Aerospace Engineering from Liverpool University in 1999. He is now a First Officer with bmi flying the Airbus A320/321.

Liverpool
The World in One City

The University of Liverpool has reacted with huge excitement to the announce-ment that Liverpool has recently been named 'European Capital of Culture 2008'.

This is thrilling news for the University's 20,000 students and 5,000 staff. Not only will there be increased investment in the city (up to £2bn!) and job creation (estimated at 14000 jobs), but this award should confirm to potential students that Liverpool and the University of Liverpool are wonderful places – both to live and study.

There really is no better time to be a student in Liverpool!

As Head of the Department of Engineering I should add that no discipline contributes more to the region's economy than Engineering. Let's look at a few of the things which will be happening in the city and in the University of Liverpool, which is celebrating the centenary of its foundation:

- The opening of a stunning new building - the Fourth Grace – on Liverpool's world famous waterfront;

(continued on page 3)

'The Fourth Grace' on Liverpool's waterfront

Integrated Engineering:

a perfect start to your engineering career

Modern engineering is complex and sophisticated. It requires an ever increasing level of interaction between the 'traditional' engineering disciplines such as mechanical engineering, electrical engineering and manufacturing, combined with a keen understanding of modern business practice. It is no longer the case that these disciplines are independent, as everyday products often contain many different mechanical, electrical and electronic components, with instrumentation and controllers embedded in computer hardware and software. Integrated Engineers are able to understand the interactions and interfaces between these different engineering disciplines, as well as being able to deal effectively with conventional engineering problems involving the more 'traditional' disciplines.

Few degrees, if any, can match Integrated Engineering for employment opportunities

Employment opportunities

Few degrees, if any, can match Integrated Engineering for employment opportunities. There is a huge demand for good engineers to tackle the wide variety of design and manufacturing challenges that industry faces. Especially bright, adaptable, highly motivated, multi-disciplined engineers who possess good inter-personal skills are exactly the sort of people that Integrated Engineering is designed for! The multidisciplinary and interdisciplinary range of engineering knowledge and skills provides for excellent job opportunities for Integrated Engineering graduates, and often leads to a very flexible choice of career. In short, an Integrated Engineer is the perfect choice for employers.

Interdisciplinary study

Our Integrated Engineering programmes are inter-disciplinary in all years of study, with all students studying a core of mechanical, electrical, manufacturing, business and materials engineering topics. However you can, if you wish, bias your course after the first two years towards one or more of these engineering disciplines, or towards business technology. Integrated Engineering students work regularly alongside students from other engineering disciplines, particularly in design and project-work. For instance, MEng students undertake a major group design project on the low speed crash-worthiness of the new small Jaguar (X400) car, in collaboration with mechanical engineering students, materials engineering students, and Jaguar Cars. The Integrated Engineers are in the ideal position to be able to bring together all the factors to optimise the design solution. There are more than 50 academic members of teaching staff involved with the Integrated Engineering programmes, with internationally recognised mechanical, electrical, manufacturing and materials engineering research backgrounds (all rated with the highest grades 5* or 5 for their research), so you can be reassured that the design-work and project-work undertaken throughout your degree programme is always of the very highest standard.

Industrial placement

A unique aspect of the four-year MEng Integrated Engineering programmes at Liverpool is the full-time six-month placement in industry, undertaken in the second half of the third year in place of conventional University studies. This is designed to provide valuable experience in solving real engineering problems, and of course you find out what working in a real engineering environment is all about. It also looks really good on your cv, and often students are paid generously by the placement company!

Dr Tim Bullough
Integrated Engineering

(continued from page 2)

- The opening of a Museum of Comedy launching an international festival of comedy;
- A multi-million pound programme of public squares, open spaces, water features, public art, sculpture and activity throughout the city centre
- The biggest Deaf and Disabled Arts Festival ever held in Europe
- Europe's only annual American/Irish Festival, linking New York, Dublin and Liverpool
- The world's biggest star-gazing event, via the International Space and Astronomy Centre (opening in 2004)

Our Department of Engineering will also be sharing in this glory: Just in time for the Capital of Culture year we will have finished our newly refurbished and extended building and students will be graduating from both our new and our established undergraduate programmes. More details of these exciting developments will follow in future editions of '*Engineering Focus*'. Many of the students starting at Liverpool in September 2004 will graduate in July 2008. They will have benefited from our excellent new facilities, including the computer-aided design and manufacturing lab and a huge new project laboratory. They will emerge into employment or further study as fully-fledged 'Liverpool Engineers', possibly even in our vibrant city.

How does a 'Liverpool Engineer' differ from an engineering graduate from other institutions? As a student he or she will be treated like a professional engineer, will have the experience of working in a team, rubbing shoulders daily with world-class engineers and will be working on the design and construction of major engineering devices. For example, at the moment students are working on improving the suspension of a Maserati racing car, designing an unmanned aircraft and making a working version of one of the earliest powered aircraft. Over the summer we helped a group of students make improvements to the flying capabilities of the Wright Brothers' aeroplane. It's a pity they (Orville and Wilbur Wright) did not study at Liverpool!

