Institution: The University of Huddersfield

Unit of Assessment: 15 General Engineering

Title of case study: Collaborative Strategic Partnership with BorgWarner Turbo Systems Ltd

1. Summary of the impact

University of Huddersfield research into engine technologies has resulted in a major new partnership with the UK arm of engineering multinational BorgWarner, leading to the company increasing R&D capabilities in the UK. This collaboration, funded partly by parent company BorgWarner US and partly by the government's Regional Growth Fund, involves multi-million-pound investment, as well as significant job creation and safeguarding. It was a key factor in the company securing a substantial contract with Jaguar Land Rover, whose decision was informed by the University's capacity to help BorgWarner further its R&D activities and upskill its workforce for the benefit of the UK automotive supply chain and the local and national economy.

2. Underpinning research

It has been estimated that 80% of automotive power-plants will be turbocharged by the end of the decade. One of the drivers of this trend is the downsizing of internal combustion engines to improve efficiency and reduce fuel consumption and CO_2 emissions. Since 2007, in tandem with an investment of more than £3.5m in equipment and facilities to underpin its automotive research, the University of Huddersfield has carried out a wide range of studies relevant to this highly significant shift.

In 2007 Professor Andrew Ball (Professor of Diagnostic Engineering, 2007-present) and Dr Fengshou Gu (Senior Research Fellow, 2007-present) joined Huddersfield from the University of Manchester, having worked in diagnostic engineering for many years. Their research expertise complemented that of established staff, including Professor Rakesh Mishra (Senior Lecturer, 2004-2009; Reader, 2009-2011; Professor of Engineering, 2011-present). The skillset for studies into the R&D challenges facing the turbocharger industry was further enhanced by the incorporation in 2011 of expertise in neutron scattering and imaging for the development of novel materials for engine systems. As a result, the University was able to carry out research in areas such as efficiency, emissions, operating temperatures, exhaust gas recirculation, boost pressures, coolants, fuel types, advanced materials and component reliability and wear.

In late 2007 and early 2008 Gu and Ball conducted studies into early fault detection and diagnosis for medium-speed Diesel engines. This work was led by Ball and carried out in collaboration with the University of Manchester. It demonstrated for the first time how subtle variations and anomalies in key combustion performance parameters (e.g. position of peak pressure and heat release rate) could be determined in real time and on a cylinder-by-cylinder basis from the instantaneous angular speed fluctuations of the crank shaft when operating across the breadth of its design envelope. [1]

Between 2008 and 2010, partly in collaboration with Manchester Metropolitan University and the University of Hertfordshire, research into acoustic monitoring was carried out under the direction of Ball. This led to significant advances in the application of real-time airborne acoustic monitoring to the fuel-injection systems of Diesel engines. The first strand of research pioneered the concept of fuel-injection timing estimation from airborne acoustic data and suggested how the use of adaptive filtering techniques could enable this [2], while the second demonstrated how such a capability could be extended and refined through the use of independent component analysis to quantify key injection parameters (e.g. moment of first needle retraction movement, moment of first fully open position, moment of first return to seat) to a high degree of accuracy [4].

Another area of research, conducted at Huddersfield from 2007 to 2009, focused on the issue of wear. Studies by Gu and Ball provided a theoretical basis for the correlation of sliding friction and surface-borne acoustic emissions, based on the elastic asperity contact of materials. The model that was developed model a means of estimating asperity load contact from monitored acoustic

emissions, so enabling assessment of the effectiveness of lubrication in extreme engineering environments such as turbocharger bearings and rotor seals [3].

Research into biofuels was carried out in 2009 and 2010, led jointly by Ball and Mishra and undertaken with Gu, Dr Nicolas Powles (Senior Research Fellow, 2006-present) and Dr Belachew Tesfa (PhD student, 2008-2011; Research Associate, 2011-present). This work explored the implications of various biodiesel formulations, along with the possibility of supplementary water injection, on the fuel-injection characteristics, combustion efficiency and emissions behaviour of a Diesel engine. These studies provided novel insights into how biofuels might best be formulated, blended and used in turbocharged compression ignition engines [5, 6].

