Materials and Design 70 (2015) 68–80

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Technical Report

Development of a fibre reinforced polymer composite clamp for metallic pipeline repairs

Luke P. Djukic [a,b], Wei Siang Sum [c], K.H. Leong [c,*], Wayne D. Hillier [a,b], Timothy W. Eccleshall [a,b], Alan Y.L. Leong [c]

[a] Advanced Composite Structures Australia Pty Ltd, 1/320 Lorimer Street, Port Melbourne, 3207 Victoria, Australia
[b] Cooperative Research Centre for Advanced Composite Structures Ltd, 1/320 Lorimer Street, Port Melbourne, 3207 Victoria, Australia
[c] Kawasan Institusi Bangi, PETRONAS Research, Lot 3288/3289 Off Jalan Ayer Itam, 43000 Kajang, Selangor DE, Malaysia

ARTICLE INFO

Article history:
Received 4 September 2014
Accepted 29 December 2014
Available online 17 January 2015

ABSTRACT

In the oil and gas industry, clamps are a common means of repairing pipelines with leaking defects. The use of composite instead of metal presents key advantages in reduced weight, smaller relative density compared to water and greater corrosion resistance. This paper presents two different composite clamp designs, with design pressures of 10.5 MPa, along with test results. The designs differ with respect to the clamp laminate thickness, the clearance gap between the pipe and the clamp, the rubber seal hardness and the test temperature. Test results show that the clamps withstand the design pressure with appreciable margins, at all three temperatures considered, namely room temperature, 65 °C and 80 °C. Generally, the leak containment capacity of the composite clamp increases with greater laminate thickness and seal hardness, and it decreases with greater clearance gap. Finally, the results have successfully demonstrated the design methodology proposed for these clamps.

1. Introduction

A long standing challenge with the use of metallic infrastructure is the management of corrosion damage. The particular challenge faced in the oil and gas (O&G) industry is the prevention and treatment of the sort of corrosion damage that reduces the operating lives of fluid transportation pipelines and associated infrastructure.

Repairs of O&G pipelines can be broadly categorised into two forms. The first involves cut-out and/or welding operations. The second involves the application of some external form of repair. Depending on the requirements of the repair, the latter category can be further broken down into two sub-categories, each requiring an added external structure. The first is a repair where the pipeline strength is reinstated, either completely, or to some degree with an appropriate pressure de-rating. The second is a leak containment repair, where the reinstatement of the pipeline strength is not the main consideration. Combined functionality repairs can be designed and used as required.

When selecting the repair method, one of the main considerations is minimisation of the shutdown time. Performing repairs "live" without a shutdown presents the highest economic benefit [1]. It is understood that generally wall thinning defects can be repaired live, while through-wall leaking defects are repaired with the pipeline shutdown due to occupational health and safety (OHS) requirements. Hence, it is necessary to develop methods of rapidly repairing leaking defects that minimise any shutdown time. Normally, when corrosion monitoring systems are effectively implemented, potential leaks are avoided by the timely installation of an external repair to the corroded region.

Traditionally, metallic repairs are one of the most common and widely used form of external repair on the market. They can be applied for both leak containment and strengthening as discussed by Coley and Caraballo [2]. While these repairs have been demonstrated to be effective, there are several drawbacks associated with their use. Firstly, highly corrosive environments including offshore above water locations, splash zone, and subsea make these metallic repairs susceptible to degradation due to corrosion over time. Secondly, metallic repairs are typically heavy, require special infrastructure for installation, and sometimes, additional pipe supports are also necessary. Examples of these types of repairs are metal clamps/sleeves installed around, and welding metal plates over, the damaged/corroded regions of the pipe.

Alternatives to the use of metallic repairs are composite repairs, with overviews provided by Shamsuddoha et al. [3] and Gibson et al. [4]. Composite overwrap repair methods have received extensive research over the last few years, with several methods having

* Corresponding author at: Kawasan Institusi Bangi, PETRONAS Research, Lot 3288/3289 Off Jalan Ayer Itam, 43000 Kajang, Selangor DE, Malaysia. Tel.: +60 12 305 6272.
E-mail address: kh_leong@petronas.com.my (K.H. Leong).

http://dx.doi.org/10.1016/j.matdes.2014.12.059
0261-3069/

been developed. This repair process involves wrapping the defect region with a composite material, and building thickness until the desired level of strengthening and/or leak-containment is achieved. While these composite repairs are effective, the installation can be time consuming, and the pipe surface preparation requirements can be demanding, with neither always achievable in field conditions. One such method is the use of a pre-impregnated composite, as presented by Leong et al. [5] and later qualified for field service as detailed Djukic et al. [6]. A second method is that discussed by Alexander and Ochoa, who used wet laid composite in conjunction with pre-fabricated composite half cylinders [7].

The objective of this research program is to develop an alternative to these types of metallic and composite repairs. A bolted repair, similar to metallic clamp repairs currently available on the market, but made from composite, was developed. This paper presents details of the design, manufacture and testing of this novel repair method for leak containment. Work to extend the functionality of these clamps to provide strengthening capabilities by means of grouting the annulus is on-going. To this end, Sum and Leong have performed finite element analysis and some experiments on pre-fabricated composite sleeves grouted in position over defective pipes [8], and experimental characterisation of grouts has been performed by Shamsuddoha et al. [9].

