The NEWSLETTER

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Contents

Low Carbon Vehicle Technology Project

By John O'Connor, Project Director, Low Carbon Vehicle Technology Project

'Reducing our carbon footprint' is a phrase that is becoming more and more familiar. As the debates rage on over global warming, renewable energy sources, the carbon cost of international supply chains, product lifecycles, and personal energy consumption, what can really be achieved and how can UK firms stay ahead in the new economy that is emerging?

With both the UK government and the European Union setting arguably ambitious targets for a competitive low carbon economy in Europe by 2050, the area that many believe will create the most rapid effect is transport. Already there is a certain amount of technology for introducing behavioural change, and it is an area that will have less impact on the less well off than other government target sectors such as domestic heat and power. More than this, there are huge opportunities for long term technological advances which are stimulating some of the biggest changes the automotive industry has ever seen.

The Low Carbon Vehicle Technology Project (LCVTP), based in the West Midlands and project-managed by WMG at the University of Warwick, addressed these changes head on with an aim to revolutionise the way vehicles are powered and manufactured. It was also pivotal to the Government's decision in 2010 to declare the West Midlands a Low Carbon Economic Area for Advanced Automotive Engineering and to make the West Midlands a global centre of excellence in low carbon vehicle engineering.

A multi-million pound project funded by Advantage West Midlands, the European Regional Development Fund and contributions from industry partners, the LCVTP brought together world class UK OEMs, consultancies, suppliers and academic institutions into a focused collaborative programme to engage the wider supply chain community and create the required R&D capability and capacity for the development of the key low and ultra-low carbon vehicle technologies of the future.

Project partners Jaguar Land Rover, MIRA, Ricardo, Tata Motors European Technical Centre (TMETC), Zytek Automotive, Coventry University and WMG also worked with a significant number of local Small and Medium Enterprises (SME's) in the West Midlands in order to deliver socio-economic benefits such as improved technical skills, business capability and new products and processes to the area. The project was declared by independent assessors to have broadly achieved its aim to accelerate the research and development of the first low carbon vehicles by up to four years and is on course to safeguard over 2,000 jobs in the region's automotive supply chain by 2014 as businesses embrace low carbon opportunities.

During the 3 year active phase of the project, with fifteen R&D workstreams addressing everything from high performance battery modules and auxiliary power units, low cost electric drive motors and flexible high voltage distribution systems, to waste energy recovery and storage systems, new control software, lightweight structures, aerodynamics, and next generation braking systems, the project has created forty-one new products and processes for the design and manufacture of automotive vehicles, and by 2014 will have created over £36m in value added. In addition, an independent Life Cycle Analysis (LCA) study has shown that if several of the key technologies developed by the project were to be incorporated into a large luxury saloon car, CO_2 emissions would be cut by up to 20%.

Key technology achievements

Batteries

Lighter, flexible, and more energy efficient attery modules and packs validated using a suite of sophisticated software tools and state of the art testing equipment, together with a new Battery Management System (BMS).

Auxiliary Power Unit (APU)

A completely new APU designed, built and tested by the project partners, fully validated on a dynamometer and integrated into an existing vehicle package.

Material Joining

A range of new advanced adhesives specifically designed for applications within next generation vehicles including the bonding of aluminium to composites, steel to composites, composites to composites and aluminium to steel.

Dynamics and Control

New designs for vehicle control systems, with improved electronics hardware and fast response software. Significant improvements in regenerative braking, power electronics, high-voltage cabling, and energy storage and recovery systems.

Efficient Passenger Comfort and Information Systems

New efficient ways for heating and cooling the vehicle cabin were developed and tested, resulting in a saving of energy. New ways of presenting information to encourage energy efficient driving were developed and successfully trialled on a driving simulator.

Aerodynamic Improvements

New body and wheel features were developed and tested in a range of conditions, resulting in a significant reduction in overall vehicle drag.

Carbon Emissions Life Cycle Assessment

A suite of new tools for assessing the total carbon footprint of a vehicle over its lifetime, capable of providing valuable knowledge to vehicle designers, engineers, manufacturers, owners, operators, policy making bodies and recycling agencies.

Lightweighting

A highly innovative seat-frame design using rapid-stamp formed thermoplastic composites resulting in a weight saving of 40%. A new design for a longitudinal beam that provides a 20% weight saving when compared to aluminium and 60% weight saving when compared to steel. The designs have been validated using newly developed virtual and physical testing methods.

Energy Efficiency

Analytical tools and practical solutions have been developed to reduce energy losses through driveline systems, alongside empirical validation of waste energy recovery and conversion techniques that could be utilised to maximise onboard energy efficiency to increase electrical range and/or reduce tailpipe emissions in Range Extended Electric Vehicle applications.

WMG's role in the LCVTP

WMG's focus for LCVTP has been on lightweight structures and new control software, power electronics, and human-machine interface technology.

Human Machine Interface

Is it enough, however, simply to build low carbon vehicles: might the public need to be persuaded to buy them? Brand experience and performance is fundamental. To aid customer acceptance, and improve the user experience of future low carbon vehicles, it is vital to consider the human-machine interfaces (HMI) from a user-centred perspective. Specifically, this means understanding the interaction between the driver/passenger and the vehicle, and designing the user interface to maximise usability, satisfaction and enjoyment.

Technological advances are also creating additional issues in how drivers interact with their vehicles such as novel starting/stopping procedures, or communicating the effect that driving style has on the potential mileage range. Project teams focused on developing new techniques for trialling and evaluating new concepts and HMI issues within hybrid electric and pure electric vehicles.

This research has resulted in a comprehensive review of methods and technologies used to aid driver interaction, with the development of new methodologies for capturing voice-of-the customer feedback from low carbon vehicle drivers and both a quantitative and qualitative analysis of driver feedback relating to current HMI issues. Jaguar Land Rover has produced a set of standards covering HMI aspects relating to hybrid electric vehicles to ensure consistency across platforms and brands, utilising the results relating to hybrid electric vehicle issues including: charging port design and location, touchscreen characteristics, instrument cluster content, warning messages and the breadth and depth of information presented in different vehicle power modes.

TMETC has developed driver information methods for electric vehicles to address the challenge of range anxiety. The results of work into remote feedback and range information have been used to develop electric vehicle driver information management systems. The expertise gained here is also being used in the development of future cross-platform infotainment systems. A state of the art simulator has been installed at WMG which will be used to continue to define solutions to customer concerns such as range anxiety and battery charging and state of charge information.

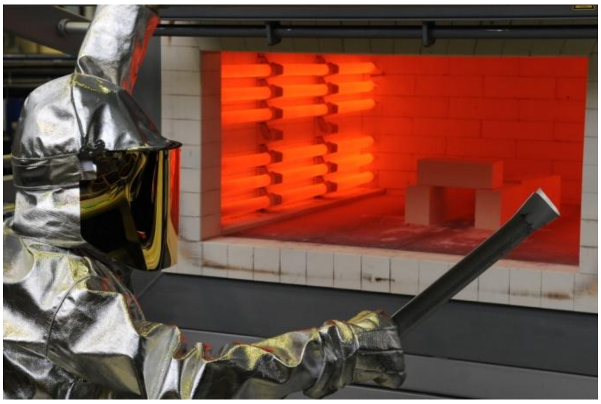
Lightweighting

The new architecture associated with hybrid and electric vehicles offers considerable opportunities for reducing overall vehicle weight and improving fuel economy, whilst maintaining desired levels of vehicle performance targets. With this in mind the project team has researched, developed and proven innovative materials and process solutions for structural applications. These materials and process solutions will contribute to a significant reduction in the overall environmental impact of future vehicles.

Following an in-depth study into the current state of the art for automotive materials, two materials and process technologies were identified for further research that could offer lightweight solutions:

- A rapid stamp-forming process for thermoplastic composites that offers up to 50% weight save over conventional materials
- Hot-forming of Ultra High Strength (UHSS) boron steels

Working alongside TMETC, WMG has developed an innovative seat-frame structure using rapid-stamp formed thermoplastic composites which has been designed and tested to international standards. This has resulted in a full seat specification offering a weight saving in excess of 40% against conventional designs.



In a similar vein, TMETC and WMG have also jointly developed a structural element (longitudinal beam) that provides a 20% weight saving when compared to aluminium and around 50% saving when compared to steel. The new tooling was designed to work with both existing metal stamping equipment and within a new composite forming process.

