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| Institution: Brunel University London | | |
| Unit of Assessment: 12 Engineering | | |
| Title of case study: An Innovation Platform in Structural Integrity | | |
| Period when the underpinning research was undertaken: 2009-2020 | | |
| Details of staff conducting the underpinning research from the submitting unit: | | |
| Name(s): | Role(s) (e.g. job title): | Period(s) employed by submitting HEI: |
| Prof W Balachandran | Professor | 09/1995-present |
| Prof T Gan | Professor | 10/2009-present |
| Dr R Kirby | Senior Lecturer | 01/1999-02/2017 |
| Dr A Mohimi | Research assistant | 02/2011-05/2016 |
| Dr B Wang | Reader | 07/2011-present |
| Prof L Wrobel | Professor | 03/1996-12/2018 and 03/2019-present |
| Period when the claimed impact occurred: 2014-2020 | | |
| Is this case study continued from a case study submitted in 2014? N | | |

1. Summary of the impact (indicative maximum 100 words)

Brunel's research programme in structural integrity, in collaboration with The Welding Institute (TWI), has been developing new technologies for the non-destructive testing of oil & gas pipelines, plates, rails, aircraft wires and other infrastructure since 2003. In 2009 the launch of a joint venture, the Brunel Innovation Centre provided a platform to address the innovation challenges of TWI's 700+ industrial members. In 2012 the 2 organisations built a new facility, the National Structural Integrity Research Centre (NSIRC), to carry out medium- and long-term research and postgraduate training focused on the structural integrity of products, plants and infrastructure across the energy, transport, advanced manufacturing and infrastructure sectors.

Since 2014 impact from this programme includes training over 250 engineers in higher level research skills, most of whom are now working at TWI or one of their member companies, the implementation or improvement of more than 50 technologies and the completion of over 81 externally funded industrial projects. Staff at TWI and their member companies have had the opportunity of working with Brunel University staff on over 70 industrially focused research papers since 2014, helping them develop research and collaboration skills, a good understanding of rigorous research methodologies and broadening their technological knowledge. The work done within NSIRC has contributed to 24 ISO standards.

TWI's collaboration with Brunel has transformed its business model, allowing it to provide a much wider range of research and innovation services to its members, and consequently it has seen its turnover and membership numbers remain healthy despite a falling oil price over the period. In addition, Brunel has worked with a TWI subsidiary, Plant Integrity, to support the development of its Teletest technology, which drove up sales to over GBP5,000,000 per annum in 2016/17, and led to the sale of the technology to Eddyfi for GBP7,750,000 in 2017.

2. Underpinning research (indicative maximum 500 words)

Brunel University London started its collaboration with TWI in 2003, by placing students from Brunel's Engineering Doctorate in Environmental Technology at TWI to pursue research in ultrasonic guided waves for oil and gas pipeline inspection, plates, rails and aircraft wires. All the EngD students were awarded their degrees for research on the development and application of ultrasonic guided waves to non-destructive testing (NDT) which contributed to the development of

the early versions of the Teletest system. Brunel and TWI continued this collaboration by signing a bi-lateral agreement in 2009 to co-fund 5 new PhD students, all based at TWI, followed by another agreement in 2011 to co-fund a further 11 PhD students under TWI's Core Research Programme. The 16 PhD students worked on different areas of NDT and structural integrity research, such as broadband eddy current system for detection of corrosion under insulation, guided waves for coated/insulated structures, development of continuous real-time structural health monitoring, defect sizing in pipelines using higher-order guided ultrasonic waves, generating fundamental knowledge with commercialisation potential. All have been successful in their research and were awarded their PhD degrees.

