Institution: BRUNEL UNIVERSITY (H0113)

Unit of Assessment: 15 – General Engineering

Title of case study: Teletest Focus, Non-Destructive Testing Device

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

In Europe, there are over a million kilometres of oil pipelines, nearly a million kilometres of railway tracks, 600 offshore platforms and 300 suspension cable bridges. However, these assets are aging as they have been in use for many years and operate under harsh conditions. Brunel research team has advanced ultrasonic non-destructive testing (NDT) which has the ability to inspect buried pipes in their original place without removing the pipes or damaging their surrounding environment. In addition, the research was pursued to improve the NDT of rail tracks, storage tanks, flexible risers in offshore platforms and aircraft wires. The research has been commercially exploited and incorporated into Teletest Focus System Mark III by Plant Integrity Limited. The significant improvement has led Plant Integrity to terminate the sale of Teletest Mark III and introduce a new version, Teletest Focus System Mark IV, to the market in late 2010. Since then, Plant Integrity has doubled its turnover from sales of Teletest Focus System Mark IV from £1 million to £2 million in less than a year.

2. Underpinning research (indicative maximum 500 words)

Professor Balachandran's research involves developing state-of-the-art sensor technologies and advanced signal processing. Since 2003, Prof Balachandran has been working in collaboration with The Welding Institute in Great Abington in Cambridge by conducting research in ultrasonic guided waves for long range non-destructive testing (NDT) of oil and gas pipes, plates, rails, wind turbines and aircraft wires, with a view to improve the performance of the Teletest Focus Mark III System. This product was marketed by Plant Integrity Ltd, which is the commercial arm of The Welding Institute.

Professor Balachandran and his research team embarked on addressing the technical short comings of the Teletest Mark III by conducting fundamental underpinning research in improving ultrasonic transducer design, new advanced signal processing techniques, new monitoring methods and significant improvements to the electronic hardware. This has resulted in a new product, which has a competitive edge in the market.

The techniques of cross-correlation, wavelet de-noising and split spectrum processing (SSP) have all been considered and SSP was found to be the most promising technique for coated pipes, which improved the signal-to-noise ratio (SNR) of received long range ultrasonic testing signals, thereby improving the defect sensitivity and test range [1]. The techniques were enhanced by incorporating robust hardware pre-conditioning, guided wave focusing and advanced signal processing into standard test procedures. Using these methods, a novel analytical model of the interaction of flexural wave modes with circumferential groove-like defects has been formulated, permitting a more accurate and comprehensive representation [2].

In addition to the conventional PZT (Lead Zirconate Titanate) transducers, fully coupled Macro Fiber Composite (MFC) transducers are also used for inspection using longitudinal waves, whilst the adapted MFC transducers are used with torsional waves. The research team developed a novel method of adapting the MFC and determined its characteristics. These improvements included the development of a robust calibration technique and the use of Full Matrix Capture for data collection and improved focusing results [3]. Using numerical modelling and experimental investigations, Professor Balachandran has identified appropriate wave modes and excitation/reception conditions needed to inspect different sections of rails. The outcome of the research was used to investigate defects such as in-plane and oblique defects for the twisted wire bundle used in aircrafts. This facility was incorporated into Teletest Mark IV where none existed before [4].

The research that has been pursued by Professor Balachandran and his research team has enabled an enhancement of Ultrasonic Long Range Guided Wave for NDT technology in general. These underpinning research findings facilitated the hardware improvements needed to be

implemented in the electronic system. Brunel research team in collaboration with Plant Integrity designed and implemented the new hardware. In this, an FPGA (Field Programmable Gate Array) based soft core processor was used to replace the previous stand-alone hardware microcontroller device to control the memory and peripherals in the system. A novel design has been developed for the multichannel transmitters with reduced size and component count. An efficient and reliable multichannel receiver system has also been designed and implemented in such a manner that fewer clock cycles are required for completing data acquisition, which makes it possible for meeting critical timing requirements for multichannel data acquisition with real-time DSP (Digital Signal Processing) functions [5&6].

