Institution: Newcastle University

Unit of Assessment: 12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Development of an International standard for composite pipeline repairs

1. Summary of the impact

Following the North Sea Piper Alpha oil rig accident in 1988 and subsequent Cullen inquiry, new and safer maintenance procedures were introduced. One of the most significant changes was the restriction in the use of welding repairs (hot work) in the maintenance of plant and pipework due to the risk of fire and explosion. Research at Newcastle provided a novel engineering model that formed the basis for implementation of a new repair technology. This used fibre reinforced polymer wraps to restore the integrity of pipes without 'hot work' or any interruption of production, thus minimising operational costs and increasing worker safety. This new technology has now become industry standard with new ISO and ASME standards for pipeline repair established as mandatory standards in 2006 and 2008 respectively (ISO/TS 24817 – Composite repairs for pipework; and ASME PCC-2, Repair of pressure vessels and piping). The period 2008-2013 has seen considerable expansion, worldwide, of an industry offering materials and support services to enable composite repairs to be designed and carried out.

2. Underpinning research

From 1988 to 2001 Newcastle University collaborated in "Cost-Effective Use of Fibre Reinforced Composites Offshore," a major EPSRC and industry sponsored research programme into the use of composites in the offshore industry (grant G1 as listed in section 3). The research was a Managed Programme of the Marine Technology Directorate (MTD) of the Science and Engineering Research Council (SERC), and the overall research programme and its outcomes were later summarised as publication P1 (as listed in section 3). The overall technical work programme was directed by Gibson at Newcastle University. Professor Gibson led a strong team of senior academics and researchers at Newcastle, Manchester, Salford, Nottingham and Liverpool Universities, UMIST, and Queen Mary & Westfield College, London.

As part of phase IV (1998-2001) of the "Composites Offshore" programme Newcastle University was funded to carry out research into the durability and reliability of composite pipes in offshore applications (projects CP404: Failure Envelopes for Composite Tubulars in Liquid Environments at High Temperatures; and CP411: Fatigue of Offshore Components in Liquid Environments). This research led to publications P2 and P3. P3 established the fundamental principles of pipeline repair using composite wrapping technology, with the research carried out by Dodds and supervised by Gibson, with industrial collaboration from Vosper Thorneycroft. The primary motivation of the pipeline repair research was to find a way of rehabilitating pipes without using the traditional method of welding, as this had been found to bring a significant risk of fire and explosion when applied in the oil industry. In order to weld safely, in accordance with the safer maintenance procedures introduced after the Cullen enquiry into Piper Alpha oil rig incident, significant downtime within a facility was required which meant that even relatively straightforward repairs were costly.

The research proved the concept of a properly engineered composite overwrap repair, applied in-situ and without hot work, which could be used to restore the pressure capacity of a corroded or damaged pipe and which had added corrosion protection benefits. It involved investigation of the adhesion parameters and fracture mechanics aspects of composite repairs on pressurised steel substrates. Good adhesion between the composite repair and the corroded substrate was found to be essential for effective load transfer between the pipe and the composite overwrap, as well for prevention of ingress of water into the repair-substrate interface. The work provided quantitative information on the failure mechanisms involved at the interface between the metal substrate and the composite. The performance of various thermosetting polymer resins was studied, and coupled with optimisation of the metal substrate surface preparation parameters in order to achieve an optimum bond. The best fibre reinforcement architecture for mechanical performance and pressure rating was also identified. Publication P3 was the first in-depth systematic evaluation of how to apply composite wrapping in order to ensure high quality performance.

The researchers involved in the work were:

- **Gibson**: Professor of Composite Materials, 1988 to date.
- **Dodds**: Research Associate, 1998-2001; Senior Research Associate 2003-2007.
- **Kotsikos**: Research Associate, 1997-2005; Principal Research Associate 2005 to date.

Gibson has led the work throughout. Dodds was a researcher on the "Composites Offshore" programme. Kotsikos has subsequently supported Gibson in work in this area, and in particular in developing test methodologies.

3. References to the research

Papers:

P1. Gibson, A.G., "The cost effective use of fibre reinforced composites offshore," Health and Safety Executive Research Report 039 (www.hse.gov.uk/research/rrpdf/rr039.pdf), 2003.

P2. Gibson, A.G., Hicks, C., Wright, P.N.H., Fahrer, A. "Development of glass fibre reinforced polyethylene pipes for pressure applications." Plastics, Rubber and Composites Processing and Applications, Volume 29, Issue 10, 2000, Pages 509-519.

P3. Mableson, AR, Dunn, KR, Dodds, N, & Gibson, AG. "Refurbishment of steel tubular pipes using composite materials." Plastics, Rubber and Composites Processing and Applications, 29(10), 558-565, 2000.
***Key publication**: the first in-depth systematic evaluation of how to apply composite wrapping in order to ensure high quality performance.*

Key Research Grants:

G1. Gibson, A.G. et al. "The cost effective use of fibre reinforced composites offshore", Managed Programme of the Marine Technology Directorate (MTD) of the Science and Engineering Research Council (SERC), sponsored by SERC and Industry, 1988–2001, Total funding £5.9M (£2.6M industrial funding). Led by Newcastle University, in collaboration with UMIST; the Universities of Glasgow, Manchester, Salford, Nottingham, and Liverpool; and Queen Mary & Westfield College.