A look to the future

So far the project has received £12.5million in knock on investment, including facilities such as battery test labs and a power electronics clean room located at WMG. LCVTP has passed on 405 new skills and business assists to companies in the automotive industry in the Midlands and work will continue through the partners until 2014.

For WMG, this continuation will come through the High Value Manufacturing Catapult. WMG is one of seven partners in this government initiative, which will enable British business to commercialise the results of world class research in the UK and leverage findings through to major new high tech markets. WMG's focus is on the international challenge of low carbon mobility technologies, with a whole-system approach exploiting leading edge capability. Immediate R&D priorities, which are being developed in collaboration with companies, are lightweight product/system optimisation, energy storage and management, and digital validation and verification.

Going forward, it is expected that work will become more cross-sectorial, for example applying the new knowledge and technology into the rail and marine transport sectors, as well as stepping outside of the automotive box and working with government on energy policies and with energy companies on strategies and technology.

For more information on the project’s findings visit www.warwick.ac.uk/go/wmglowcarbon, or contact Alan Curtis, Chief Executive Officer of the High Value Manufacturing Catapult at alan.curtis@wmg.warwick.ac.uk

Aluminium automotive sheet for affordable mass manufacture of cars

By Geoff Scamans (Innoval Technology) and Adrian Tautscher (JLR)

Aluminium has a long history of use in cars but to date this has mainly been confined to castings with much more limited use of sheet and extrusions. The benefits of aluminium in body-in white (BIW) structures are well known in terms of reduced weight leading to better fuel economy together with a high recyclability value and excellent corrosion resistance. However, with most consumers having little consideration of fuel economy, nor the other benefits, as a factor in choosing a model of car, its substitution for steel has been difficult as the cost of aluminium pressed sheet parts has been roughly four times the steel cost for an equivalent BIW part.

This situation has now changed significantly due to the effects of global warming that has galvanised legislation to tax CO_2 emissions in various ways and to drive fleet average emissions for vehicles sold in the EU down to 130g CO_2/km by 2015, 90g CO_2/km by 2020 and then potentially to 60g CO_2/km by 2030 backed by severe financial penalties for non-compliance. These requirements, have forced the EU OEMs to consider new materials, and to significantly increase their use of aluminium sheet for BIW applications.

To date the use of aluminium sheet for BIW structures has been confined to high-end models like the Jaguar XJ and XK, or more widely to parts like closure panels, and consumption has increased progressively as shown in Figure 1.

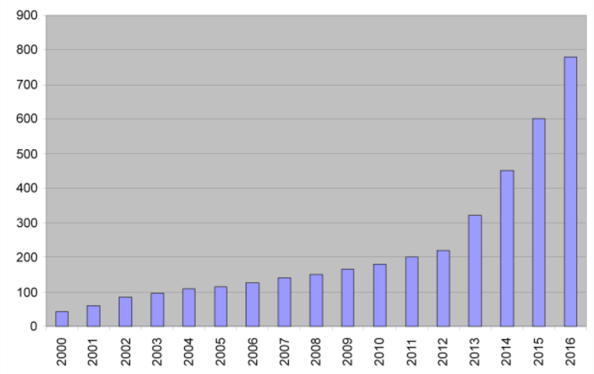


Figure 1: Actual and projected EU aluminium automotive sheet growth for BIW applications (kt)

Today, EU consumption is already of the order of 200,000 tonnes per year (tpy), with projected consumption of 600,000 tpy by 2015 based on new aluminium intensive models already announced by JaguarLandRover (JLR) and Audi for example. Expansion in automotive sheet capacity is also happening in North America where Novelis recently announced expansions of 200,000 tpy capacity at their plant in Oswego and Alcoa have announced a $300 million investment in automotive sheet capacity expansion at Davenport. In Asia, several new rolling mills and finishing lines are being considered to support Chinese car production. Developments in Europe have been the driving force behind this growth elsewhere. Aluminium automotive sheet production will increase rapidly to supply the expanding globalised automotive industry, with consumption in North America and in Asia expected to reach equivalent levels to those in the EU, all driven by the same low carbon requirements.

Production of aluminium automotive sheet is largely constrained by the capacity of the continuous solution heat treatment stage and this line, together with the finishing line are likely to be the slowest within the overall process. The step-wise growth in EU heat treatment and finishing capacity for aluminium automotive sheet is shown in Figure 2.

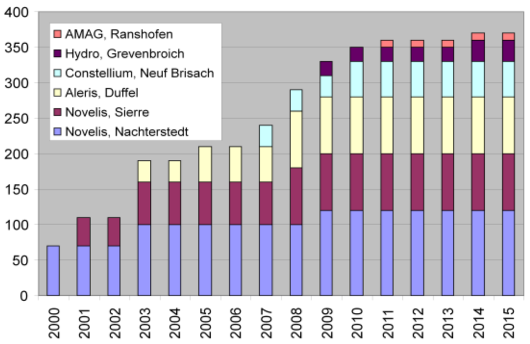


Figure 2: Progressive investment in EU aluminium automotive sheet heat treatment and finishing capacity (kt)

Progressive investment in combined heat treatment and finishing facilities has anticipated and kept pace with the market requirements with typical investments adding 100 to 120kt of heat treatment and finishing capacity with an investment cost of about $100 million.

Novelis, a leading producer of aluminium automotive sheet, announced earlier this month that they will build their first automotive sheet heat treatment and finishing facility in China in the Jiangsu Province close to where both JLR and Audi are setting up their vehicle production lines. The plant is expected to be commissioned for operation in late 2014. Consideration of the tonnages required and the installed finishing capacity shows that further investment must also be made in the EU to keep supply and demand in balance.

The key to the more extensive use of aluminium sheet in more affordable cars is to make its cost per part far closer to that of an equivalent steel part. JLR have suggested that in order for aluminium sheet to be considered for D and possibly even C/D segment vehicles, the price of aluminium sheet should be of the order of $1400/tonne. As this is considerably lower than the average London Metals Exchange (LME) price for primary aluminium that is presently around $2000/tonne this is a considerable challenge for the aluminium industry.

The only way to achieve these sheet price targets is to use recycled aluminium rather than prime aluminium in the same way that aluminium can sheet is made from recycled used beverage cans (UBCs). Figure 3 shows the price that Novelis has paid for consolidated UBC’s delivered to its recycling plant in Latchford over the past few years compared to the LME price for prime smelter grade aluminium. The figure shows that on average the price paid for recycled cans is set at roughly 56% of the LME price. This supply of UBC scrap directly back into can sheet production makes aluminium sheet cost competitive with steel sheet for beverage can making and aluminium dominates for can making in all markets where there is open competition. The aluminium intensive car should be viewed in precisely the same way as the aluminium beverage can although the product life cycle is measured in years rather than days.

The issue of using recycled aluminium to make automotive sheet was addressed in the recently completed REALCAR project that was led by JLR and supported by the Technology Strategy Board. The project was based on making and testing high recycled content aluminium automotive sheet through existing production processes at Novelis. The target recycled content, including both JLR production scrap and post consumer scrap was set at 75% for AA5XXX series sheet with properties fully suitable for BIW manufacture. The project considered non-automotive sources of old aluminium scrap as well as end of life vehicle (ELV) waste as shown in the schematic diagram in Figure 4. The first 50% of recycled scrap was obtained from press shop offal from automotive stamping plants with strict alloy segregation and avoidance of cross contamination. This is presently in place at the JLR Castle Bromwich press shop where the segregation is between steel, AA5XXX and AA6XXX series aluminium sheet. Similar scrap recovery will soon be in operation at both their Halewood and Solihull press shops. The segregated press shop aluminium sheet scrap will be returned to Novelis via their Latchford recycling centre for the manufacture of rolling blocks for aluminium automotive sheet production in Germany.