There is much more I could say but let me be brief:

How I wish I was young again and could experience being a student here myself!

Professor
Peter Goodhew
Head of Department and
Henry Bell Wortley
Professor of Materials
Engineering

Industrial Placements for Integrated Engineering Students

Integrated Engineering students Chris Butcher, Giles Eaton, Kieran McLeod, Geoff Murphy and Andy Benson are pictured after returning to the University of Liverpool following completion of their 6-month Year 3 MEng industrial placements.

Geoff Murphy spent his time with Shell Oil Products at Ellesmere Port working as a Power and Control Instrumentation Engineer, and he described his experience as "An excellent opportunity to experience engineering in a dynamic working environment". His industrial supervisor was particularly impressed with him: Geoff's solution to one of the engineering problems he worked on has now been implemented at a cost of £70,000 to the company!

The other students worked at CorusColors in North East Wales, and at Balfour Beatty Rail in the outskirts of Liverpool. All the students commented that the experience was of great value to their personal and professional development, especially being able to experience engineering practice first-hand.

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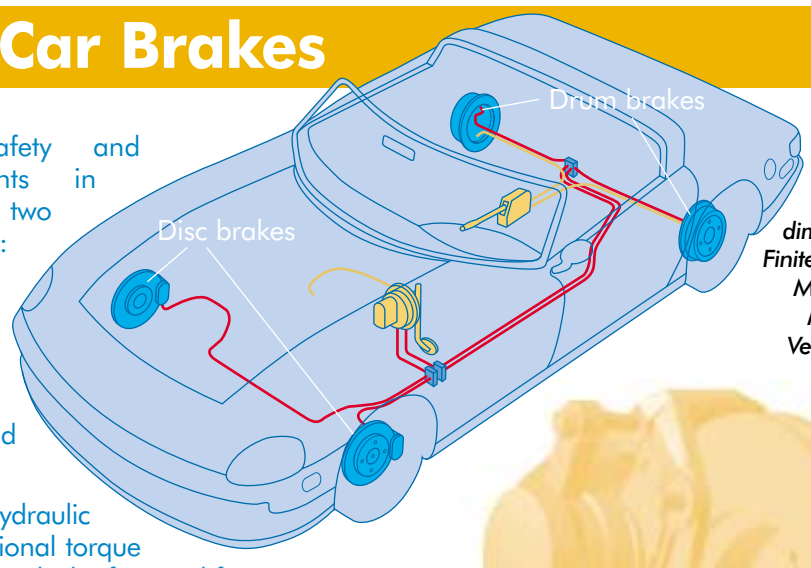
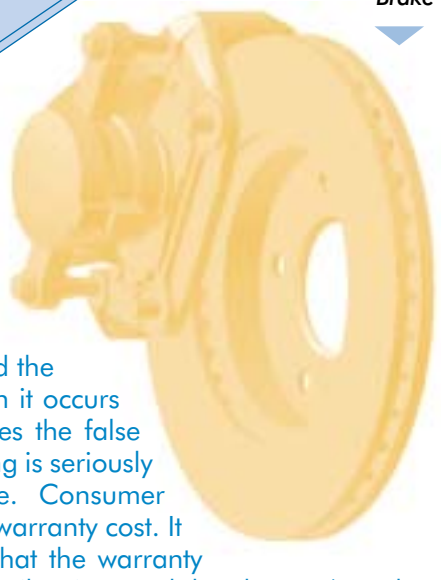
Designing Quieter Car Brakes

Braking energy when transferred into vibration of the brake may cause an alarming high-pitched noise known as 'Squeal'

Brakes are crucial safety and performance components in automobiles. There are two types of vehicle brakes: disc brakes and drum brakes. Disc brakes are gradually replacing drum brakes and are now widely used in cars, small commercial land vehicles and aircraft.

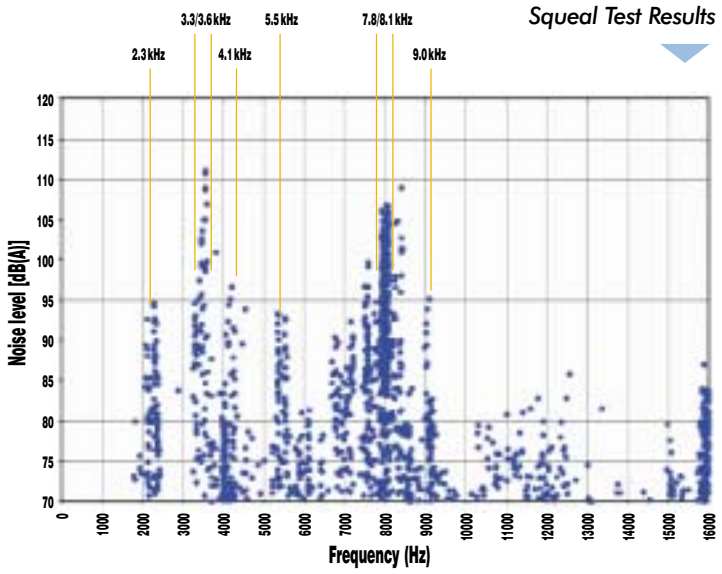


Three-dimensional Finite Element Model of a Mercedes Vented Disc Brake



Disc brakes are actuated by hydraulic pressure that in turn produces a frictional torque to slow down or stop a travelling vehicle. Unfortunately the frictional forces give rise to various brake noises, which occur over the whole audible frequency range of 20Hz to 20kHz. Squeal is a high-pitched, sustained noise with a frequency normally above 1kHz.

