Institution: University of Warwick

Unit of Assessment: B9 - Physics

Title of case study: Exploiting Non-Destructive Testing research through spin-outs (b9ICS-2)

Period when the underpinning research was undertaken: 2000 - (ongoing)

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:
Steven Dixon	Lecturer	1994 – present day
Rachel Edwards	Lecturer	2003 – present day

Period when the claimed impact occurred: 2014 - (ongoing)

Is this case study continued from a case study submitted in 2014? N

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

Research by the Dixon group on ultrasonic sensors and non-destructive testing (NDT) methods led to the establishment of 2 spin-out companies operating in distinctly different sectors. Sonemat Ltd and, more recently, Sonic Driver Ltd have generated a combined income of over GBP1,500,000 since 2014. During the assessment period, the spin-outs have also generated income or benefits of over GBP6,500,000 for their UK and overseas clients, in addition to opening up new markets, safeguarding existing and generating new jobs in partner companies, and improving safety and reliability of plant.

2. Underpinning research (indicative maximum 500 words)

The Warwick Ultrasonics and NDT group is a world leader in electromagnetic acoustic transducer (EMAT) research, having published more than 70 peer reviewed papers in the field's leading journals since 2000. EMATs are capable of generating and detecting ultrasonic waves in metal components without contacting them, providing a means of measuring metal sample thickness to a very high accuracy **[3.1]**, and a route to inspecting safety critical components that are hot or moving, such as cast steel billets in production **[3.2]** or rail tracks **[3.3]**.

Being non-contact, EMATs do not require an acoustic couplant, which makes them suitable for use where sensor alignment or placement requires some degree of tolerance, such as automated or robotic inspection applications. EMATs are an obvious candidate for high temperature inspection applications, and research into transducer design, the combination of suitable materials, fabrication methods and applicability to target sample materials **[3.4]** has led to the commercial development of a number of high temperature ultrasonic probes using EMATs magnetostrictive and piezoelectric based technologies. EMAT sensors capable of operating continuously up to temperatures of 500°C without requiring any cooling (see Fig.1 below) are a huge technological step forward, taking potentially dangerous water cooling out of sometimes enclosed high temperature environments. EMATs can also generate guided ultrasonic waves, some of which have the ability to travel around complex shaped components with minimal energy loss **[3.5]** – it is not practically possible to do this using conventional contacting ultrasonic transducers. Dixon's research in this area has led to the commercialisation of EMAT sensors for inspecting a range of different component types **[G1-G5]**, and has mainly been focused on pipe inspection (Fig.2), but has included infrastructure such as rail **[G4, G5]**.

Research into ultrasonic measurement of flow research started in Dixon's group in 2010, using transducers that were both in direct contact with the fluid flow (wetted) and transducers that were attached to the outside of the pipe through which fluid was flowing (clamp-on) **[3.6]**. Dixon realised that new, low-cost designs of ultrasonic sensors could be realised for clamp-on measurements that would maintain the required high accuracy and repeatability of wetted sensors, but at a

fraction of the price and with greater ease of use. Patent applications that have been filed for ultrasonic flow sensors **[3.7, 3.8]**, with a range of different features and sensor designs that reduce the cost of clamp-on ultrasonic flow measurement systems without compromising their technical performance. The Warwick IP on transducers also covers simultaneous measurement of fluid temperature, by accurately measuring the speed of sound in the liquid. This enables the system to self-calibrate for variations in the temperature of the liquid, which would otherwise affect the accuracy of the measurement. Further research at Warwick has explained how ultrasonic waves propagate along thin walled, fluid filled pipes, which has led to the second patent application **[3.8]**.

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

[3.1] **Dixon, S.M.,** Edwards, C and Palmer, S.B. (2006) *High accuracy non-contact ultrasonic thickness gauging of aluminium sheet using electromagnetic acoustic transducers.* Ultrasonics, 39(6). pp.445-453. doi: 10.1016/S0041-624X(01)00083-X

[3.2] **Jian, X., Dixon, S.M.; Baillie, I. et al.** (2007) *Integrity evaluation of steel products using EMATs*, Journal of Physics D-Applied Physics, 40, pp. 300-304. doi:10.1088/0022-3727/40/2/002