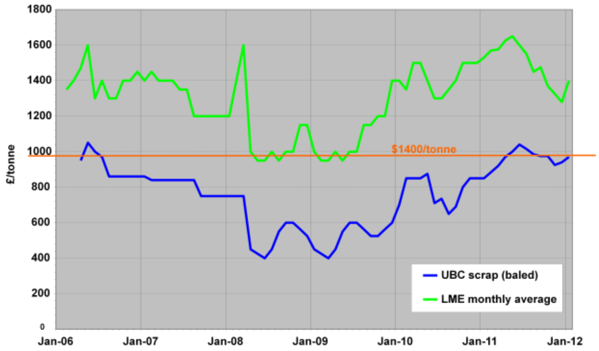


Figure 3: Relative price paid for UBC scrap compared to the average monthly LME aluminium price. On average it is 56% of the metal price. The orange line is the price JLR target for the aluminium sheet ($1400/tonne) for use in D and C/D sector cars.

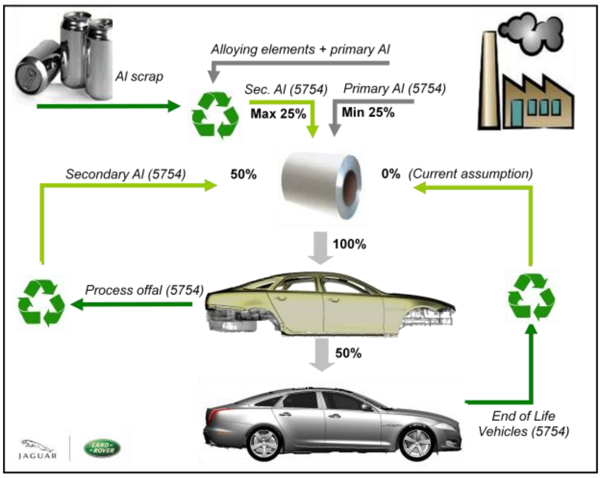


Figure 4: REALCAR recycling of process scrap and post consumer scrap into AA5754 aluminium automotive sheet for BIW manufacture

The REALCAR project evaluated a range of different AA5XXX series sheet chemistries and process parameters using material produced by Novelis who produced both lab scale strips and full sized coils for evaluation. The detailed assessment of the sheet for BIW manufacture included stamping, joining and CAE requirements for use in the next generation Jaguar Land Rover vehicle platforms. Parts made using AA5754 with increased levels of impurities are shown in Figure 5.

Figure 5: Trial stamped parts made from AA5754 sheet with increased levels of impurities

The project defined two AA5xxx alloy compositions with increased tolerance for higher levels of iron, silicon and copper as impurities arising from the recycled metal. These impurities control mechanical performance in terms of formability, joining, fatigue and crush behaviour. Investigations were also conducted to source aluminium post consumer scrap from other industries, including those that have potential to divert from landfill such as Mechanical Biological Treatment (MBT) plants that process general household waste.

Detailed End-of-Life (ELV) vehicle evaluations were also carried out; the largest and most significant of which involved the scrapping of 40 Jaguar XJs and 2 Jaguar XKs previously used for engineering testing. The vehicles had all fluids, batteries and tyres removed, pyrotechnics deployed and the engines and wheels were removed for separate recycling. The vehicles were then crushed and shredded and the resulting aluminium fraction was taken to Norton Aluminium to be melted in a rotary tilt furnace and cast into ingots as shown in Figure 6.

Figure 6: Crushing shredding and melting of End-of-life Jaguar XJs and XKs

The composition was analysed to determine its suitability as a future recycled automotive sheet source. From this work it was clear that further development is required in this area, in particular to improve the segregation technology to remove a greater percentage of the contamination from other metals, other aluminium alloys and in particular the high silicon containing cast alloys used more generally in vehicle applications. Without this to provide more careful control of elements such as iron, only small quantities could be re-cast into automotive AA5XXX series sheet.

A REALCAR2 project has recently been proposed to tackle these issues.

The REALCAR project clearly demonstrated the value of recovery of press shop scrap for making more cost competitive aluminium automotive sheet and showed the route to further cost reduction through the incorporation of suitable post consumer scrap from both household waste and from end of life vehicles provided separation techniques can be improved. These measures provide the clear route for making aluminium automotive sheet cost competitive with steel sheet for BIW manufacture for affordable mass produced cars.

For more information, please contact Geoff Scamans at Geoff.Scamans@innovaltec.com

Coca-Cola biomethane trial

By Steve Carroll, Technical Specialist, Cenex

Cenex, the UK's centre of excellence for low carbon technologies, specialise in the real world performance of alternatively fuelled vehicles and helping transport operators to place new technologies into the right fleet applications. This article details the approach and results of a vehicle trial that compared the performance of a 26 tonne Iveco Stralis gas vehicle operating on biomethane with that of a diesel Stralis vehicle.

Biomethane and gas vehicles

Biomethane is the term given to biogas (which is created during the anaerobic decay of organic matter) that has been upgraded (i.e. unwanted gases and contaminants have been removed) to vehicle fuel quality which typically has a high >95% methane (CH_4) content. Biomethane is a renewable fuel as its conversion from organic matter to CO_2 is sustainable and within the planets natural carbon cycle.

Biomethane is similar in energy content and chemical composition to natural gas and is fully interchangeable with natural gas when used in an engine. There are currently over 13 million natural gas vehicles operating throughout the world. The market leader in Europe is Italy with over 760,000 and the UK lags behind with around 220 gas vehicles in operation. However, the recent focus on environmental performance means that OEM gas vehicles are now available in most vehicle classes in the UK.

The trial vehicles

The trial vehicles were new registrations at trial commencement that met enhanced environmentally-friendly vehicle (EEV) emission standards. The vehicles were operated from the Coca-Cola Enterprises (CCE) depot in Enfield where a temporary biomethane filling station was installed. The temporary refuelling station is shown below in Figure 1.

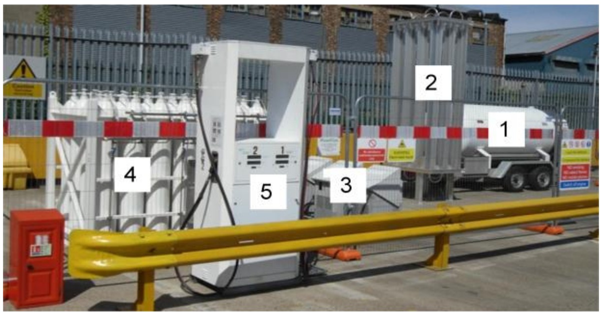
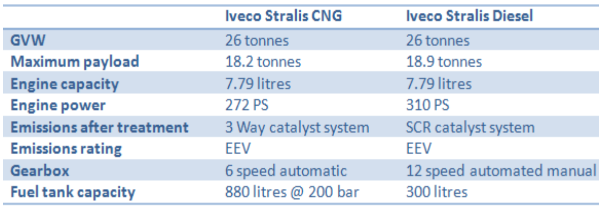


Figure 1: Temporary refuelling station showing (1) cryogenic storage tank (2) vaporiser (3) gas compressors (4) compressed gas storage (5) gas dispenser

The main vehicle specifications are summarised in Table 1.



	Iveco Stralis CNG	Iveco Stralis Diesel
GVW	26 tonnes	26 tonnes
Maximum payload	18.2 tonnes	18.9 tonnes
Engine capacity	7.79 litres	7.79 litres
Engine power	272 PS	310 PS
Emissions after treatment	3 Way catalyst system	SCR catalyst system
Emissions rating	EEV	EEV
Gearbox	6 speed automatic	12 speed automated manual
Fuel tank capacity	880 litres @ 200 bar	300 litres

Table 1: Trial vehicle specification

Drive cycle based vehicle testing

During the trial the trucks operated on three main routes (Central London, Reading and Essex) that were representative of the range of delivery routes from Enfield. GPS and CAN-bus logging equipment was fitted to the trucks which recorded speed, time and engine parameters on a 1 hertz frequency. From the logged data, a drive cycle (speed and time trace) was created that was statistically representative of the CCE delivery patterns.

A drive cycle is a very robust method of analysing the comparative performance of vehicles for the following reasons:

1. A drive cycle allows different vehicles to be directly compared over identical driving conditions on a rolling road with external sources of variation (such as traffic conditions and driving style) removed.
2. Repeatable test conditions allow new technologies to be evaluated over real-world derived drive cycles and compared to existing fleet vehicles in very short times at a relatively low cost (when compared to a vehicle trial).
3. Testing vehicles over a representative drive cycle in an emissions testing facility allows air quality performance as well as tailpipe CO_2 and fuel consumption to be measured.