Squeal Test Results

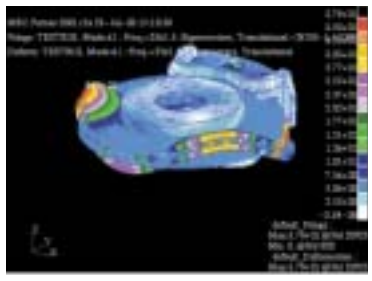


efforts on ways to achieve good noise performance at the design stage. One powerful way of doing this is through numerical simulations and experimental studies. The computer-generated vibration mode shapes below show the exaggerated deformation of the brake components when squealing at different frequencies.

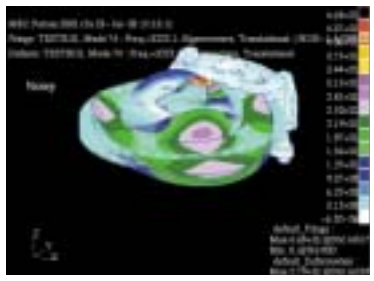
The Department of Engineering at the University of Liverpool has one of most active research teams working on disc brake squeal noise. They have received a continuous stream of funding from EPSRC and industry (Ford, BBA Friction, TRW Automotive) since late 1980s and are presently working closely with engineers from TRW Automotive on structural modifications to suppress disc brake squeal.

Dr Huajiang Ouyang
Mechanical and Aerospace Engineering

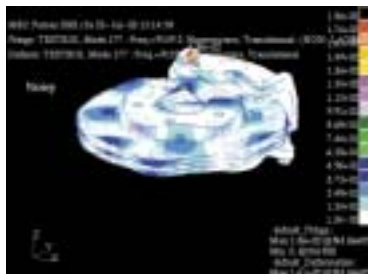
Brake squeal is an annoyance to drivers and the general public and when it occurs unexpectedly, often leaves the false impression that something is seriously wrong with the vehicle. Consumer complaints lead to high warranty cost. It was recently estimated that the warranty cost due to the noise, vibration and harshness (together known as NVH issues in automotive industry) is around one billions US dollars a year to the industry in North America alone. Brake pad material manufacturers spend about 50% of their budgets on dealing with the noise problem. All major car manufacturers and disc brake producers have their own research teams working on noise suppression and alleviation. However, a squealing brake is very difficult and expensive to correct, so researchers and designers focus their



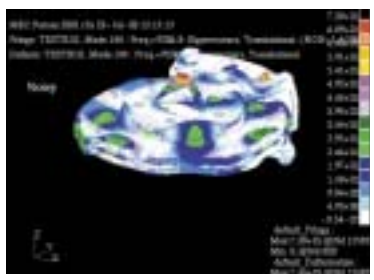
Predicted Noisy Mode at 2562Hz



Predicted Noisy Mode at 3222Hz



Predicted Noisy Mode at 9159Hz



Predicted Noisy Mode at 9206Hz

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Problem-Based Learning

How do you think Engineering is taught at University? Lectures and laboratory classes certainly play a part. But Tim Bullough, a lecturer in the Engineering Department at Liverpool, has been using an innovative approach to teaching that not only allows students to learn important engineering principles, it also helps them develop the sort of skills that leave Liverpool graduates better prepared for employment.

Problem based learning (also known as PBL) is a method that allows students to work in teams to develop knowledge at their own pace, with team members ensuring that everyone keeps up. In Tim's module, students took on roles within a fictional research team based within the steel industry, considering the best way to reduce the weight of a car door panel through material selection. This is a real issue for the automotive industry and students had the chance to ask experts in various areas of steelmaking and design for specific advice relating to their team's goal. A visit to the Jaguar press shop also gave students some practical understanding of the ideas they were developing.

Another novel aspect of this course was that students were able to use the computer network to stay in touch throughout. Supported by MATTER, a group of software developers in the department, online chat rooms were used to host technical discussions and message boards used to keep everyone up to date with information gathered by team members. Even some of the assessments were carried out online.

The module was assessed not just by individual tests, but also by group report writing and through a group presentation to an industry expert. This gave the teams the maximum opportunity to develop written and oral skills and to gain confidence in dealing with senior people from industries they could end up working in. Overall the module was well-liked by students and in future years it is hoped that teams will not just come from Liverpool but, by taking advantage of the internet, from all over the world. Watch the website for details of next year's course.

Dr Cheryl Anderson
MATTER Project

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