[3.3] **Edwards, R.S.**, **Dixon, S.M.** and Jian, X. (2006) *Characterisation of defects in the railhead using ultrasonic surface waves.* NDT & E International, 39, pp. 468-475. doi:10.1016/j.ndteint.2006.01.005

[3.4] **Lunn, N., Dixon, S.M.** and Potter, M.D.G. (2017) *High temperature EMAT design for scanning or fixed point operation on magnetite coated steel*, NDT & E International, Volume 89, pp. 74-80. doi:10.1016/j.ndteint.2017.04.001

[3.5] Clough, M., Fleming, M. and **Dixon, S.M.** (2017) *Circumferential guided wave EMAT system for pipeline screening using shear horizontal ultrasound.* NDT & E International 86, pp. 20-27. doi:10.1016/j.ndteint.2016.11.010

[3.6] **Li, Z.**, Hughes, F., Kerr, N., Wilson, R. and **Dixon, S.M.** (2019) *Liquid flow measurement using silicone polymer wedge clamp-on ultrasonic transducers.* IEEE Transactions on Instrumentation and Measurement, 69 (7). pp. 5157 – 5165. doi:10.1109/TIM.2019.2954235

[3.7] **Dixon, S.M.,** *Clamp-on ultrasonic transducer* (**Low-cost and self-calibrating clamp-on ultrasonic transducer),** GB1814909.6, **Filing Date: 13.09.2018.**

[3.8] **Dixon, S.M.**, *Ultrasonic flow measurement* **(Guided wave clamp-on flow measurement),** GB2007303.7, **Filing Date: 18.05.2020.**

Grants Awarded

[G1] **Dixon S.M.,** EP/K028995/1, EPSRC, Development of on-line, high temperature, non-destructive measurement/sensing techniques during manufacturing of power plant components, April 2014- March 2017, GBP358,326.

[G2] **Dixon S.M., Edwards R.S**. and **Hutchins D.A.,** EP/I03160X/1, EPSRC, *EMATs for non-contact NDE of austenitic steel,* September 2011-March 2015, GBP247,405.

[G3] **Dixon, S.M., Edwards, R.S**. and **Holland D**., EP/G042284/1, EPSRC, *High temperature ultrasonic measurements of plant and components for defect detection and monitoring*, July 2009-March 2012, GBP252,122.

[G4] **Dixon S.M. and Edwards R.S.,** EP/C534808/1, EPSRC, *New Instrumentation for the Scientific Study of Rail Defects*, September 2005 – February 2009, GBP269,827

[G5] **Dixon, S.M.,** GR/A93016/01, EPSRC, *Applications and characterisation of novel non-contacting ultrasonic techniques*, October 1999 – September 2004, GBP197,149.

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

Sonemat Ltd was set up to ensure that research outputs from Dixon's group on ultrasonic non-destructive testing could be provided to industry on a commercial basis, bridging the technology transfer gap in an area that required specialist expertise. Established in 2005, the spin-out draws on Warwick's research to deliver a range of products and services for industry, including bespoke solutions for extreme environments using EMATs and piezoelectric transducers; corrosion and erosion monitoring of long pipelines using guided wave EMAT technology; inspection and condition monitoring of metals and the application of ultrasonics for fluid fill-level monitoring in the food industry. The company has provided specialist R&D (mainly confidential) to a range of clients, developing test and inspection systems that are licensed to third party companies operating in a broad range of industries including manufacturing, processing, power generation, transport, and inspection. Sonemat EMATs have been used by companies in a range of testing and measuring applications, as the examples in Fig.1 & 2 show.

Sonemat sells a range of off-the-shelf hardware, all of which has been developed from research projects within Dixon's group **[5.1]**. This combination of consultancy, IP licensing, and off the shelf equipment sales is a deliberate strategy to ensure that research outputs from Dixon's group are widely commercialised. The CEO of Sonemat estimates that the use of IP that originated from Warwick has generated approximately GBP6,500,000 of benefit or income for the company's clients in the census period **[5.1]**, when income generated by third parties using Sonemat IP and cost savings they have made by using Sonemat's products is included. Sonemat also confirmed that the company had recorded a total turnover of more than GBP1,500,000 since 2014, stating: *"This income has arisen directly as a result of Sonemat exploiting the research findings from [Professor Dixon's] University research group."* **[5.1]**.