The drive statistics of the gas and diesel vehicles were sufficiently similar which allowed a single 19.5 km drive cycle to be produced that was statistically representative of the CCE delivery routes. The drive cycle and its key characteristics are shown in Table 2 and Figure 3.

CCE drive cycle key stats		
Duration	30.8	minutes
Distance	19.5	km
Avg speed	37.6	kph
Town driving	55	%
A/B road driving	24	%
Motorway driving	21	%

Table 2 – Key characteristics of the CCE drive cycle

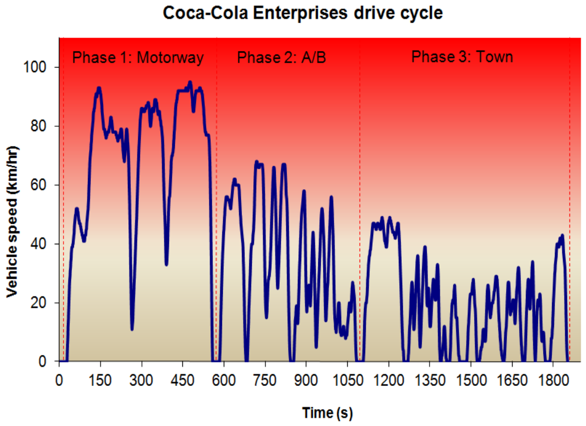


Figure 3 – The CCE drive cycle

Fuel economy, carbon and air quality performance

The gas and diesel trucks were tested over the CCE drive cycle on a chassis dynamometer at Millbrook Proving Ground. NOx and PM emissions were key performance measurables for CCE and the gas vehicle reduced these by 85.8% and 97.1% respectively.

The gas truck consumed 34.9 kg/100 km compared to the diesel truck that consumed 31.9 litres/100 km over the CCE drive cycle. Since the efficiency of a SI engine is lower, a reduction in vehicle efficiency is normal when converting a fleet from diesel to dedicated gas technology. Additionally on the trial vehicles the transmission changed from an automated manual in the diesel to a fully automatic unit in the gas which is also likely to have a negative effect on efficiency. The overall reduction in fuel efficiency (MJ/100km) from the diesel to gas vehicle was 31.8%.

Figure 4 – The gas truck on the chassis dynamometer at Millbrook

Cenex performed a well-to-wheel emission analysis on the transport fuels. This quantified the total carbon footprint of the fuels and included the energy intensity of fuel extraction, processing, transportation and dispensing. The overall well-to-wheel savings achieved from biomethane vehicle operation were 50.3% during the trial, which would rise to 60.7% if a more efficient high volume permanent station were installed. Whilst the tailpipe CO_2 emitted from the trucks was circa 9% higher for the gas vehicle, absolute CO_2 from the exhaust pipe is not relevant when combusting a renewable fuel and is therefore not a reportable direct emission under the UK Government's emission accounting guidance to which CCE adhere.

Driver feedback

Drivers were surveyed and feedback was very positive from both vehicles. The performance indicators are shown in the radar chart below. Drivers rated the performance aspects on a scale of 1 to 5 denoting "Not acceptable" [1] to "Excellent" [5]. The gas truck was unanimously scored full marks in all acceleration and refuelling categories where feedback from the drivers implied i) they preferred the gas truck's fully automated transmission to the automated manual in the diesel, and ii) they preferred refuelling the gas vehicle on site rather than refuelling with diesel on a public forecourt. Drivers rated gas as a safer method of refuelling than diesel.

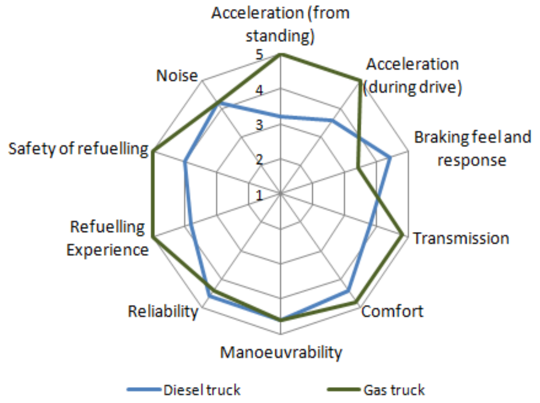
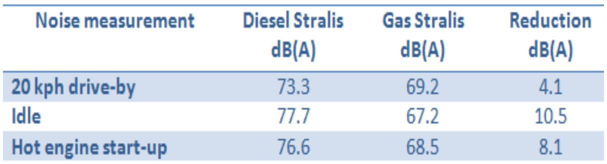


Figure 5 - Driver feedback chart

Noise emissions

Long term exposure to traffic noise in city centres is reported to have an adverse effect on human physical and psychological wellbeing. HGV movements in urban areas are often constrained during night time and weekend periods by local curfew regulations put in place to avoid noise impacts. Relaxation of these curfews would allow deliveries to be performed outside of working hours resulting in improvements in fuel consumption, emissions, time and productivity. Back-to-back noise measurements were conducted at the certified noise site at Millbrook Proving Ground. The tests were designed to measure noise emissions relevant to inner-city operational conditions. Specifically drive-by, idle and hot engine start up noise levels were measured. Drive-by noise measurements were conducted at 20 kph, which represents the average speed of the town section in the CCE drive cycle. Noise levels were significantly reduced in all key areas as shown below in Table 3.



Noise measurement	Diesel Stralis dB(A)	Gas Stralis dB(A)	Reduction dB(A)
20 kph drive-by	73.3	69.2	4.1
Idle	77.7	67.2	10.5
Hot engine start-up	76.6	68.5	8.1

Table 3 - Noise testing results

Noise levels at the driver's ear were also monitored and these remained similar between the gas and diesel trucks.

Fuel and oil condition

In the absence of a European or UK biomethane standard, Iveco's key requirements from biomethane are that the fuel has a high methane content (> 95%) and a low level of contaminants such as siloxanes, hydrogen sulphide (H_2S) and moisture. Siloxanes and H_2S are formed during the anaerobic digestion process and cause accelerated engine wear. Moisture in the fuel can damage the fuel delivery system and impede the lubrication properties of engine oil. Independent fuel analysis by Ceram Laboratories showed that the biomethane maintained a high methane content and low levels of contamination when measured throughout the fuel supply chain. The final fuel delivered into the vehicle exceeded the quality levels required by the vehicle manufacturer.

Economics

Operating the gas vehicle on biomethane reduced the fuel costs by 12.8%. However, the total cost of ownership increased by 15.3% primarily due to the additional capital cost of the gas vehicle. Estimated future cost reductions between the vehicle technologies coupled with a further reduction in gas price due to either a higher volume supply or the use of a public gas refuelling station would achieve a similar total cost of ownership between the two vehicle technologies. In 2011 Transport for London removed the incentive for operating alternatively fuelled vehicles in the London congestion charge zone. Previously this measure would have saved CCE £1250 per annum per vehicle and reduced the overall operating premium to 12%.

A successful trial

The thorough approach to vehicle evaluation and comparison presented here enabled CCE to invest in a fleet of 14 gas Iveco Stralis vehicles and a gas station (shown below) that is due to be operational at the Enfield depot in June 2012. The CCE gas fleet will consume approximately 168 tonnes of biomethane saving over 300 tonnes of CO_2, 1590 kgs of NOx and 33 kgs of PM emissions per annum.

Figure 6 – CCE Iveco Stralis gas vehicle

The full report is available for download from the Cenex website www.cenex.co.uk/resources. The report was placed in the public domain with the aim of enabling fleet operators and decision makers to understand the truck's operational performance and gain the confidence to help reduce, or eliminate, the need for repeated technology comparisons across fleets, and hence reduce the time required to deploy greater numbers of gas commercial vehicles throughout the UK. References are available upon request. For more information please visit www.cenex.co.uk or contact Steve Carroll at Steve.Carroll@cenex.co.uk

Emissions after-treatment for light-duty Diesels

Professor Stephen Benjamin, Coventry University

Rising fuel costs and concerns regarding greenhouse gas emissions have resulted in an increase in the number of diesel passenger vehicles both in Europe and the US. The fuel economy improvement is due to the inherently better thermal efficiency of diesel over conventional petrol engines. However, diesels produce higher emissions of nitrogen oxides (NO_X) and particulates. Whilst technologies to deal with the latter are well advanced (particulate traps), reducing NOx is more problematic with the automotive industry facing tough challenges in order to comply with European and US emission regulations.

