REF3b: Impact Case Study 2- UoA12

Title of case study: New Technologies for Electric Vehicles

1. Summary of the impact

Fundamental work on transmission and power management systems for electric vehicles has resulted in local and national impact with emerging international reach. Computer simulation and rig-based prototype modelling has shown that it is possible to improve overall energy consumption levels by around 5 to 12 % by using a variable ratio gearbox within an electric vehicle. A local company, AVID Vehicles Ltd have demonstrated the potential of this work in the conversion of a Nissan Note supplied by Nissan Motors UK Ltd into an electric powered car. This, and related, work on hybrid vehicles has gained international recognition and has been used as the basis for further developments, including regional impact with Sunderland Council, and influencing regional strategy.

2. Underpinning research

This research is in the area of simulation for transmission design, powertrain systems (Mashadi and Crolla, 2012) and power management for electric vehicles (Hu et al, 2010).

Most research into transmission systems for electric vehicles is based on investigating the effects of coupling gearboxes to an electric motor in order to optimise the motor's operation into the most efficient configuration for speed and load (Crolla et al, 2008). This research set out to dramatically increase efficiency and range (Elmarakbi et al, 2013). Early experimental work undertaken by the team used computer simulation and a laboratory rig (Ren at al, 2010); this work has shown that by using a CAN controller and software it is possible to use a multi speed gearbox to dramatically increase efficiency and so range. In particular the work developed an electric vehicle model and predicted its energy consumption with a variable and fixed ratio gearbox over a standard driving cycle in order to understand whether this could offer significant efficiency gains. The conclusion of this research was that it is possible to improve overall energy consumption levels with a variable ratio gearbox depending on the driving cycle used.

Ren's PhD work (2007 – 2010) included the analysis and modelling a twin epicyclic gearbox; the analysis and modelling of the twin epicyclic system in a vehicle and a comparison of the results with a single epicyclic system; and the analysis and modelling of electric vehicles with and without a transmission system of varying levels of complexity and showed that there are worthwhile performance benefits from using improved transmission designs for low carbon vehicles. Simulation results of two electric vehicle examples confirm that energy consumption benefits are indeed achievable; of between 7 and 14% depending on the driving cycle.

The approach was extended to model (using a computer and a full scale prototype rig) the application of an electric motor to the existing transmission of an electric vehicle. This model was then used to study the possible efficiencies in each gear. From this work a prototype for a novel gearbox control system was produced. The approach (Ren et al, 2010) has created a radically altered perception of how gearboxes should be used within electric vehicles and is very different from the approach being pursued by other researchers and manufacturers. Initial modelling of a traction motor coupled to the 4 speed 'automatic manual' transmission has shown significant benefits can be achieved leading to a reduction in the traction motor size of up to 25% in some configurations, a reduction in the battery pack size and weight of up to 10% and a reduction of the systems operating voltage to 100v which reduces the cost of the battery management system / control electronics.

The related EcO2Trans project was a collaborative project with Shanghai's Shen Li High Technology and Avid vehicles which used simulation to design a power management system for fuel cell and battery powered buses (Hu et al, 2010). One North East has invested £314,000 to sponsor the ECO2Trans project, which is converting two electric Gulliver

U500EUK buses into hydrogen vehicles using a fuel cell, battery and capacitor combination. The University of Sunderland's Institute of Automotive and Manufacturing Advanced Practice (AMAP) has joined forces with experts from Shanghai's Shen Li High Technology and Cramlington-based AVID Vehicles to carry out the work. Alongside this the team have been exploring the use of hydrogen as an alternative fuel source for vehicles, in collaboration with Nissan and with Sunderland City Council.

Staff involved in the research: Adrian Morris (Head of AMAP, Institute for Automotive and Manufacturing Advanced Practice, 1994 - present), Dr. Qinglian Ren (PhD student, 2007 – 2010, graduated and now employed at Changan UK), Prof. Dave Crolla (Visiting Professor at University of Sunderland; 2004 until he sadly passed away in 2011); Professor Ahmed Elmarakbi (Professor, 2007 - present), Dr David Baglee (Senior Lecturer, 2000 – present), Dr Mike Knowles (Senior Lecturer, 2007 – present), Dirk Kok (Research Assistant, 2003 – present).