3. References to the research *Note: all of the following outputs feature in REF2.*

1. P. Charles, J.K. Sinha, F. Gu, L. Lidstone and A.D. Ball, 'Detecting the crankshaft torsional vibration of diesel engines for combustion related diagnosis', J. of Sound and Vibration 321 (2009), 1171-1185. http://eprints.hud.ac.uk/4262/ *Citations 34. Estimated contributions: Univ. of Manchester 40%, Univ. of Huddersfield 60%.*

2. A. Albarbar, F. Gu, A.D. Ball and A.Starr, 'Acoustic monitoring of engine fuel injection based on adaptive filtering techniques', Applied Acoustics 71 (2010), 1132-1141. http://eprints.hud.ac.uk/8244/ *Citations 13. Estimated contributions: Manchester Metropolitan Univ. 20%, Univ. of Hertfordshire 10%, Univ. of Huddersfield 70%.*

3. Y. Fan, F. Gu and A.D. Ball, 'Modelling acoustic emissions generated by sliding friction', Wear 288 (2010), 811-815. http://eprints.hud.ac.uk/8397/ *Citations 14. 100% Univ. of Huddersfield.*

4. A. Albarbar, F. Gu and A.D. Ball, 'Diesel engine fuel injection monitoring using acoustic measurements and independent component analysis', Measurement 43 (2010), 1376-1386. http://eprints.hud.ac.uk/8384/ *Citations 29. Estimated contributions: Manchester Metropolitan Univ. 30%, Univ. of Huddersfield 70%.*

5. B. Tesfa, R. Mishra, F. Gu and N. Powles, 'Prediction models for density and viscosity of biodiesel and their effects on the fuel supply system in CI engines', Renewable Energy 35 (2010), 2752-2760. http://eprints.hud.ac.uk/7659/ *Citations 26. 100% Univ. of Huddersfield.*

6. B. Tesfa, R. Mishra, F. Gu and A.D. Ball, 'Water injection effects on the performance and emission characteristics of a CI engine operating with biodiesel', Renewable Energy 37 (2012), 333-344. http://eprints.hud.ac.uk/9678/ *Citations 9. 100% Univ. of Huddersfield.*

PI	Title	Funder	Dates	Value
Prof. A.D.Ball	KTP #6507 John Crane - Monitoring of Mechanical Seals	TSB	2007 - 2009	86,600
Prof. A.D.Ball	Rolls-Royce - Remote Engine Health Monitoring Demonstrator	Industry	2007 - 2009	67,431
Prof. A.D.Ball	Rolls-Royce - Remote Engine Health Monitoring Demonstrator	Industry	2008 - 2010	149,016
Prof. A.D.Ball	David Brown Gears - Regional Growth Fund 1 - Gear Condition Monitoring	RGF 1	2011 - 2014	46,203
Prof. A.D.Ball	TSB Smart Fasteners - Intelligent Sensor Development	TSB	2012 - 2013	31,594
Dr F.Gu	Network Rail - Smart Washer - Phase 1	Industry	2010 - 2012	59,986
Dr J.Fieldhouse	Bentley Motors - Noise Analysis	Industry	2009 - 2011	21,700
Prof. S.Kilcoyne	KTP #8659 BorgWarner - Novel Materials for Turbochargers	TSB	2011 - 2014	93,160
Prof. A.D.Ball*	BorgWarner - Regional Growth Fund 3 Centre of Excellence for	RGF 3	2012 - 2018	7,600,000

	Turbocharger R&D			

*Grant awarded to BorgWarner in line with RGF rules. £2.3M from DBIS and remainder from BW (US). £4.75M allocated to research projects with UoH with Ball as PI.

4. Details of the impact

A recent Automotive Council report stressed the need to link research carried out by UK universities to Tier 1 suppliers in the automotive industry. It also highlighted a shortage of highly skilled engineers with knowledge and expertise in boosting systems. University of Huddersfield research has helped address such concerns by providing the basis for a major R&D and training collaboration with the UK arm of a multinational engineering company.