Based on the success of their collaborations, in 2009 Brunel and TWI established a joint venture, the Brunel Innovation Centre (BIC), based at TWI headquarters in Cambridge, in order to further extend their research collaborations. BIC is a world-class research and technology centre that sits between the knowledge base and industry offering high quality research in an innovative environment focused on non-destructive testing, condition and structural health monitoring, power ultrasonics and allied technologies covering a range of materials, sensors, electronics and software systems and supporting partners in industry to transfer academic research into industrial application. BIC pursues initiatives that span national and international platforms including Innovate UK, EPSRC and EC. The Centre has been building a strong portfolio of projects in line with its multinational interdisciplinary vision. Its current staff comprises the Academic Director (Professor Tat-Hean Gan) and the Technical Director (Jamil Kanfoud) who are both jointly employed between Brunel and TWI. In addition, there are 7 research managers, 11 research fellows, 3 research assistants and 5 administrative and business development support staff who are wholly employed by Brunel. Other academic staff from across Brunel, as well as staff from TWI, are involved in the supervision of research projects within BIC. BIC has been awarded over 70 EU projects related to aspects and applications of NDT, and has helped more than 50 students to begin their careers with leading science and technology companies.

These activities have led to an exponential growth in the volume of collaborative research being carried out by Brunel and TWI; between 2000 and 2010 Brunel and TWI published 5 joint papers, then 18 between 2011 and 2015 and 56 between 2016 and 2020. These papers have received over 400 citations on the Web of Science. Within this portfolio, strands of research activity have included scattering of elastic waves in pipes (lead by Kirby), materials for high temperature transducers (Mohimi and Balachandran), advanced data processing for the inspection of powder metallurgy parts (Gan) and vibrational and acoustic emission

3. References to the research (indicative maximum of six references)

[Ref 1] **Kirby R**, Zlatev Z, Mudge P, On the scattering of torsional elastic waves from axisymmetric defects in coated pipes, *Journal of Sound and Vibration*, **331** (17): 3989-4004, 2012. <http://dx.doi.org/10.1016/j.jsv.2012.04.013>

[Ref 2] **Kirby R**, Zlatev Z, Mudge P, On the scattering of longitudinal elastic waves from axisymmetric defects in coated pipes, *Journal of Sound and Vibration*, **332** (20): 5040-5058, 2013. <http://dx.doi.org/10.1016/j.jsv.2013.04.039>

[Ref 3] **Mohimi A**, Richardson P, Catton P, **Gan T**, **Balachandran W**, Selcuk C, High temperature dielectric, elastic and piezoelectric coefficients of shear type Lithium Niobate crystals, *Key Engineering Materials*, **543**, 117-120, 2013. <http://dx.doi.org/10.4028/www.scientific.net/KEM.543.117> [Grant 2].

[Ref 4] Ponomarev M, Kappatos V, Selcuk C, **Gan T**, Amos M, Halai H, Gierl C, Ilovea M, Digital radiographic inspection technique for production friendly quality assessment of powder metallurgy parts, *Powder Metallurgy*, **56** (2): 92-95, 2013. <http://dx.doi.org/10.1179/0032589913Z.000000000103> [Grant 3].

Impact case study (REF3)

[Ref 5] Soua S, Van Lieshout P, Perera A, **Gan T-H**, Bridge B, Determination of the combined vibrational and acoustic emission signature of a wind turbine gearbox and generator shaft in service as a pre-requisite for effective condition monitoring, Renewable Energy, **51**, 175-181, 2013. <http://dx.doi.org/10.1016/j.renene.2012.07.004> [Grant 4].

[Ref 6] Romero A, Soua S, **Gan T-H**, **Wang B**, Condition monitoring of a wind turbine drive train based on its power dependant vibrations, Renewable Energy, **123**, 817-827, 2018. <http://dx.doi.org/10.1016/j.renene.2017.07.086> [Grant 4].

Relevant Grants

[Grant 1] UK Research Partnership Investment Fund (UKRPIF) Grant Research England/UKRI, National Structural Integrity Research Centre, GBP15,000,000 . [Details here on page 22](#).

[Grant 2] EU Joint Project HotScan (www.hotscan.eu)

[Grant 3] EU Joint Project AutoInspect (www.autoinspectproject.eu)

[Grant 4] EU Joint Project CMSWind (www.cmswind.eu)

4. Details of the impact (indicative maximum 750 words)

The initial success of the research programmes [Ref 1-6] demonstrated to Brunel and TWI that if they made a joint offer to TWI's industrial members through a managed and co-ordinated innovation platform then this would reduce the barriers to industrial participation in research and innovation projects.