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

1) Mallett, R, Blakeley, B and Balachandran, W, "Automated Radiographic Inspection of Flexible Risers: A Feasibility Study", Journal of the British Institute of Non-Destructive Testing, Vol. 47, No. 12, pp. 752-755, December 2005. http://dx.doi.org/10.1784/insi.2005.47.12.752

2) Catton P, Mudge P, Balachandran W, "Advances in Defect Characterisation using Long-Range Ultrasonic Testing of Pipes", Journal of the British Institute of Non-Destructive Testing, Vol. 50**,** Issue 9, (2008), pp 480-484 http://dx.doi.org/10.1784/insi.2008.50.9.480

3) Haig A G, Sanderson R M, Mudge P J, Balachandran W, 2013, "Macro-fibre composite actuators for the transduction of Lamb and horizontal shear ultrasonic guided waves", Journal of the British Institute of Non-Destructive Testing, Volume 55, Issue 2, pp 72-77 http://dx.doi.org/10.1784/insi.2012.55.2.72

4) Gharaibeh Y, Sanderson R, Mudge P, Ennaceur C, Balachandran W, "Investigation of the behaviour of selected ultrasonic guided wave modes to inspect rails for long-range testing and monitoring", Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, V0l.225, (2011), pp 311-324 http://dx.doi.org/10.1243/09544097JRRT413

5) L Zhang L, Mudj P J, Amira A, Balachandran W, "Improved performance of guided wave ultrasonic testing for long range inspection of pipelines using multi-channel system", Proceedings of the 3rd Int. Gas Processing Symposium, March 2012, Qatar http://www.sciencedirect.com/science/article/pii/B9780444594969500357

6) Parthipan T, Nilavalan R, Balachandran W, Mudge P J, "Design and Analysis of an Ultrasonic NDT Instrumentation Through System Modelling," International Journal of Modern Engineering, volume 12, issue 1 (2011)

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

Plant Integrity Limited is the commercial arm of The Welding Institute and has been selling its trademarked Teletest Systems (I, II and III) since 1998. Prof Balachandran's research identified that significant improvement could be made to the then-current version Teletest System Mark III. Teletest Mark III used an old communication protocol and the data rate was limited to 5 Mbps. It had 24 transmitting but only 8 receiving channels, which meant that the system had to be activated 3 times in order to receive signals from all 24 channels. The ultrasonic transducers were not properly matched, reducing its accuracy, and hence it often produced unwanted mode conversions. Also, it was bulky and difficult to handle during field tests.

Professor Balachandran and his team's research addressed these limitations by advancing

research in the field of ultrasonic non-destructive testing. The Welding Institute commercially exploited his research advancement so that it can be incorporated into their Teletest System.

Teletest® FOCUS+ System Mark IV

The improvement was so significant that Plant Integrity decided to manufacture a new version of Teletest System Mark IV. The unit is sold at £80,000. Since its introduction to the market in late 2010, 20 units per year have been sold, doubling the market share of Teletest System Mark IV from £1 million in 2010 to more than £2 million in 2013. Plant Integrity no longer markets Teletest Mark III.

The improvements incorporated in Teletest Mark IV are listed below:

- The design of the ultrasonic transducers for transmitting and receiving has been improved to achieve better focusing and to eliminate unwanted dispersive modes
- The new system has 24 transmitting and receiving channels and they can be activated simultaneously
- The gain of each channel can be independently controlled and calibrated
- The use of FPGA has significantly reduced the requirements for external components, ADC interpolation etc.
- Incorporates Ethernet protocol (100 Mbps) as opposed to 5 Mbps in Teletest Mark III
- Operational speed is 7 times faster (2 minutes)
- The power electronics used is a hybrid of a number of custom made SMPS topologies with overall efficiency in excess of 86%
- The size and weight of the battery has been reduced from 2.5 kg to 0.5 kg without compromising the system performance
- Teletest Mark IV is 45% lighter
- It can handle full matrix capture
- It incorporates WiFi and GPS
- It has better Electromagnetic Compatibility protection
- Significant reduction in physical size (33cm x 33 cm x14 cm)
- Four units can be interlinked and synchronised to the master clock and the transmission distance is 100m
- Data link can be increased to 120 channels thereby extending application to tanks

The Electronic system incorporated in Teletest Mark IV has the capability to be used with high temperature ultrasonic transducers that have been developed by Professor Balachandran and his research student for NDT in nuclear and food manufacturing industries. Furthermore, it can also be configured and used for NDT using Electromagnetic Acoustic Transducers (EMAT), which has the advantage of being non-contact transducer and hence not requiring air pressure for coupling to the target surface.

Teletest Mark IV has 10% domestic and 90% export market and has even distribution globally (Europe, North America and Asia). Typical clients in oil and gas industries are ConocoPhillips, Petrobras, Chevron, Shell etc. Plant Integrity is intending to market the system to rail and aircraft industries in the near future.

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

Contactable source: All information regarding sales and technical improvement of Teletest Mark IV has been provided by the Manager at Plant Integrity Limited, Cambridge, UK.