Conventional petrol engines operating at stoichiometric conditions with 3 way catalysts are extremely effective at reducing NOx. Diesels, however, burn with excess air and so reduction of NO_X to N_2 in the exhaust gas stream is more difficult. Whilst Euro 5 NOx emissions might be met with improvements in combustion technology it is almost certain that NOx after-treatment systems will be needed to meet Euro 6 and current US Federal Tier 2 Bin 5 regulations. The two main NOx after-treatment technologies under consideration are Lean NOx Traps (LNT) and Selective Catalytic Reduction (SCR). Each technology presents its own set of challenges and it is still uncertain as to which will prevail. Whilst both technologies have been demonstrated on engine test stands and in vehicles there is still a great deal of uncertainty as to the physio-chemical processes involved and developing optimum design strategies is extremely challenging.

Figures 1 and 2 show typical simulations. They show selected concentration profiles through a cross section of an LNT (see figure 1) and SCR device (see figure 2). Figure 1 shows NO_2 concentrations in the gas stream during the storage phase. The incoming NO oxides to NO_2 on the oxidation catalyst (the first blue brick) and is subsequently absorbed by the LNT (the second blue brick).

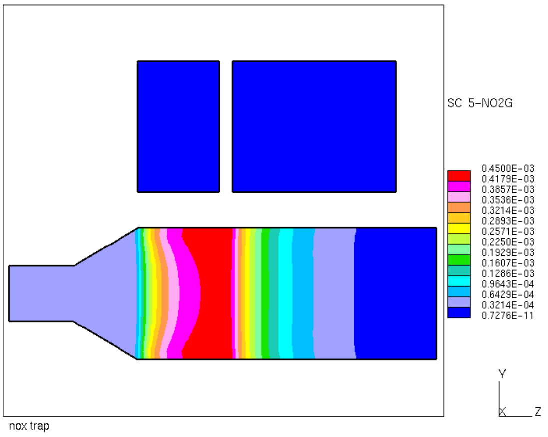


Figure 1: Simulation of NOx storage

LNT catalysts are typically Pt-group metals, which catalyse the reduction/oxidation process and a basic adsorbent or base-metal-oxide (BMO) that provides the storage capacity. Typical BMOs are barium oxide (BaO) and barium carbonate ($BaCO_3$). An oxidation catalyst converts engine-out NO emissions into NO_2. This is subsequently stored on the LNT during lean engine operation as NO_2 reacts with the BMO to form a nitrate. Periodic regeneration of the trap under all driving conditions is essential since it has a finite trapping capability. Regeneration is achieved by running the engine rich for a few seconds so that excess hydrocarbon (HC), CO or H_2 reacts with the NOx that is released by disintegration of the nitrate under these conditions. LNTs are sulphur sensitive and achieve highest conversion efficiencies within a temperature window. Other technical challenges relate to identifying the optimum storage/purging periods, preventing NOx “slippage” during purging events and developing appropriate control strategies. In particular, too frequent purging provides a fuelling penalty whilst insufficient purging reduces trapping efficiency.

Figure 2 shows urea droplets and NO gas concentrations for a SCR simulation. The droplets are shown to evaporate forming ammonia which reacts with the NO removing it on the SCR catalyst (the blue brick).

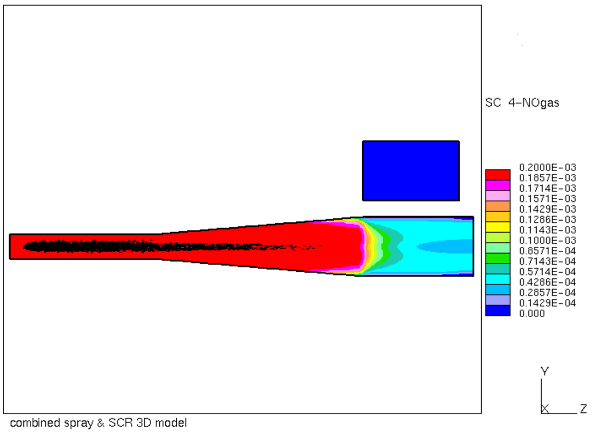


Figure 2: Simulation of SCR

SCR involves the catalytic reduction of NOx with urea/ammonia (NH_3). A solution of urea (Adblue) is injected into the exhaust system as a spray of fine droplets. The droplets subsequently decompose to NH_3 which selectively reduces NOx over a catalyst. In Europe, a number of heavy-duty vehicle manufacturers have chosen urea-SCR for meeting emission standards and the infrastructure for urea outlets within Europe has been steadily developing. The application to light-duty vehicles and passenger cars presents additional challenges. Their operational characteristics are quite different from heavy duty vehicles as they typically operate at high speed and low load with lower exhaust temperatures. Further, light duty vehicle homologation requires emissions compliance over drive cycles featuring significant transients. Amongst a number of important issues to be addressed will be the urea dosing strategy, the positioning of the injector and the type of the catalyst. Sufficient urea dosage is needed for reducing the NOx but ammonia “breakthrough” needs to be avoided.

Currently almost all prototype development work for LNTs and SCRs is conducted on engine test stands and chassis dynamometers. Validated mathematical models of these after-treatment devices would allow design engineers to vary operating parameters and system design features prior to prototype testing. This would potentially save development time and costs whilst also providing systems with reduced emissions and better fuel economy.

The Automotive Engineering Applied Research Group (AEARG) at Coventry University, under the direction of Professor Steve Benjamin, has been working with a Consortium of Automotive companies (Faurecia, Jaguar Cars/Land Rover and Johnson Matthey) for a number of years to develop such models. The models are validated from test rigs and engine studies and then delivered to the companies for use on their own development programmes. Companies provide funding, specialist hardware, software licences and technical expertise. Coventry University develops the models and validates them in engine test cells and flow laboratories. The laboratories are equipped with specialist emissions equipment which enables exhaust gases to be sampled with high time resolution. This is essential in order to understand the behaviour of these systems which operate in a transient mode. The flow laboratory is equipped with laser diagnostic equipment which is used for measuring the flow in these exhaust systems and for characterising the urea sprays used in the SCR devices. These facilities and the modelling expertise provide a unique environment for undertaking this research at Coventry.

Coventry University along with Consortium partners have recently been awarded an EPSRC grant to model and validate NOx reduction by SCR appropriate for light-duty vehicles under steady and transient conditions. The research programme has involved designing an exhaust assembly which permits the evaluation of key system parameters (see figure 3).

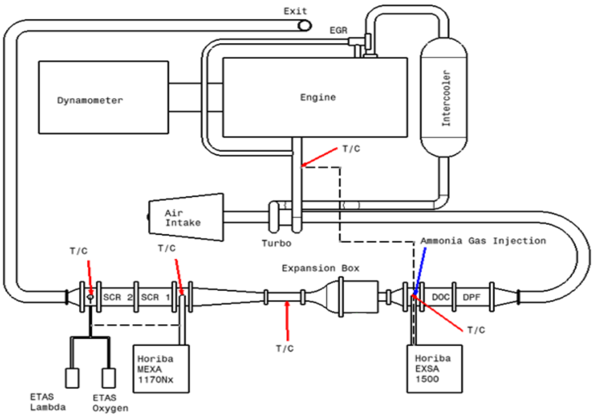


Figure 3: Engine installation showing SCR exhaust system.

These include the NO_2/NOx ratio, catalyst size (space velocity), exhaust gas temperature, injection location and urea/NH_3 dosage. Figure 4 provides an example of predicted NO/NO_2 conversion compared to measurements along a SCR catalyst. These studies have resulted in the development and refinement of simulation software which has been assessed and validated over a wide parameter space. The models are delivered to the members of the Consortium who can then use them as part of their own development programmes. The models will allow the design engineer to investigate a range of options prior to expensive prototype testing. In this way designs can be evaluated more effectively leading to a reduction in development cost and time and optimised systems.

