Institution: University of Bristol

Unit of Assessment: 15 - General Engineering

Title of case study: Imetrum - allowing convenient cost-effective high precision measurements using video-based metrology

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

From strains within a single carbon fibre to deflections in a bridge, dam or railway line, accurate measurement is vital to industry and public infrastructure. In many engineering contexts, traditional approaches to measurement are inadequate or involve unacceptable costs and delays. These shortcomings have been addressed by the University of Bristol’s research into high-precision, video-based metrology and its application through Imetrum, a spin-out company. Imetrum was founded in 2003 and launched its first product – the Video Gauge – in 2007. In the area of mechanical testing, the company has brought the first video-based extensometry system that can be supplied calibrated to international standards to market. For structural monitoring and safety inspections, deformation measurements are usually required. The Imetrum system is being used to precisely measure such deformations in rail bridges and other vital parts of the infrastructure without costly and inconvenient interruptions to their operation. Imetrum has approximately doubled its turnover each year since 2007. *[text removed for publication]*.

2. Underpinning research (indicative maximum 500 words)

Metrology underpins much of engineering, and improvements in metrology can have significant and wide-ranging benefits. The initial work at the University of Bristol to secure such improvements was carried out as part of the EPSRC-funded ‘Innovative Approaches to Composite Structures’ (IACS) programme. IACS involved investigating novel design and manufacture approaches that required access to mechanical test data that were not available through conventional technology. Specifically, small strains needed to be measured in small and delicate samples [1], which required the use of non-contact methods.

Previous work in Bristol’s Faculty of Engineering had demonstrated that sub-pixel resolution could be obtained in tracking target areas within video streams and that the movements of those targets could be used to measure structural displacements in flexible, large-span road bridges [2]. This work needed significant development in several areas to generate a workable, laboratory-based tool for strain measurement in mechanical testing within the IACS project. These areas included improved tracking algorithms, better understanding of the factors controlling accuracy, resolution, errors and reliability, and issues around system integration to develop a potentially marketable product, and were addressed by Setchell (UoB 1997-2012 and now Technical Director of Imetrum), Towse (UoB PhD student 1995-2000), Potter (UoB since 1995 and a Director of Imetrum since 2003) and Wisnom (UoB since 1987) [3]. After further development of the technique, it was patented for the monitoring of aircraft structures by the University in 2003 [4].

Additional development in all of these areas has taken place within the University spin-out company Imetrum Limited. This has driven an order of magnitude improvement in resolution over the system used in the original work and has led to an extensometry system that can be supplied with a calibration certificate traceable to international standards as required by the industrial customer base – a world first. Close liaison has been maintained between the University and Imetrum to develop the systems for applications in materials testing.

The IACS programme ran from 1995 to 1998. The recognition that current strain-measurement approaches were inadequate was deduced in 1997. A specific programme to link the video analysis capabilities and the materials and testing expertise across the Faculty of Engineering commenced that year. The development of the Imetrum video metrology systems for structural monitoring and other applications, see for example [5], has relied on an ongoing relationship between Imetrum and the Faculty of Engineering through EngD projects within the Faculty’s

Systems Centre.

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

[1] *A. Towse, K.D. Potter, M.R. Wisnom and R.D. Adams, 1998. *Specimen size effects in the tensile failure strain of an epoxy adhesive*. Journal of Materials Science, 33, 4307-4314, dx.doi.org/10.1023/A:1004487505391.

[2] J.H.G. Macdonald, C.A. Taylor, B.T. Thomas and E.L. Dagless, 1998. *Real time remote monitoring of dynamic displacements by computer vision*. Proceedings of the Sixth Society for Earthquake and Civil Engineering Dynamics Conference, Oxford, 389–396 (can be supplied upon request).

[3] *A. Towse, C.J. Setchell, K.D. Potter, A.B. Clarke, J.H.G. Macdonald, M.R. Wisnom and R.D. Adams, 2001. *Use experience with a developmental general purpose non-contacting extensometer with high resolution.* Nontraditional methods of sensing stress, strain and damage in materials and structures, West Conshohocken, Pa, USA, 1999, *ASTM Special Technical Publication 1323*, 2, 36-51 (can be supplied upon request).

[4] *K.D. Potter and C. Setchell. 2003. *Positional measurement of a feature within an image and monitoring an aircraft structure*, US2006115133 and EP1563252 Patents.

[5] J. Martin, J.-J.Heyder-Bruckner, C.D.L. Remillat, F.L. Scarpa, K.D. Potter and M. Ruzzene, 2008. *The hexachiral prismatic wingbox concept*. Physica Status Solidi, B: Basic Research, 245(3), 570-577, dx.doi.org/10.1002/pssb.200777709.

* References that best indicate the quality of the underpinning research.