It should be highlighted that, compared with metal clamps, a composite equivalent has several key advantages. Firstly, there are weight savings coming from the use of composites and these permit simplified installation procedures. Secondly, the smaller relative density difference between the water and composite clamp material for in-water applications leads to reduced submerged installation weight. Lastly, greater corrosion resistance of the repair means enhanced durability. In addition, compared with composite overwrap repairs, a composite repair clamp also presents other advantages. Not only can these clamps can be pre-fabricated rather than requiring in-field fabrication, thus reducing installation times, but these clamps can also provide leak containment via rubber seals without being bonded to the pipe. These clamps are not without disadvantages. While a composite overwrap repair will conform to almost any pipe, an individual article needs to be generated for each clamp repair. Also, the clamp technology integrates rubber seals which can have a shorter life expectation than cured composite.

2. Details of clamp

2.1. Concept, materials and manufacture

2.1.1. Concept

The concept of the composite repair clamp is shown in Fig. 1. The composite clamp comprises two half cylindrical shell sections with flanges (referred herein as the half-clamp), which are brought together over a pipe and fastened together using bolts to effect the repair. Seals are made from rubber, or an alternative sealing material, and are located within grooves machined into the composite at both ends of the clamp and along the flanges, forming a pressure tight annulus between the pipe and the clamp. In the event of a leak, this annulus is pressurised by the fluid being transported by the pipeline. The only contact between the repair system and the pipe is from the seals.

2.1.2. Composite shell

The composite from which the clamp is made is comprised of a 1200 g/m^2 E-glass biaxial non-crimp fabric and vinyl ester resin. The plies are laid up to be parallel to the upper and lower surface of the flanges, and parallel to the inner mould line, in a 0/90 configuration with respect to the pipe axis. The flanges were thickened through the use of additional glass ply insertions, spanning the width of the flange, located between the plies that spanned the entire cross-section of the clamp and flanges, in order to allow sufficient resistance to localised compressive loads applied by bolts during tightening. The composite was manufactured via Vacuum Bag Resin Infusion (VBRI) at room temperature and subsequent machining processes. The use of glass in this case allowed the clamp more widespread application in comparison to carbon, as carbon presents a galvanic corrosion concern in certain applications if left unaddressed [10]. An image of a completed prototype clamp, after it has been painted, is shown in Fig. 2.

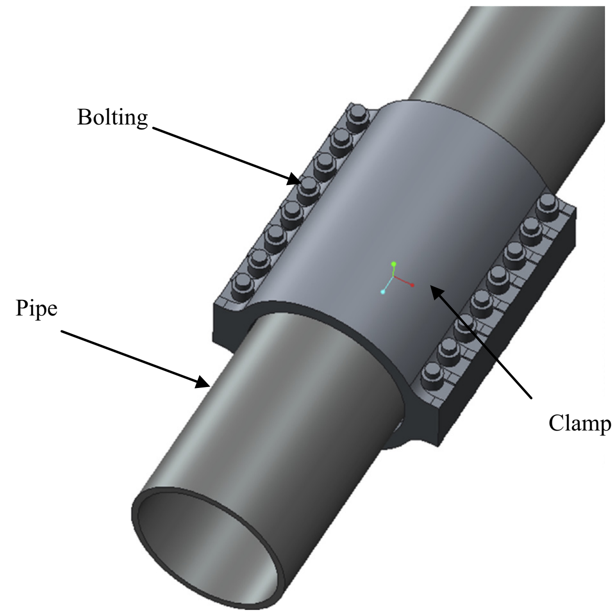

Fig. 1. Schematic diagram showing components of the composite clamp assembly.

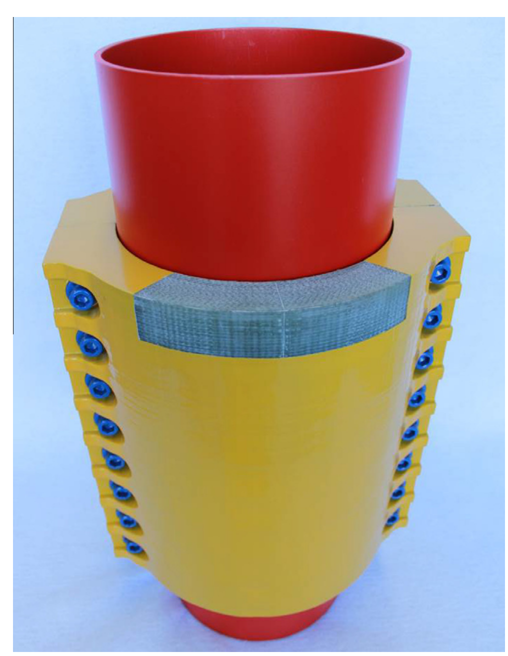

Fig. 2. Assembled and painted 35-56 clamp.