In 2011 BorgWarner Turbo Systems sought a university partner able to deliver both collaborative R&D capability and bespoke postgraduate training. Representatives met with a number of HEIs to ascertain the research capabilities that could underpin the company's development of next-generation systems. The process included a series of meetings with Huddersfield, which had an existing relationship with BorgWarner through a Knowledge Transfer Partnership, to discuss the company's proprietary R&D requirements. The breadth of Huddersfield's research in automotive engineering, as exemplified by the work of Ball, Gu, Mishra et al, proved pivotal to BorgWarner's decision, and a strategic partnership was officially established in 2012.

The agreement led to the securing of millions of pounds in regional funding. During the negotiation process the Department for Business, Innovation and Skills (DBIS) announced a call for Regional Growth Fund (RGF) applications, presenting an opportunity to drive inward investment from the company's parent firm, BorgWarner US – which has an annual turnover of around $7bn – to expand turbocharger R&D capability within the UK. Huddersfield partnered BorgWarner in an application that committed to the establishment of new R&D facilities alongside the company's existing factory in Bradford, the development of bespoke training for the next generation of turbocharger engineers and, most importantly, job creation and inward investment [a]. The five-year project is valued at £7.6m, with £2.3m from DBIS and the majority from BorgWarner US. The success of the bid was first confirmed in October 2012, with full details announced in May 2013.

The partnership with Huddersfield, in tandem with the successful securing of RGF funding, was also a key factor in a decision by Jaguar Land Rover (JLR) to award a major contract to BorgWarner Turbo Systems. This brought further investment to the region and was also fundamental to JLR's commitment to strengthening the UK economy as a whole. JLS senior management saw the R&D capabilities and next-generation training made possible by BorgWarner's strategic alliance with the University as in keeping with the company's efforts to enhance and develop the automotive supply chain in the UK. Announcing the deal in May 2013, JLR's Purchasing Director described the eight-year, multi-million-pound agreement to supply technology for the company's new family of four-cylinder engines as "a great example of how we want to work in partnership with our supply chain to develop innovative solutions to support future growth... [and] help the UK become even more competitive in its investment in innovation that will make the difference to the growth in the UK economy" [b, c]. The President and General Manager of BorgWarner Turbo Systems said the deal would "help to support the local economy with highly skilled engineering and manufacturing jobs" [b, c, d, e, f]

These significant industry investments in and commitments to the region have helped raise awareness of its nascent role as a key location in the automotive supply chain. In ... 2013 representatives of the Leeds City Region Local Enterprise Partnership and the UK Trade and Investment Automotive Investment Organisation, including the former Chairman of Ford UK, visited the University to discuss its research. UKTI is working closely with the Automotive Council to strengthen the sector's supply chain and attract further inward investment to the UK. The Advanced Propulsion Centre, the UK's £1bn new automotive research centre, which is co-funded by the government and industry, was among the issues discussed. Leeds City Region LEP

requested a case study on the University-BorgWarner partnership to highlight the growing strategic importance of the automotive sector in the region [g,h].

5. Sources to corroborate the impact

a. Regional Growth Fund 3 application (copy available on request)

b. BorgWarner press release, May 5 2013
http://www.borgwarner.com/en/News/PressReleases/BWNews/2013%2005%2015%20BorgWarner%20Expands%20Cooperation%20with%20Jaguar%20Land%20Rover.pdf

c. 'US firm's expansion will help to engineer 130 jobs in Yorkshire', *Yorkshire Post*, May 25 2013
http://www.yorkshirepost.co.uk/business/business-news/us-firm-s-expansion-will-help-to-engineer-130-jobs-in-yorkshire-1-5714888

d. Chief Engineer, BorgWarner Turbo and Emissions Systems Bradford

e. Testimonial from Senior Buyer, Turbo Charger and Supercharger Engines, Jaguar Land Rover

f. Testimonial from Director, BIS Yorkshire Humber and North East

g. Testimonial from Chairman, Leeds City Region Local Enterprise Partnership

h. Case study for the Automotive Investment Organisation and LCR LEP (copy available on request)