This led to a substantial change in TWI's business strategy [E1], which manifested itself in the scaling up of BIC, the development of NSIRC and the launch of innovation centres with other universities in other technology areas. This allowed TWI to provide an enhanced research and innovation offer to its industrial members, helping retain existing members whilst recruiting new members. It also increased the industrial members participation in R&D projects, and meant that more members took part in those programmes more regularly. The training of PhD students within these programmes, and the scaling up of these student numbers allowed by NSIRC, brought a steady stream of technologists with higher level research skills into TWI, its member companies and into the industry [E1]. The progression of these technologists, who did Brunel PhDs in TWI's laboratories on industrially focussed projects, has helped ensure repeat business for TWI whilst improving the quality of research and innovation across a number of industrial sectors.

Scaling-up BIC

As a result of its growth since 2014 BIC has secured over GBP13,000,000 from 54 funded research projects, participated in over 100 research publications and employed over 35 staff. Most of BIC's projects have involved multi-national and multi-partner consortia with SMEs, academic institutions and end users [Grants 5]. The end-user beneficiaries of these projects include more than 50 large and small, UK and international industrial companies such as Airbus, Doosan Babcock, Network Rail, Jackweld Ltd, H.J. Heinz, Romax Technology, Transense, Intrinsic Materials, Lloyd's Register, and many others.

Creating the National Structural Integrity Research Centre

The experience of working together on this high volume of industrially inspired research programmes led Brunel and TWI to discuss the formation of a large-scale postgraduate campus at TWI headquarters in Granta Park, Cambridge, aligned to the identified needs of the UK industry for enhanced techniques, technology and staff qualified in the field of structural integrity of large

plants. This was realised through a successful application to the previously called HEFCE UKRPIF scheme for GBP15,000,000, alongside a linked application to the Regional Growth Fund for GBP45,000,000, to create a new world-class laboratory at Granta Park called the National Structural Integrity Research Centre (NSIRC). Opening in 2013/14, and operated jointly by Brunel and TWI, the laboratory runs novel postgraduate programmes (PhD and MSc) to train the next generation of researchers and engineers to support the UK science and innovation; accelerates the translation of science into commercially relevant products and services; contributes to the development of effective standards and regulations, and is the research provider of choice for industry in the area of structural integrity [E2]. Since 2014 over GBP26,300,000 [E3] in industrial co-investment (cash and in-kind) from TWI and Lloyd's Register Foundation has been invested in supporting NSIRC.

NSIRC now provides a place where TWI's industrial members can collaborate with over 35 universities worldwide, managed by Brunel University London, TWI and founder sponsors BP and the Lloyd's Register Foundation. NSIRC currently offers PhD degrees in Structural Integrity, 2 MSc courses on Structural Integrity and on Oil & Gas Engineering, both in collaboration with Brunel University London, and an MSc course on Engineering Leadership and Management in partnership with Aston University [E2, E4].

Currently NSIRC has almost 101 PhD and 20 MSc students enrolled, and has graduated 56 PhDs and 122 MSc students since 2014. To date there is a 100% employment rate amongst the graduates, all securing jobs in their specialist fields upon completion of research [E4]. The work done within NSIRC has contributed to 24 ISO standards [E5].

The economic impact of the Brunel/TWI collaboration is evidenced by the re-alignment of TWI's core business from technology provision and consultancy to research and postgraduate training, and the re-allocation of TWI's corporate budget to co-fund NSIRC. Together with other funding bodies, including BP and Lloyd's Register, NSIRC have developed an academic environment where a rigorous research training programme is located within a challenging commercial setting, providing students with exciting opportunities to further their research experience.