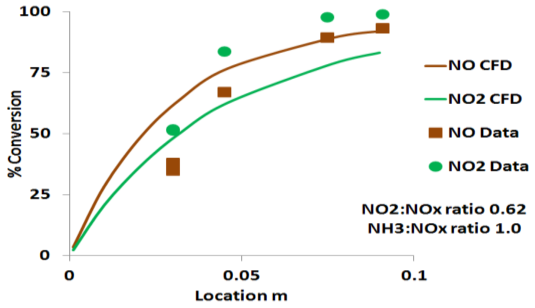


Figure 4: Conversion profiles along an SCR

Coventry University's Low Carbon Vehicle Grand Challenge Initiative

Professor Benjamin's research is part of Coventry University's Low Carbon Vehicle Grand Challenge Initiative. The Low Carbon Vehicle Grand Challenge Initiative brings together a diverse range of expertise from across the University to create a multidisciplinary research team to address one of the key challenges facing the world – how to reduce carbon emissions from transport. The project above shows just one of the ways in which the Grand Challenge is tackling the technological issues associated with a switch to lower carbon vehicles but Coventry University also has significant expertise in vehicle design and research into the social and economic aspects of the low carbon vehicles market.

For more information, please contact Professor Steven Benjamin at mex059@coventry.ac.uk.

Powering in wheel sensors - clockwork energy harvesting

Dr Carl Anthony, School of Mechanical Engineering, University of Birmingham

In Europe tyre pressure monitoring has been driven by the benefit to both the car owner and the environment. Under inflation of tyres is known to lead to additional tyre wear and reduction in fuel efficiency. The European Union has estimated that a 40kPa reduction in tyre pressure from the recommended level will result in a 2% increase in fuel consumption and a 25% decrease of tyre lifetime. By contrast in the US the monitoring of tyre pressures has been a mandatory requirement since 2007, due to safety legislation introduced as part of the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act. All new passenger cars, light trucks and buses are required to have Tyre Pressure Monitoring Systems (TPMS) that monitors the tyre pressure and reports back to the central control system, providing a warning when the tyre has deflated by 25% or more. In the US most systems are 'direct' sitting in the wheel measuring pressure directly. This is in contrast to many systems seen on European cars that are based on wheel speed differential, termed 'indirect', and work off the antilock braking signals, not requiring in-wheel sensors.

The direct systems offer a challenge to sensor designers as they cannot be wired and need an in-wheel power source to drive the measurement and wireless transmission system. The TPMS must warn the driver within 10mins of the deflation, hence measurements are infrequent and the system can power down to a sleep state in between measurements. With the higher power wireless transmission only taking milliseconds, the average power of such systems can be as low as a few tens of microwatts. Power is currently provided by lithium button cells that can in principle provide 7-10year lifetime given the low power requirements. In practice the extremes of temperature seen in automotive applications mean that the battery driven system becomes less reliable toward the end of its designed lifetime. This is a major concern to automotive manufacturers and the TPMS designers are looking at ways to supplement or replace the battery. Vibrational energy harvesting as a source to trickle charge the battery has been the main focus of this work, however power generation at low speed is an issue.

In addition to the battery lifetime issue the mandatory introduction of direct TPMS systems in the US has resulted in a significant environmental cost. With 16million new cars being sold in the US each year there are now 64million new batteries each year that will require disposal at the end of their lifetime.

Dr Carl Anthony from the University of Birmingham is developing an alternative method of powering the TPMS that alleviates both the battery lifetime and environmental impact consideration altogether. With the support of EPSRC he is developing a clockwork based energy harvesting system that has spring energy storage in place of the battery.

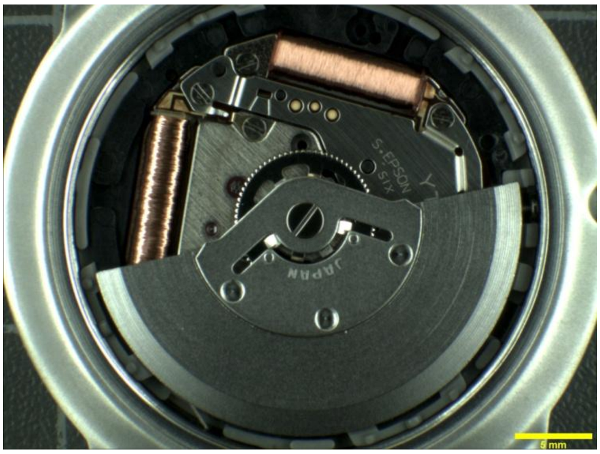


Figure 1a: Seiko kinetic watch showing harvesting mass, generator coil and movement coil

Clockwork has had a resurgence since the introduction of the Trevor Baylis windup radio. However the technology for powering TPMS needs to be at a scale an order of magnitude smaller. The spring based energy storage technology has been available in the form of automatically wound watches for over a century, however the generation of electricity from the spring storage at the milliscale is a more recent addition to watch technology (see figure 1a). Kinetic watches house a tiny dynamo system, (see figure 1b), that is normally driven by the motion of the arm and recharges a built in battery. The rotor is a rare earth magnet of only 2.6mm diameter. The dynamo saturates at a maximum power of ~3mW into a matched load at high speed.

In the in wheel energy harvesting system under development the rotational motion of the car wheel will be used to wind the automatic watch spring, which will then be used to drive the kinetic micro-generator directly. This is achieved in practice by a hinged mass that rotates outward as the wheel speed increases, Fig 1c; each time the car stops and starts the spring is progressively wound to its maximum torque. A slip clutch on the hinged rotation point allows the mechanism to return to its rest point without unwinding the storage spring. Springs do not have a high energy density and will only store enough energy for hours of operation rather than years.

Figure 1b: rotor and stator of seiko mini-generator

The stop start nature of most journeys though ensures that the spring will be recharged on a regular basis providing power for that journey. For such a system with an optimised 0.1Nm/rad storage spring, a car speed of 75 KPH and a mass of the system of 30g the energy available is ~2.2 mW-hrs. Far in excess of the few tens of microwatts a TPMS requires, allowing more than a day of operation on a fully wound storage spring. One of the key factors of the system is the controlled release of the spring energy; the watch escapement is currently used to achieve this but could turn out to be the weak point in the system when the vibration of the wheel is taken into consideration.

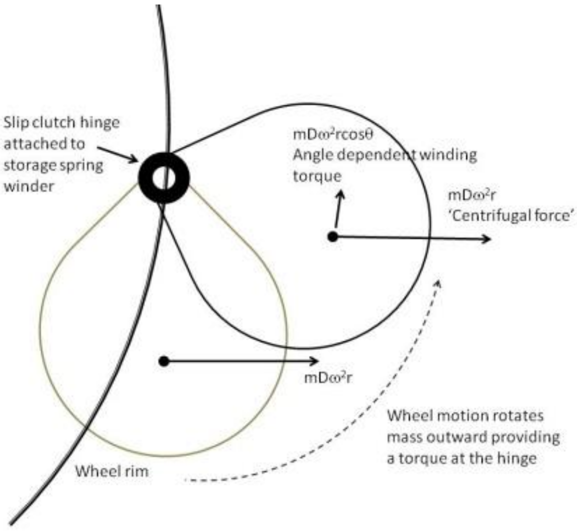


Figure 1c: schematic showing principle of proposed final system

With any energy harvesting system the energy that can be generated is dependent on the host system conditions. For in wheel harvesters this is the vibration and rotation characteristics of the car wheel hub. To determine the performance of the final system and to allow comparison to the alternative vibration based energy harvesting systems, understanding these characteristics during typical car journeys is required. An additional part of the project has therefore been to measure the vibration and wheel rotation speed seen by the wheel of a typical small car (Ford Fiesta). A DJB A/130/V 100mV/G triaxial accelerometer was attached to the front suspension of the car to measure the xyz vibration that the wheel hub would experience, (see figure 2a,b).

A hall sensor was used to measure the wheel speed with 12 metal discs equally spaced around the inside rim of the wheel, (see figure 2a).

A special fixture was produced to attach the hall sensor to the shock absorber to allow it to be accurately positioned inside the wheel rim.