Fig. 1 Sonemat EMAT installed at a petrochemical refinery for *in situ* measurement of pipe wall thickness at 500ºC.

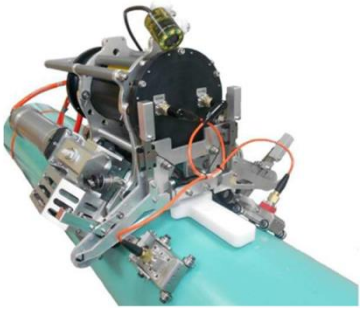

Fig. 2 Sonemat EMAT built into a robotic crawler for pipe testing.

Fig. 3 A high temperature ultrasonic ZIP probe, developed by Sonemat and Zinco, submerging into molten zinc to measure kettle tank wall thickness.

A client of Sonemat, Zinco International Ltd., provides advanced technical services to the hot dip galvanizing industry worldwide. The company approached Sonemat in 2014 for support in designing a new, reliable ultrasonic sensor, capable of measuring the remaining wall thickness of steel galvanizing kettles (the wall corrodes away during its lifetime in contact with the molten zinc); the sensor would need to work at 450ºC whilst immersed in molten zinc (Fig.3).

The Zinco CEO explained: "*Zinco wanted to be able to offer a more reliable kettle wall inspection because operating the original ultrasonic sensors was not only very expensive, but also exposed both Zinco and its clients to risk of probe failure during an inspection… We approached Sonemat to explore how ultrasonic technology could be used be used to test the kettle's integrity while still loaded with molten zinc."* Warwick and Sonemat's expertise in high temperature ultrasonic transducers was used to design a new sensor and measurement system, with Sonemat producing

a complete measurement utilising Warwick research; the Zinc Immersion Probe (ZIP) System. *"… Using the ZIP system is not only quicker, cheaper and safer, but it also causes minimum disruption to the galvanizer, often with inspections being undertaken quickly in the down time i.e. on the weekend or during shutdowns."* **[5.2]**.

Since obtaining the ZIP System, the number of inspections the company performs has risen rapidly, increasing by 50% over the past year, safeguarding existing jobs and enabling Zinco to expand. According to their CEO, "*We have new markets opening up in overseas sectors that would have not been previously possible.... Zinco has taken on extra staff and there are further plans for growth as we work toward our target of serving at least 30% of the world-wide market with this safety critical testing."* He added, *"At the moment, Zinco offers ZIP as an inspection service, but in the future we are moving towards leasing or selling systems to other organisations around the world."* **[5.2]**.

Zinco CEO said the benefits of the technology were not just financial but offered improved safety. *"Using the ZIP system is quicker and cheaper than performing a pumped-out inspection, meaning that more galvanisers will do more regular inspections, increasing safety even further. There will of course always be a need for galvanizing steel, and introducing an inspection method such as ZIP, requires much less energy than a pumped-out test, so wider adoption of ZIP will also provide environmental benefits*,'' he said, adding that the research contribution had "*safeguarded Zinco's future*'' and "*provided a strong platform for growth"* **[5.2]**. New overseas markets for Zinco include France (Prestia Group), Portugal (Eurogalva SA) and India, where in 2019 Zinco reported to have undertaken their first inspections at "*one of the largest galvanising groups in the world*." **[5.3].**

Sonic Driver Ltd. (incorporated March 2017) designs and manufactures ultrasonic clamp-on flow metering products for clients in industrial water treatment, energy management, irrigation, utilities, transportation, food and chemical handling. The Director of Sonic Driver stated, "*This is an exciting time for Sonic Driver, and we expect the company to grow significantly and expand into new areas of activity. The very existence of Sonic Driver has arisen as a result of research findings from the research group at Warwick, and the continued growth and innovation we see at Sonic Driver is heavily underpinned from both decades of expertise and knowledge from the Directors of Sonic Driver and the Warwick research group, and new knowledge based on more recent research from the Warwick group."* **[5.4]**. After over 2 years of product development and two rounds of investment, Sonic Driver started to generate sales revenue in Q4 of 2020. Warwick licensed patented IP to Sonic Driver **[3.7, 3.8]**, which has enabled the company to commercialise new high-performance low-cost transducers that will be disruptive for the process industry.

