Institution: University of Northampton		
Unit of Assessment: 12: Engineering		
Title of case study: Improving the Inspection Method for Metal Castings and Developing the Skills of Indian Foundry Workers		
Period when the underpinning research was undertaken: April 2017 – April 2019		
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:**
1. Dr Abdeldjalil Bennecer 2. Prof Philip Picton	1. Senior Lecturer 2. Professor	1. 2012 to present 2. 2005 – 2017
Period when the claimed impact occurred: 2017 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

There is a lack of *awareness* and suitable *training* amongst foundry workers in India in adapting and implementing inspection technologies in order to meet global *quality standards*. Casting production in India is expected to triple over the next 10 years, with employment doubling over the next 4 years. Researchers at the University of Northampton (UoN) and Hindustan Institute of Science and Technology (HIST) have collaborated to introduce a novel 3-D ultrasonic method of measuring the dimensions, profile, material integrity, defects and nodularity of cast components to foundries in India. The development of training materials, and workshops on how to implement non-destructive testing, have led to 17 small and medium enterprises to change the process of testing casting components. It is estimated that 50% of the country's total production of metal castings are concentrated in the state of Tamil Nadu where HIST is located. The changes have improved the performance of testing to meet quality standards and decreased the number of rejected component using accurate measurements, thus reducing environmental waste, and increased business capacity through decreasing down time and lead time.

2. Underpinning research

Dr Bennecer and **Professor Picton** have worked in partnership with HIST and industry partners such as INDSAT Corporation who manufacture foundry castings and machined parts. The research has focused on the use of Manual Ultrasonic Testing (MUT) for inspections of metal casting. MUT is a non-destructive testing method that generally provides cost-effective flaw detection with high sensitivity for inspections of metal castings at short distances and/or where there are challenges to practical access to pieces under inspection. **Bennecer's** research has resulted in a novel approach that optimises the reliability of MUT **[3.1, 3.2]**.

Between 2017 and 2019, in partnership with **HIST** in Tamil Nadu, India, the researchers developed a graphical user interface to convert ultrasonic measurements into 3D models **[3.3]**. The first objective of the research was gauging and measuring casting components using inexpensive ultrasonic non-destructive technique. The current process includes a selection of 10 samples from a batch of 1,000 components. The samples are then cut and inspected manually to make sure their thickness geometry in the critical parts meets the automotive industry requirements. They are not usually checked for any internal flaws. Should any of the samples fall short, the whole batch is discarded. This process is both wasteful and inefficient and does not always meet international standards. Therefore, a fast and non-destructive method that can be automated to reconstruct casting component models from laser scanning measurement combined with ultrasonic thickness gauging was introduced to 17 industry partners **[3.4]**.

The researchers developed a new technique using a laser and ultrasonic 3D scanning system **[3.3]** in order to measure more accurately and reliably the profile and thickness of complex casting geometries with inaccessible areas and rough surfaces. The technique is fast, reliable and exhaustive since the whole batch can be checked at once. Furthermore, the samples can be checked for internal flaws which offers added value to the foundry industry.

In addition to the thickness gauging, austempered ductile iron (ADI) castings, which are widely used as automotive components and accessories, comprises of a matrix and graphite nodules. Samples with nodularity ranging from 90% to 98% is one of the key selection criteria for automotive components. In order to meet industrial requirements for measuring nodularity percentage with high accuracy to characterise their castings, a novel inspection technique was developed to correlate the percentage of nodularity to the shift in the peak of the frequency spectrum obtained from the ultrasonic signals **[3.3 - 3.5]**.

A second key objective for this research was to address the shortage of trained engineers in Indian foundries who could implement the new technology. The research focused, therefore, on developing course materials, training the trainers and training foundry workers to improve their skills in the field of non-destructive testing and simultaneously to train the future work force **[3.3]**. The focus of this research emphasises the use of additional devices based on information technology and intelligent inference engines to minimise the effects of human factors. This is in contrast to the earlier evolution of improving the reliability of MUT, which consisted of training operators to adhere to written procedures. The research demonstrated the devices were most effective in assisting operators in those areas where they are least well adapted to controlling the quality of the test **[3.1, 3.2]**.

3. References to the research

[3.1] Bennecer, A. (2018). *Reliability of manual ultrasonic testing*. Paper presented at International Conference on Robotics, Automation and Non-Destructive Evaluation (RANE 2018).

[3.2] Chong, Y. B., **Bennecer, A.**, Hagglund, F., Siddiqi, S., Kappatos, V., Selcuk, C., & Gan, T-H. (2015). A new synthetic training environment system based on an ICT-approach for manual ultrasonic testing. *Measurement: Journal of the International Measurement Confederation*, *71*, 11-22. https://doi.org/10.1016/j.measurement.2015.04.013

[3.3] Dinakaran, D., Samuel Harris, D. G., Ramya, M. M., **Bennecer, A.**, & **Picton, P.** (2019). *Application of NDT for Foundry Products and improving skill of Indian Foundry Men*. Royal Academy of Engineering.