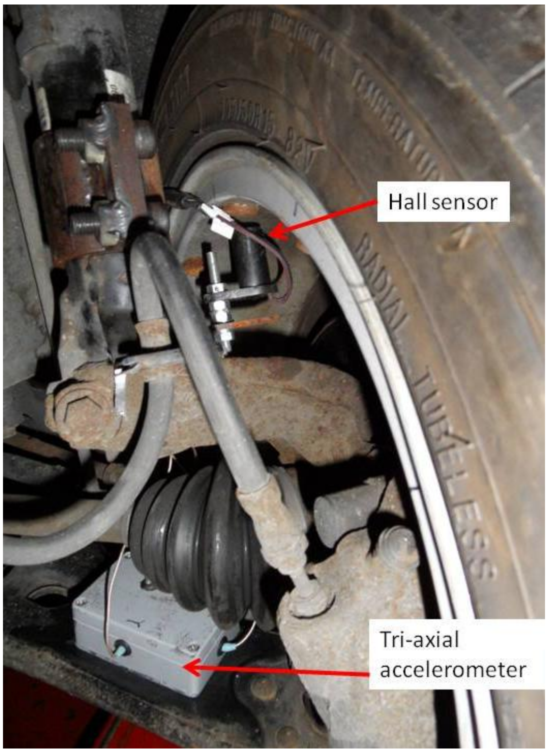


Figure 2a: Accelerometer and hall sensor mounted on car suspension

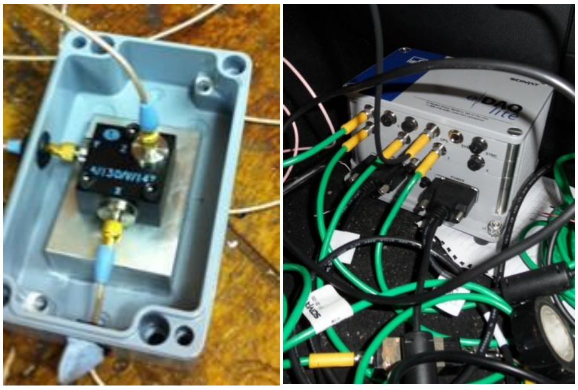


Figure 2b: DJB A/130/V triaxial accelerometer in housing;
Figure 2c: eDAQ-lite measurment and data logging system

A SoMat eDAQlite microprocessor-based data acquisition system, (see figure 2c), was used to record the sensor outputs. GPS data for the journeys was also logged. This measured data from the road journeys is being analysed and will be made available to other researchers through the Energy Harvesting Network Data Repository, where other automotive vibration data is also available.

For more information, please contact Dr Carl Anthony at c.j.anthony@bham.ac.uk

Low cost impedance based battery management systems

Nigel Brandon, Paul Mitcheson, Vladimir Yufit, Greg Offer, Imperial College London Dave Howey, Oxford University

In any electric or hybrid vehicle the battery is typically one of the most expensive components and therefore maintaining its longevity is extremely important. One important way to do this is to ensure proper monitoring and management of the cells.

Generally, battery management systems (BMS) are not equipped with diagnostic tools that provide information about electrochemical processes occurring in the cells. Mostly, they monitor cell voltages and temperatures, and they commonly estimate the state of charge (SOC) using two complementary methods: (a) the initial SOC is estimated by measuring cell open circuit voltage (OCV) when the battery is relaxed and then consulting a look up table relating SOC to OCV, (b) when the battery is charging or discharging ‘coulomb counting’ gives a real time update of SOC by direct current measurement and integration over time to give the increase or decrease in charge. This is a form of ‘dead reckoning’. For some types of vehicle and battery chemistry this approach is adequate. However, determination of the initial SOC takes time, accurate coulomb counting is not always possible, and integration drift occurs with time. Furthermore, for Li-ion batteries with phosphate cathodes, especially nanostructured ones such as those produced by A123 Systems, the variation of SOC with OCV is very small over much of the operation as shown in Figure 1, particularly between 70% and 40% SOC.

There is therefore a need for improved BMS’s which include accurate calibration of the SOC measurement, which also measures degradation processes to ascertain state of health (SOH). Such systems must also add as little additional cost and weight as possible.

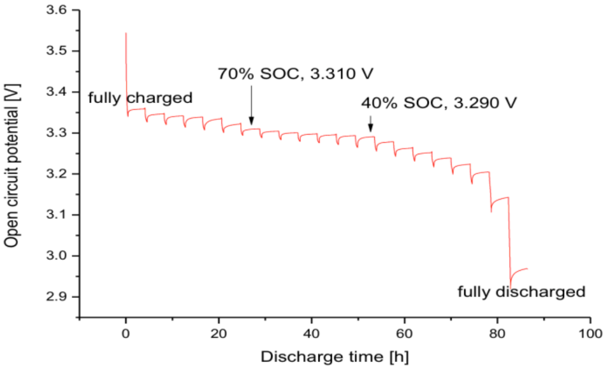
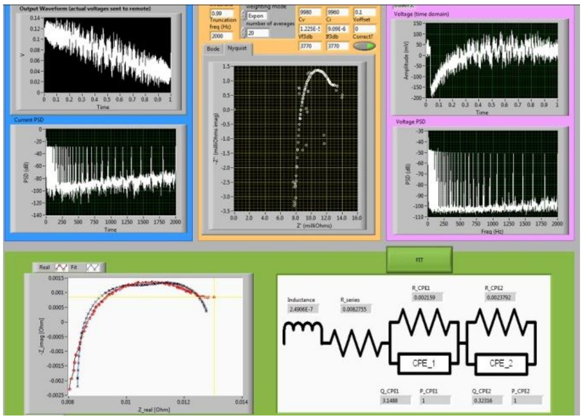


Figure 1: OCV versus discharge for a commercially available A123 System Li-ion cell, measured in our laboratory

Through a recently completed UK research council funded project (EPSRC EP/H05037X/1, feasibility study, September 2010 - February 2012), a low-cost method for the measurement of the electrical impedance of batteries over a range of relevant frequencies has been developed and patented. So called Electrochemical Impedance Spectroscopy, or EIS, is a general laboratory technique for the non-invasive investigation of electrochemical cells. However it typically requires very expensive, large, high precision scientific laboratory equipment. A signal generator draws a small sinusoidal AC current from a cell or applies a small AC voltage across a cell at various frequencies. By measuring the frequency response of the cell impedance using a frequency response analyzer, information relating to the SOC and SOH can be calculated. For example one indicator of irreversible consumption of lithium through changes to the solid-electrolyte interphase (SEI) is that the cell resistance increases with time. This is one of many parameters that can be accurately measured using EIS.

In pure electric vehicles, the battery pack capacity is relatively large and therefore there is usually no significant power limitation even under relatively high currents. In this situation the EIS SOC method may be used to periodically recalibrate the BMS over time when the batteries are relaxed (e.g. at the start of the day before driving), and for SOH estimation. However in hybrid vehicles, with a smaller energy capacity, specific power levels may be much higher resulting in a smaller number of cells being worked very hard – experiencing high current densities. This can result in battery SOC changing much more quickly and therefore the EIS method for determining SOC and SOH becomes crucial in this situation. This is because the internal state within the cells in a hybrid vehicle may be very uneven, and the EIS method gives vital information about various processes occurring inside the cell that may be related to whole battery pack performance.

The approach we are developing uses existing vehicle powertrain electronics coupled with proprietary signal and data processing to extract EIS data from Li-ion cells. The approach is also suited to other battery chemistries. A Complex-Nonlinear-Least Square (CNLS) algorithm is then used to establish, in real time, the measured parameters of a small signal equivalent circuit model appropriate to the battery chemistry, comprising a number of capacitors, inductors, resistors, constant phase elements and diffusion components. It has been found that the SOC can be characterized by a unique EIS response, which is also a function of temperature and cycle life. Figure 2 illustrates a typical output from our automated measurement procedure.



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R_CPE1 0.002159
R_CPE2 0.0023792
Q_CPE1 3.1488
P_CPE1 1
Q_CPE2 0.32316
P_CPE2 1

Figure 2: Screen shot of a typical output from our real time low cost EIS measurement and fitting procedure.

Figure 3 compares outputs obtained on the same battery from a high integrity laboratory scale frequency response analyser, and from our low cost approach, showing that our new system provides data equivalent to that obtained using the expensive and bulky laboratory instrumentation at all other than very low frequencies.