Fig. 4 Sonic Driver's industry-leading hand-held ultrasonic flow meter, with typical accuracy better than 1.5% - the most compact unit available prior to Sonic Driver's Android device.

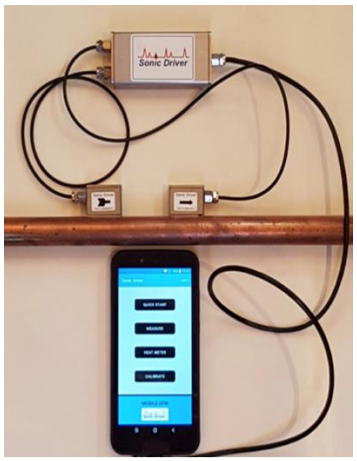

Fig. 5 The world's first Android clamp-on ultrasonic flow meter, announced in 2020 by Sonic Driver, bringing ultrasonic flow measuring to the mass market without compromising on performance or accuracy.

Sonic Driver announced the launch of its first process industry clamp-on ultrasonic liquid flow meters in 2019; a fixed wall mounted unit with modular communication add-ins and data logging, and a unique small hand-held unit a little larger than a mobile phone (Fig. 4). With performance and accuracy as good as market leading products **[5.5]**, these units are typically 25%-60% lower cost than the exiting competitors, thanks to their innovative design. These products are directly sold to end users by Sonic Driver and are also sold through distributors **[5.6]** or are rebadged under different brand names to be sold by third parties.

Using Warwick IP arising from and described in publications and patent applications **[3.7 & 3.8]**, Sonic Driver has developed new, miniature ultrasonic transducers that can be mass produced, using small amounts of PEEK (polyether ether ketone) plastic that are a viable sensor for low cost, high volume applications. Warwick and Sonic Driver have used these miniaturised transducers to develop a compact and low-cost clamp-on ultrasonic flow meter for liquids, which utilises Warwick's IP in both transducer design technology and signal processing for ultrasonic signals. This has recently led to the development of the world's first clamp-on flow meter based around a tablet or phone (see Fig. 5) with an anticipated cost of under GBP500 per unit, to bring clamp-on flow measurement to the mass market and widen access to the technology through lower costs and ease of use. It is particularly effective in small pipes, such as those found in residential or commercial buildings, where it is often difficult to use the larger and costly process-industry systems. With UK insurers paying out on average GBP1,800,000 per day on damage caused by domestic burst pipes **[5.7]**, these compact flow meters have applications for live water leak monitoring and alerting, with the capability of the system to automatically shut off the water supply remotely. Sonic Driver's Director said the company had *"seen a large increase in demand for our flowmeters, receiving large numbers of orders for our units ... in the last month of 2020, we had supplied over 31 flow meters, and had just completed negotiations that had secured orders for over another 50."* **[5.4]**.

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

[5.1] **Sonemat.** Statement evidencing how Warwick's research has led to the development of a number of ultrasonic instruments that are either sold directly to the end customer by Sonemat or sold to third parties who incorporate hardware and software into their commercial equipment or services.

[5.2] **Zinco International Ltd**. Statement evidencing how Warwick's research and the additional support of both Sonemat and Warwick led to a new ultrasonic instrument for inspecting galvanising kettles, transforming business for Zinco.

[5.3] News updates from the **Zinco Ltd**. website: Kettle Inspections for Prestia Group, France (May 2019); First Kettle Inspection in Portugal (June 2019); Zinco International – Summer Update! (October 2019). PDFs available dated 15/02/2021.

[5.4] **Sonic Driver Ltd**. Statement evidencing how Warwick's research and ongoing support in the transfer of the technology has enabled the company to develop several new, market leading ultrasonic flow measurement instruments.

[5.5] Calibration certificate from Young Calibration – a company used by the world leading manufacturers to certify their ultrasonic flow meter products, https://sonic-driver.com/wp-content/uploads/2020/11/Young-Calibration-221020.pdf

[5.6] PDF of https://smartstormgroup.com/products/portable-clamp-on-flow-meter-sonic-driver/ Distributor product page for the Sonic Driver Pocket UFM: - accessed 01/01/2021

[5.7] https://www.abi.org.uk/products-and-issues/choosing-the-right-insurance/home-insurance/burst-pipes-and-water-leaks/ - information from the Association of British Insurers on the costs of burst pipes - accessed 01/01/2021