[3.4] Dinakaran, D., Samuel Harris, D. G., Ramya, M. M., **Bennecer, A.**, & **Picton, P.** (2017). *Application of NDT for Foundry Products and improving skill of Indian Foundry Men: Initial Report*. Royal Academy of Engineering.

[3.5] Qu, Z., **Bennecer, A.**, Selcuk, C., & Gan, T-H. (2012). Development on the laser-based weld flaw identification system. In *51st Annual Conference of BINDT* (pp. 21-29). (51st Annual Conference of BINDT). Curran Associates, Inc.. http://www.proceedings.com/16287.html

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The research includes a specially devised algorithm based on wavelet coefficients accumulation which is able to reliably and accurately identify and locate fine surface features. The research has contributed to the selection of methods and techniques to address the needs of the foundry industry in India.

4. Details of the impact

Bennecer's and **Picton's** research has had impact on industry and the technical skills of personnel within Indian foundries. India has overtaken the United States to become the second largest producer of metal castings in the world. It is expected that the foundry sector will grow at least three-fold over the next 10 years and double the 2,500,000 million employee capacity in the next four years. South India, particularly Tamil Nadu where HIST is located, contributes 50% of the country's total production of metal castings. Casting profile measurements in Tamil Nadu and the rest of India's foundries are still conducted using destructive methods. This process is both wasteful and inefficient and does not detect the existence of internal flaws.

Change in the *process* of testing casting components:

The collaboration with the industry partners and UoN was initiated through shared contacts and research partners from HIST. The new method introduced enabled a non-destructive testing person to generate a computer model using 3D modelling software with the actual dimensions of the component. This helped the foundry industry to improve the quality of casting. The technique also has the potential to lead to further automation of the inspection process for production. One key measure of the impact this research has had on the participating companies is the reduction of rejected components and the decrease in industrial waste by avoiding a complete disposal of the whole batch of manufactured castings. Since these companies are charged for commercial waste, the impact translated to considerable cost savings as commented by NELCAST Ltd India 'the company now accrues less waste of components and the money spent to dispose of them decreased by 12%. This has led to a reduction of carbon footprint and hence managed to make huge strides towards the environmental impact target' **[5.1]**.

Training to meet quality standards for increased *business* capacity

To mitigate the shortage of engineers trained in non-destructive testing, we worked with 17 industry partners **[3.4, 5.1, 5.2]** to develop training materials and programmes to train technicians to inspect casting products using the new technique. 50 graduate students from HIST and 76 supervisors and technicians from the companies participated in the training. The impact is summarised by NELCAST Ltd in India whose workforce benefited from the research and training "I am pleased to report that this has secured contracts with the automotive industry and enabled us to expand in new ways. To this end, we intend to contribute to the training centre established at HIST under the leadership of Prof Dinakaran to deliver long term training in the novel techniques introduced to us by your research" **[5.1]**. The course materials were prepared in English and translated into the native language (Tamil) to cover the needs of foundry workers. The project researchers delivered 'train the trainers' at HIST **[5.3]**. A training centre in the Centre for Automation and Robotics at Hindustan University has been established to achieve long term training activities **[5.4]**. This training has been identified as important by companies across the South Indian foundry industries **[5.5]**

The increasing requirements for quality and reliability in components demands effective quality and testing methods for example, in the automotive industry with which most of the participating companies are sub-contracted, nodular iron castings are produced with 21% to 98% nodularity. SMEs (Small and Mid-Size Enterprises) in Chennai do not have access to the advanced testing techniques due to the lack or high cost of training and infrastructural facilities. Moreover, alternative examination such as metallography involves machining, polishing, and etching operations, which are time consuming as well as requiring skilled technicians.

SMEs, which still use outdated inspection procedures, are struggling to meet the demands of Original Equipment Manufacturers. We have, therefore, identified that an awareness programme on advanced methods of inspection techniques and study materials in a regional language is currently needed for manufacturing and inspection companies as pointed out by Southern Inspection Services (Chennai) '*we have been able to adopt the new inspection technique for castings with high nodularity content and develop our skills to improve the quality of our inspection services*' **[5.2]**.

5. Sources to corroborate the impact

[5.1] NELCAST Ltd Testimonial

[5.2] SIS Inspection Testimonial

[5.3] D Dinakaran, H Samuel, M M Ramya. ANRO Hindustan university: (2018), Chennai, India. *Ultrasonic non-destructive testing Handbook* (Non-destructive ultrasonic test).

[5.4] Prof D Dinakaran, Head of Centre for Automation and Robotics (HIST) Testimonial

[5.5] Survey feedback Indian Foundries