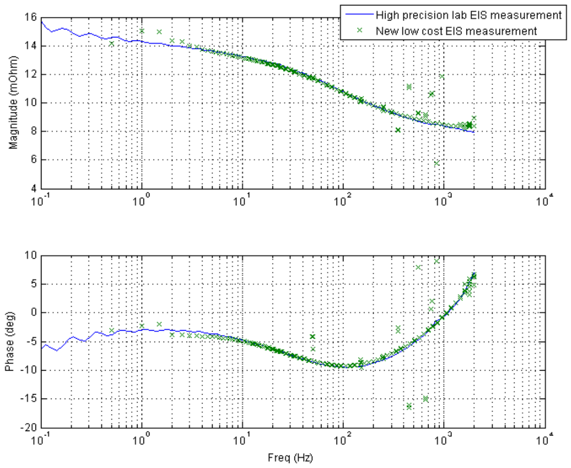

Figure 3: comparison of the outputs of our new low cost EIS measurement with data obtained on the same battery using a high precision laboratory scale frequency response analyser.

We are now seeking to work with partners to continue to develop this approach and apply it on board electric and hybrid vehicles. For more information please contact Prof. Nigel Brandon (n.brandon@imperial.ac.uk; 020 7594 5704), Dr. Paul Mitcheson (paul.mitcheson@imperial.ac.uk ; 020 7594 6284), or Dr. David Howey (david.howey@eng.ox.ac.uk; 01865 273004). References are available on request.

Motor controllers for electric vehicle applications explained

By Dave Lamb, Global Applications Engineering Manger, Sevcon Ltd.

The role of the motor controller in EVs

The motor controller is an electronics package operating between the battery and the motor that essentially acts as the 'brains' of a vehicle. Its main role is to convert power from the battery (DC) into an AC or DC motor and to provide intelligence as to how and when to deliver power to the motor. This enables it to control the speed, torque, direction of rotation or position of the motor, helping to control the movement of an electric vehicle.

Depending on the configuration, the controller either controls the motor on its own or acts as a 'slave' and follow demands given by the Vehicle Control Unit (VCU).

Another function is to recover kinetic energy from the motor and send it back to the battery, recharging the battery as the vehicle slows down. Known as 'regenerative braking', this helps to increase the range of electric vehicles.

Motor controllers are also integrated with other onboard systems such as electric steering, battery displays and chargers. Typically, one motor controller is needed per AC motor.

In most modern electric vehicles, the controller essentially transforms – or inverts – DC supply voltage from the battery into AC (typically three phase) which is used to drive the motor. Some electric vehicles still use a DC motor – although numbers continue to decrease.

The vast majority of today's controllers are AC controllers – controlling either AC induction (asynchronous) motors or PMAC motors (permanent magnet synchronous). AC motors are the norm due to their high efficiency, improved performance and lower maintenance.

AC controllers vary the speed, acceleration and torque of the motor by modulating the frequency and voltage of the AC supply fed in to the motor. The controller decides what frequency – or voltage – to provide the required torque or speed.

Developments in motor technology and motor controllers

Developments in motor technology have had a huge impact on motor controllers – and vice versa. Over time the use of AC induction motors became more widespread and usage of traditional DC motors has dropped. This has occurred as motor controller technology has become more competitive and allowed greater use of induction motors on vehicles.

DC motors are simpler (relatively speaking) to control because they can operate off the battery current without the need for a complex electronics package and software. DC is single phase and AC usually three phase which makes the electronics needed more complicated. More feedback is typically required from an AC motor than a DC one, making real time tracking of the actual motor operation more complicated.

The introduction of AC motors has driven the need for more processing power in controllers. AC induction (asynchronous) motors now account for around 70% of the world's motors – although the quantity of AC motors used on electric vehicles is tiny compared to the total of AC motors used in power generation, air conditioning and pumps. Controllers have also become increasingly lightweight, high powered and smaller; but that has come from more general improvements in design and components.

The use of PMAC motors (used in a vehicle like the Nissan Leaf) has increased markedly in the last ten years. In a vehicle environment, PMAC motors are typically smaller and more efficient than an equivalent power AC induction motor.
Unfortunately, the use and cost of these 'rare earth' materials for magents will be affected by economics and politics. The demand for rare earths used in magnets is forecasted to grow at 8-11% per year between 2011 and 14, driven largely by the growth in hybrid and electric vehicles and wind turbines. This will occur in the context of an increasingly restricted supply, exacerbated by China's draft ban on the export of rare earths from 2015 (although there is talk of other mines outside China coming on stream over the next decade). Such a scenario could affect the popularity of PMAC motors.

Work is being carried out to find other motor technology, suitable for traction, which does not rely on rare earth materials. Switched reluctance offers some benefits (compared to AC induction) although presents many new challenges.

Technical advances in motor controllers

The widespread adoption of AC motors has been driven by advances in microprocessor-based motor controllers, like Sevcon's Gen4 series, which are increasingly powerful, intelligent and lightweight. Such improvements have been achieved as a result of:

- Advances in power electronics which has resulted in more powerful motor controllers with lower losses, lower costs and high reliability

- State-of-the art microprocessor controls, delivering better torque accuracy and higher efficiency.

These characteristics are essential given the increased performance demands of today's AC motors.

An additional advantage is the level of miniaturisation that has been achieved through the use of lightweight materials – a major benefit in on-road EVs where space is at a premium. Silicon technology improves year-on-year, creating smaller, more efficient devices. Promising developments in solid state materials such as silicon carbide or gallium arsenide could lead to further miniaturisation. This space and weight saving is vital in the on-road EV market.

Motor controls of the future

In future, we are also likely to see greater integration between motors and controllers. Rather than having separate motors and controllers, it is likely they will be combined - perhaps with auxiliaries such as DC/DC converters too. The overall benefits of this are a system that is more compact with simpler electrical wiring and ultimately better on-road performance.

Improvements in this area will make installation easier, as there will be fewer connections and the performance of the motor and controller will already be optimised 'out of the box'. For high voltage systems, high level integration means less interconnect cables running around the vehicle, minimising high voltage areas on a vehicle making a safer overall system.

This would reduce the reliance on rare earth metals used in current EV motors. Sevcon recently started work on a joint research project that would see rare earth metals in motors replaced by steel – which would be controlled by a new cutting edge control system. This is a collaborative project involving Cummins Generator Technologies of Lincolnshire and Newcastle University's Power Electronics and Drives Research Group that has received funding from the Technology Strategy Board (TSB) and the Department for Business Innovation and Skills (BIS).

On road EVs: challenges and opportunities

Once restricted largely to the industrial sector, the number of on-road EVs continues to grow as technology improves and a new generation of vehicles like the Nissan LEAF and Renault Twizy are launched.

Looking ahead, the there will be significant growth demand for on-road cars such as the new Mia city car. A key reason for this is that they need a smaller battery which keeps the price down. It's possible that new car classifications will emerge as people use EV vehicles differently to engine driven cars.

Europe and Asia will be key markets. The US is also important although there are additional challenges to overcome there such as longer driving distances faced outside cities.

The growth in on-road EVs is creating new challenges for drivetrain and component makers from new regulations and safety demands to power requirements and integration needs.

Industrial traction applications traditionally use lead acid batteries for power which are relatively simple to operate although far less efficient. On-road vehicles typically use lithium-ion batteries which are smaller, lighter and have a higher energy density.

Compared to lead acid batteries, lithium-ion batteries are more expensive and need a battery management system to maximise life, reliability and safety. Whilst not essential, the battery management system is often fully integrated with our motor control system something we can do via the CAN-bus (Controller area network) system software in our controllers.

Power and safety is also a big issue. If you need more power in electric vehicles it's a straight choice between more voltage and current. On-road EVs typically go for voltage as opposed to current to keep the weight down (extra current requires extra cables) and also because higher voltage can mean less losses and greater efficiency. Most EVs operate between 48V and 400V but above 60V additional safety measures are required to meet regulations and protect vehicle users. This includes chassis leakage detection to prevent high voltage leakage and making sure all supply terminals are insulated.

The two biggest restrictions on the growth of on-road EVs are battery technology and cost and the lack of a rapid charging infrastructure. To increase the range of EV vehicles, you need bigger batteries and the weight and cost of these is still prohibitive – which is why the range of EV vehicles is limited by the size of batteries at the moment.

However, even if battery technology improves overnight, we still need a far more developed infrastructure. If an EV was capable of a range of 400 miles, it would take the best part of a weekend to charge it up at home or at a charging point.

In the short-term, one of the biggest drivers of the on-road EV market is likely to be price legislation and Government action to reduce the use of combustion engines. Take up could be increased by Government's providing financial incentives to motorists or ploughing money into the charging infrastructure.

For more information, please visit:
www.sevcon.com