3. References to the research

1. Elmarakbi, A., Ren, Q., Trimble, R. and Elkady, M. (2013) "Performance Analysis of Hybrid and Full Electrical Vehicles Equipped with Continuously Variable Transmissions" *Advances in Automobile Engineering*, 2 (1), 1-8, Paper No. 1000103. *This paper presents the results of the research on the use of variable transmissions within an electric vehicle, the impact that this can have on range, and power consumption, and the reduction of carbon emissions.*

2. Knowles, M., Baglee, D., Morris, A. and Ren, Q. (2012) "The State of the Art in Fuel Cell Condition Monitoring and Maintenance" *World Electric Vehicle Journal, 4, 487-494*. *This paper reviews the state of the art of fuel cells as a power source.*

3. Mashadi, B. and Crolla, D. (2012) "Vehicle Powertrain Systems" Wiley, ISBN: 978-0-470-66602-9. *This research text presents a series of chapters which represent the state of the art in powertrain system design and manufacture.*

4. Hu, Z., Ren, Q., Crolla, D., Morris, A., Kok, D. and Hu, M. (2010) "Design and Implementation of Power Management System for Fuel Cell and Battery Powered Buses" *The 25th World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium EVS-25, Shenzhen, China, Nov. 5-9, 2010*. *This paper presents the results of work on the use of alternative power sources for electric vehicles.*

5. Ren, Q., Crolla, D. A., & Morris, A. (2010) "The effect of Transmission Design on Electric Vehicle (EV) Performance" *Journal of Energy and Power Engineering, 4(3), 46-51*. *This paper presents the work developed during Ren's PhD.*

6. Crolla, D. A., Ren, Q., ElDemerdash, S. and Yu, F. (2008) "Controller design for hybrid vehicles—state of the art review" *Vehicle Power and Propulsion Conference, 2008. VPPC'08. IEEE* (pp. 1-6). IEEE. *This paper reviews the state of the art on controller design within hybrid electric vehicles.*

The ECO2Trans project was supported by £314,000 funding from One North East.

Papers 1, 2 and 5 are representative of the quality of the work of the group, and cover work on transmission design and alternative power sources.

4. Details of the impact

This research has enabled a demonstration vehicle to be built which verifies the theoretical model with actual test data, and has established the cost/benefit ratios which can be gained.

Batteries are very heavy and expensive, so the smaller the battery packs the better. The impact comes from the manufacture of CAN control systems that maximise the efficiency of an electric vehicle Driveline considering electric motor and battery pack characteristics. The research aimed to model, and develop, a novel ultra-high efficient gearbox control system for electric vehicles. The project has been developed by the University of Sunderland and Avid vehicles at Cramlington, UK. The research has produced technology with a market lead, which achieves additional efficiency and range that cannot be matched by competitors. The resultant product will be manufactured in the North East by Avid, their partners and sub-contractors. The estimated timeframe for introduction to the market is early to mid-2014 (Evidence 1).

The University was invited by the North East Local Enterprise Partnership (NELEP) (in 2012/13) to produce a report to inform the Lord Andrew Adonis-led Independent Economic Review: "Analysis of Barriers to Growth in Key Manufacturing Sectors in the North East Region". The University was approached because of its research expertise as outlined above. This report (Evidence 2) "made a significant impact on the Independent Economic Review process". It was presented to a conference of senior representatives including the Adonis Review Team, Leaders of local authorities and business leaders. The report was then used by the review team to inform their recommendations to grow the North East's economy. The piece of work produced by Sunderland (in early 2013, Evidence 2) "will be critical in informing strategy going forward. This will be reflected in the European Investment Plan that NELEP is preparing, and also in the Local Growth Plan that each Local Enterprise Partnership has been asked to produce by Central Government".

In 2012 the University, in conjunction with The Energy and Environmental Industries Forum (EEIF), held a conference: "Low Carbon Vehicles And Their Role in the Low Carbon Economy" (Evidence 3) which presented the "pioneering technology being developed in the region".