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

The broad area of research into non-contact metrology has expanded greatly in recent years with several techniques competing in the marketplace. Many of these techniques are only applicable within specific scale ranges, require specific preparation of the surfaces to be examined or need highly trained staff to make use of very complex measurement approaches that are sensitive to operator error. By contrast, the video-based technology, originally developed at the University of Bristol and commercialised through Imetrum, overcomes most of these limitations. The current Imetrum products are directly derived from the research carried out at, and are protected by a patent assigned to, the University [4]. These products would not exist without the Bristol research – this research provides the fundamental understanding, the technology and the market knowledge on which Imetrum was based.

Imetrum

Despite launching its first product during a recession, in 2007, Imetrum has almost doubled its turnover in each year of operation, *[text removed for publication]* and currently sells its materials-testing products internationally. *[text removed for publication]*. Most sales are now exports, including to China, the USA, France, Germany, Scandinavia, the Czech Republic, Brazil and Korea.

Current Imetrum customers include major engineering companies such as Airbus, Rolls-Royce, BAE Systems, Amey and Network Rail as well as specialist companies such as the Red Bull and McLaren F1 teams [a], which are using the system for both materials characterisation and measuring deflections in structural testing. To further expand application areas, ongoing TSB-funded research is being undertaken by Imetrum in areas such as the monitoring of nuclear power systems.

User Benefits

The current state-of-the-art technique, based on the Bristol research and Imetrum developments, is embedded in systems for the real-time or post-processed measurement of displacements, strains, rotations and other deformations across a wide range of industrial applications. It has, for example, enabled the detailed measurement of strains in single, 5µm-diameter carbon fibres or even at the nanometre scale range within electron microscope images, through to deflections in bridges and dams. Imetrum has realised significant impact across a range of sectors including railways and Formula 1.

Composites: Within the mechanical test area, the Imetrum technology is now widely used in research and development, including at the National Composites Centre, to understand the details of failure processes in ideal and defective materials. This is a very important current topic of research in composite materials in support of increasing industrial applications of these materials. It is also routinely used to acquire hard-to-measure data in support of virtual engineering simulations for such topics as dimensional fidelity in large moulded parts. Many of the measurement applications for which Imetrum's Video Gauge is routinely used in the academic environment would either not be achievable by any other approach or could only be achieved at much greater cost.

Railway Infrastructure: The resolution of the system developed for structural monitoring is sufficiently fine to enable it to measure the displacement of rail lines due to individual wheels passing along the rail. This permits the direct measurement of track deflections and is currently being used to identify whether the track responds safely to the passage of a train. Traditional measurements only measure the maximum deflection and fail to capture all the deformation. The Imetrum system overcomes this problem entirely [b]. In another example, bridges on the Paddington to Penzance main line were monitored for deflection to check their safety. Deflections of less than 1mm were detected with good fidelity, with deflections associated with individual engines and carriages being clearly and separately resolved [c].

In terms of the monitoring tasks undertaken, the Imetrum solution usually means that there is no need to access a structure directly. This offers benefits in terms of timescales, safety and cost to asset owners and the public at large. For example, for rail-track measurements, as there is no need to access a railway directly, there is no need to obtain a possession order to allow access, which will typically remove around a six week delay. In addition, the work itself can be carried out by just one or two individuals rather than the five or six typically required (e.g. to act as lookouts). Additionally, workers are not put at risk, either from live traffic loads or working at height, and delays are not caused to the infrastructure users. When the system is used to monitor bridges, road closures are not required during its installation avoiding costs in the range of £10,000s - £100,000s. Imetrum generally provides these measurements as a service to its clients. This element of the Imetrum business is now growing rapidly *[text removed for publication]*.

*[text removed for publication]:*The impact of the technology to date has also been important in terms of improved understanding of materials and structural responses and reduction of the costs to industry and academia in generating such understandings. For example, the development by Imetrum of systems capable of calibration to international standards has eliminated a major limitation on the take-up of such non-contact strain measurement technology in the materials test area. Such technology underpins much advanced engineering, significantly reducing the costs of acquiring data and allowing previously difficult-to-gather data to be routinely collected, such as data from high temperature tests (up to 1,000^{o}C). This is being used in the rapid characterisation of novel composite material solutions for use in hot structures in racing cars.

Imetrum has just launched a new product allowing direct strain mapping of test samples whilst retaining the very high fidelity strain measurement that is the hallmark of Imetrum products. This new product should enable an acceleration of sales into the materials-testing market.

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

The impact can be corroborated by:

- Technical Director, Imetrum.

The specific documents referred to are:

[a] Imetrum website news article - *Imetrum Continues to Expand*, June 2013.
[b] Imetrum website case study - *Measuring Voids*.
[c] Imetrum website case study - *Rail Bridges*.