NSIRC is also making a direct and important contribution to the continued economic and safe operation of existing plant, products and infrastructure, through improved maintenance and life extension. The latter is particularly important in view of the increasing pressures on energy supply and transport systems. This integrated and collaborative focus is genuinely interdisciplinary and unique amongst current academic establishments worldwide.

New Innovation Centres

The outcomes of Brunel's initial research programmes within BIC [Ref 1-6] led TWI to open a network of 9 new Innovation Centres [E1,E2], working in different technology areas with other university partners, as follows: London South Bank Innovation Centre (LSBIC), established in August 2015, focusing on developing mobile robots that provide access to very large and vertical, safety critical structures that may be located in hazardous environments, and on the deployment of a range of NDT techniques; the Advanced Resins and Coatings Technologies Innovation Centre (ARCTIC), established in August 2016 with London South Bank University, focusing on resins and coatings technologies for sectors including aerospace, construction, and energy; the Brunel Composites Centre (BCC), set up in September 2016, specialising in novel composites processing and joining technologies applied to industrial environments across TRLs 1-6, underpinning TWI's work across TRLs 4-6 and giving the BCC the opportunity to work together with TWI Industrial Members; the Materials (Metallic and Alloys) Innovation Centre (MatIC), set up with the University of Leicester at the end of 2016, focusing on materials characterisation and novel materials development, especially small and full-scale materials testing in harsh environments; the Healthcare Innovation Centre (HIC), established in February 2017 with Teesside University, whose mission is to carry out interdisciplinary research to develop new interventions, tools and therapies for health and social care, thus creating a centre of excellence in healthcare technologies; the Joining 4.0 Innovation Centre (J4IC) with Lancaster University, set

Impact case study (REF3)

up in April 2017, focusing on the digitalisation of joining and associated manufacturing technologies in the context of industry 4.0; the Polymeric Materials Engineering, Research & Innovation Centre (PolyMERIC), established in 2018 with London South Bank University (LSBU), which develops new polymer materials, testing and inspection methodologies in harsh environments; the Additive Manufacturing Innovation Centre (AMIC), set up in March 2019 with Lancaster University, focusing on additive manufacturing, including the complete value chain of design and build optimisation, prototyping, performance validation and product industrialisation; and the recently created Artificial Intelligence Innovation Centre (AIC) with Essex University, focusing on AI for risk-based maintenance scheduling, automated weld inspection, automated guided waves defect detection, phased array ultrasonic testing data interpretation, automated shearography defect detection and other related topics.

Completing the Commercialisation Story

Plant Integrity Ltd. had been commercialising its trademarked Teletest Systems (I, II and III) since 1998. A Brunel team, headed by Prof Balachandran, identified that significant improvements could be made to the Teletest System Mark III. The improvement was so significant that Plant Integrity decided to manufacture a new version of Teletest System Mark IV. Since it was introduced to the market in late 2010, 20 units per year were sold, doubling the market share of Teletest System Mark IV from GBP1,000,000 in 2010 to more than GBP2,000,000 in 2013 and then to GBP5,000,000 in 2016/17.

Following the above success, in October 2017, TWI sold the Teletest® equipment business for GBP7,750,000 to Eddyfi Technologies [E6], a world leader in advanced non-destructive testing solutions. This completed the commercialisation story for Brunel and TWI, passing a technology Brunel helped develop to Eddyfi, an established industry player, to productise. A total of 19 Plant Integrity staff involved in the product portfolio transferred to the new Eddyfi Teletest business unit, including 6 former Brunel EngD and PhD students.

5. Sources to corroborate the impact (indicative maximum of 10 references)

- E1) Corroborating letter from the Chief Executive, The Welding Institute.
- E2) NSIRC Impact Review 2020. PDF provided.
- E3) UKRPIF Letter from TWI to Brunel 28 May 2019. PDF provided.
- E4) Page 24, TWI Business Review 2018. PDF provided.
- E5) Corroborating Letter from Director of Technologies, Lloyd's Register Foundation.
- E6) Page 1, Eddyfi UK Ltd. Annual Report and Financial Statements, year ending 30 September 2018. PDF provided.