A programme is underway (2012) to investigate the use of a range of conventional and low carbon vehicles in the fleets of the University of Sunderland and Sunderland City Council including hybrid buses and electric cars (Evidence 4). Cost effective strategies for carbon reduction are being developed with low-Cost tracking units being used to record the operations of a number of vehicles. Software developed by the university will analyse the use of the vehicles and determine best options for carbon minimisation by identifying options for new charging locations, different power trains and improved scheduling. The outcome of the project will be a strategy for reducing carbon emissions along with a set of tools to allow on-going improvement in changing circumstances. The University has played a major role in the development of the Sunderland Strategy on Low Carbon Vehicles, which has concluded that "the use of low-carbon vehicles would positively impact the city environmentally, financially and economically" and that "the council should consider implementing targets to adopt electric cars into its fleet" (Evidence 4).

Work on hydrogen cells, in the ECO2Trans project (2009 – 2011) was evaluated in two hydrogen buses which were tested on the streets of Sunderland. Work with Nissan adapted a Nissan Almera (2008) to run from hydrogen fuel cells. This research has resulted in a start-up company (in 2011) which is developing a system to extend how far electric vehicles can travel, making them more commercially viable. North East firm Inova Power Ltd http://www.inova-power.com/ has teamed up with the University of Sunderland to commercialise the breakthrough, which extracts hydrogen from water to power vehicles (Evidence 5).

Professor Dave Crolla was part of a team of British engineers working on the Bloodhound Supersonic Car (SSC) project (Evidence 6), which was described as a "great British engineering adventure" by the Government. The team was designing a car powered by a Eurofighter Typhoon jet engine and hybrid rocket that will be capable of about 1,050 mph –

twice the speed of a bullet fired from a handgun. It is expected the car will be able to accelerate from 0 to 1,050mph in only 40 seconds.

5. Sources to corroborate the impact

1. Contact details of CEO of Avid Vehicles will be given for corroboration purposes.

2. Statement from Economic Strategy Manager, North East Local Enterprise Partnership, available on request. The report can be found at:
   http://www.nelep.co.uk/media/2142/sunderland-university-submission-key-manufacturing-sectors-for-the-north-east-economic-review.pdf
   The report examines the current state of play in the automotive and low carbon sectors in the North East.

3. Low Carbon conference held at University of Sunderland (2012): https://bdaily.co.uk/environment/20-02-2012/sunderland-gears-up-for-low-carbon-conference/
   This conference evidences the key role that the Sunderland team have within the regional local carbon strategy, and the importance of the research developments of the team.

4. Work with Sunderland City Council on low carbon vehicles within the city (2012).
   This press coverage presents a University of Sunderland / Sunderland City Council programme to investigate the use of a range of low carbon vehicles within the city.
   http://cenex-lcv.co.uk/assets/downloads/posters/sunderland-university-sunderland-city-council.pdf
   The Sunderland Strategy on Low Carbon Vehicles can be found here:
   http://www.sunderland.gov.uk/CHttpHandler.ashx?id=12663&p=0

5. The use of Hydrogen fuel cells as alternative power source
   This press coverage demonstrates the work of the ECO2Trans Project which is exploring the use of hydrogen fuel cells within buses in collaboration with Shen Li High Technology, China (2009):
   http://www.thegreencarwebsite.co.uk/blog/index.php/2009/11/11/hydrogen-fuel-cell-buses-hit-the-road-in-sunderland/
   This press coverage demonstrates work with Nissan on hyrdrogen as a power source (2008):
   http://www.alternative-energy-news.info/university-helps-nissan-green-future/
   This press articles provide evidence of the Sunderland team's work on alternative power sources, particularly the use of hydrogen fuel cells.
   The work has resulted in the establishment of a company to commercialise the research (2011):
   http://www.inova-power.com/
   http://www.thejournal.co.uk/business/business-news/inova-power-hoping-create-hundreds-4439431

6. Press coverage demonstrating Prof Crolla's impact on the Bloodhound project (2008):
   http://www.bloodhoundssc.com/project/car/aerodynamics/vehicle-dynamics
   http://www.thenorthernecho.co.uk/news/3847249.University_joins_land_speed_record_attempt/