4. Details of the impact

The growth in interest in composite pipeline repairs led Shell International, who were a partner in the "Composites Offshore" programme, to approach the standards bodies in order to establish international standards which would ensure the quality of pipeline repairs. Their knowledge of the original work led them to approach Gibson and Kotsikos to support drafting of the standards, based on P3.

This led to the drafting of two entirely new standards, ISO/TS 24817 – Composite repairs for pipework, published in 2006 and revised in 2011 (S1 in section 5) and more recently ASME PCC-2, Repair of pressure vessels and piping, published in 2008 and revised in 2011 (S2), with the ASME standard based on the ISO standard. These are now mandatory standards for any organisation undertaking composite pipeline repair. The introduction of engineered composite pipeline repairs underpinned by these standards marked a clear step forward in safety enhancement in the offshore industry whilst simultaneously minimising disruption and therefore reducing costs. Their use in off-shore installations is especially widespread because they are a cold temperature repair solution. The technology has played an essential part in maintaining the productivity of ageing offshore plant around the world and in particular in the North Sea.

4.1 Impact on Standards

Composite pipeline repairs are used by a wide variety of sectors including aerospace, automotive and the offshore industry mainly because of their versatility and cold application. Until the development of the new international standards based on Newcastle's research in this area, uptake of composite repairs was limited due to the inconsistent application of repairs and consequent variation in the failure rates of the repairs.

The standards were developed to cover all aspects of installation including the training and validation of the repair staff. These two standards have enormously improved the consistency of repair works in this area and given a significant stimulus to their uptake in the offshore industry. In the development of the ISO standard (which covers the material qualification, design, installation and inspection of composite repairs) several new test methods and analysis routines were developed. These test methods were specifically concerned with assessing and quantifying the adhesion characteristics of composite repairs to metallic pipes. The Chairman of the ISO committee supports the contribution made by Newcastle University to the ISO/TS 24817 standard [**S3**]:

"During the development and writing of the ISO standard the work performed by Newcastle University formed the basis for the test protocol and the analysis routine used to convert the qualification test data into an engineering parameter which is used in the design of the composite repair. Without doubt without the supporting work of Newcastle University the current ISO standard, ISO/TS 24817, would not be such a robust standard in terms of the engineering rigor of the test and analysis routines of the measured qualification test data."

4.2 Impact on Pipeline Industry

Several successful companies (or parts of companies) specialising in composite repair technology have been created offering pipeline rehabilitation services around the world (e.g. Prokem Pipeline Products, IMG Composites, Walker Technical, ENECON and Clock Spring). The size of the worldwide market for pipeline repairs is estimated to be £250-350M p.a., with at least 10% growth expected in the European market next year [**S4**]. The development of the international standards, underpinned by the original research at Newcastle, has given the technical confidence to support the growth of this industry sector. The work at Newcastle has played a key role in transforming the working practices of the pipe repair and maintenance industry.

Comments in an article entitled 'Composite pipe repairs gain acceptance' by the Chief Executive at Belzona, an industrial company specialising in the repair and maintenance of buildings, structures, machinery and equipment identified the following as the characteristics which have led to the wide adoption of composite pipe repairs [**S5**]:

"*Composite repairs have gained greater acceptance among asset owners and equipment operators because they provide an engineered, durable and affordable solution and they comply with international engineering standards.*"

Concluding his article he goes on to state**:**

"Composite repairs are indeed the right solution for extending the lifetime of equipment in an efficient and reliable manner."

The Technical Director of Walker Technical, a UK company involved in composite technology for the oil and gas, petrochemical, refinery and power industries supports the increasing use of composite repairs and in particular in off-shore installations [**S3**]:

"*Composite repairs over the last few years have become a common repair solution for damaged or corroded pipework in Oil and Gas installations. Their use, particularly in off-shore installations, has become widespread due to the fact that they are a cold repair solution. Hot repair solutions e.g. welding are considered a safety risk due to the presence of both heat and ignition sources."*

5. Sources to corroborate the impact

[S1] ISO/TS 24817 – Composite repairs for pipework, published 2006. Revised in 2011 as ISO/CD 24817 - Composite repairs for pipework -- Qualification and design, installation, testing and inspection, currently at ISO Committee Stage.

[S2] ASME PCC-2, Repair of pressure vessels and piping, published 2008, revised 2011.

[S3] Letter from ISO Chairman, who is also Technical Director of Walker Technical.

[S4] Communication from Manager of Prokem Pipeline Products.

[S5] Chief Executive, Belzona Inc. USA, 'Composite pipe repairs gain acceptance', Plant Engineering Journal, 11/04/2010. Available at:
http://www.plantengineering.com/industry-news/mechanical-news/single-article/composite-pipe-repairs-gain-acceptance/288696a442f8bf025f912b26f5a34b84.html