GRP ASSESSMENT AS STRUCTURAL REINFORCEMTN OF API 5L GR B PIPELINES

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Abstract. *Corrosion by environmental factors is a type of defect almost inevitable in pipes used in oil industry. The rehabilitation of pipelines due to corrosion damage with fast and low cost methods has been a challenge, in the past years. This work aims to evaluate the efficiency of a composite material (GFRP) sleeve as structural reinforcement for strain reduction in steel pipelines, submitted to internal pressure, used as hydrocarbon transport. The study of polymer matrix composites as structural reinforcement is characterized as an alternative for repair of metallic pipelines which operates in limited conditions of temperature and pressure. A comparative analysis between strain values obtained analytically and experimentally was performed, in order to verify the applicability of polymer matrix composites as structural reinforcement. Strain measurements were performed for both conditions – GFRP reinforced and unreinforced pipe.*

Keywords*: Composites, Reinforcement, Pipelines, Strain*

1. INTRODUCTION

Offshore and onshore pipelines are one of the safest, economical and, as a consequence, the most applied means of transporting oil and gas in the world nowadays. Unfortunately, the increasing number of aging pipelines in operation has significantly increased the number of accidents. According to the Office of Pipeline Safety (2004), the major causes of accidents in liquid and natural gas pipelines are internal and external corrosion defects. As a pipeline ages, it can be affected by a range of corrosion mechanisms, which may lead to a reduction in its structural integrity and eventual failure. Clearly, regular inspections of pipelines with state-of-the-art tools and procedures can reduce the risk of any accident caused by a lack of unawareness of the integrity of the line (Grimes and Jones, 1996). Corroded pipelines with part-wall metal loss defects can be repaired or reinforced with a composite sleeve system. In these systems, a piping segment is reinforced by wrapping it with concentric coils of composite material after the application of epoxy filler in the corrosion defect. Laboratory hydrostatic burst tests and field practice of several years have shown that these repairs are effective for pipelines with external corrosion defects. Information about requirements and recommendations for the qualification, design, installation, testing and inspection for the external application of composite repairs to corroded or damaged pipeline in petroleum, petrochemical and natural gas industries can be found in Jaske et al. (2006) and ISO 24817 (2006).

Studies developed by Kiefner (1973) and Kiefner and Vieth (1990) resulted in the well-known ASME B31G criterion (1991) and its improved version coded on a computer program called RSTRENG (Remaining Strength of the Corroded Pipe) for assessing the detrimental effect of surface corrosion defects on the burst pressure of pipelines. Later, DNV (1999) published recommended practices for assessing corroded pipelines under combined internal pressure and longitudinal compressive stress. Based on both experimental tests and numerical calculations, the proposed empirical formula comprise single and interacting defects, and complex-shaped defects.

More recent experimental and numerical analyses done by Cronin and Pick (2000a, 2000b, 2002), Loureiro et al. (2001), Benjamim et al. (2002), Choi et al. (2003) and Netto (2005) indicate that these currently accepted assessment codes involve safety factors that can occasionally impose costly and unnecessary repair of defects or replacement of the affected region.

2. EXPERIMENTAL PROCEDURE

Three types of materials were used to fabricate the composite sleeve and evaluate repaired pressure pipelines for rupture testing: a segment of pipeline steel, an epoxy putty (to fill defect regions in the pipe), and a glass fibre/epoxy composite wrap. The pipeline steel was API 5L Grade B, a seamless, plain carbon steel that is commonly found in the pipeline industry. The putty that is used to fill the defects on the pipe, restoring its undamaged dimensions is diglycidyl ether of bisphenol-A (DGEBA) based epoxide cured with an alphatic amine hardener. The glass fibre/epoxy wrap that provides the structural reinforce- ment is created by impregnating a woven glass fibre fabric with a similar unthickened DGEBA epoxy/amine prepolymer resin. The plane weave fiber glass fabric consists of 312 g/cm^2 E-glass.

Test pipes were prepared from 12 in. nominal diameter, Schedule 20, steel pipes cut into 1.5 m (5 ft) lengths with welded end-caps, each having a 15 mm NPT fitting. The Schedule 20 designation corresponds to a wall thickness (t) of 6.35 mm (0.250 in.) and an outer diameter (D) of 323.85 mm (12.75 in.)

Simulated defects were machined into the pipe wall using defects with a longitudinal length of 300 mm (11.81 in.), and a depth to 80% of the wall thickness (5 mm or 0.20 in.). In the hoop dimension defect lengths are 100 mm (3.94 in.).

Figure 1 displays the geometry of the external defect introduced to the tubular specimen without composite reinforcement.

Figure 1. External defect of a specimen without composite reinforcement, also showing the strain gage and burst pipeline

Once the defects were created in pipe test pipes, the steel was sandblasted to a near-white finish and placed on a support structure to allow the repair system to be applied. An electric strain gauge was attached to the surface n order to measure the strain during the test. Then, the two-part high viscosity putty was mixed using a paddle and applied to fill the defect. Again, two strain gauges were attached to the pipe outside the created defect to measure the strain in the non-defect surface, see figure 2. The glass fabric was impregnated with the premixed low viscosity epoxy/amine hardener using an adhesive roller. After the fabric was properly saturated, it was wrapped around the test pipe and the freshly applied putty using hand tension to pull the wet fabric, while keeping the centerline of the wrap with the center of the defect. A total of 8 layers of glass/epoxy wrap were used to cover the flaw, giving the repair (excluding the epoxy putty) a thickness of 1.5 mm (0.059 in). Once the wrap was applied the epoxy was allowed to cure for at least 24 h, in a room temperature environment, before testing began. A picture of a completed instrumented with strain gauges pipe is shown in Fig. 2. The composite thickness repair thickness was calculated according to Costa-Mattos et al. (2009).

The hydrostatic test was consisted in filling the wrapped pressure pipe with water vertically to insure no air was present within the system. Then, the pipe was moved to a secure area to prevent injury to personnel. An air actuated, hydraulic power unit was used to pressurize the test pipe. The hydraulic pump was connected to the pipe and a transducer was used to record the pressure in the line. The pipe was pressurized by the pump in steps of 100psi until it reached the unwrapped pipe rupture pressure. The internal pressure required to fail the unwrapped pipe was recorded.

Figure 2. Composite sleeve installation

3. RESULTS AND DISCUSSION

The internal pressure test of the unwrapped pipe is presented in figure 3 were outside 1 and 2 means the non-defect measured area and Defect means the reduced thickness area.

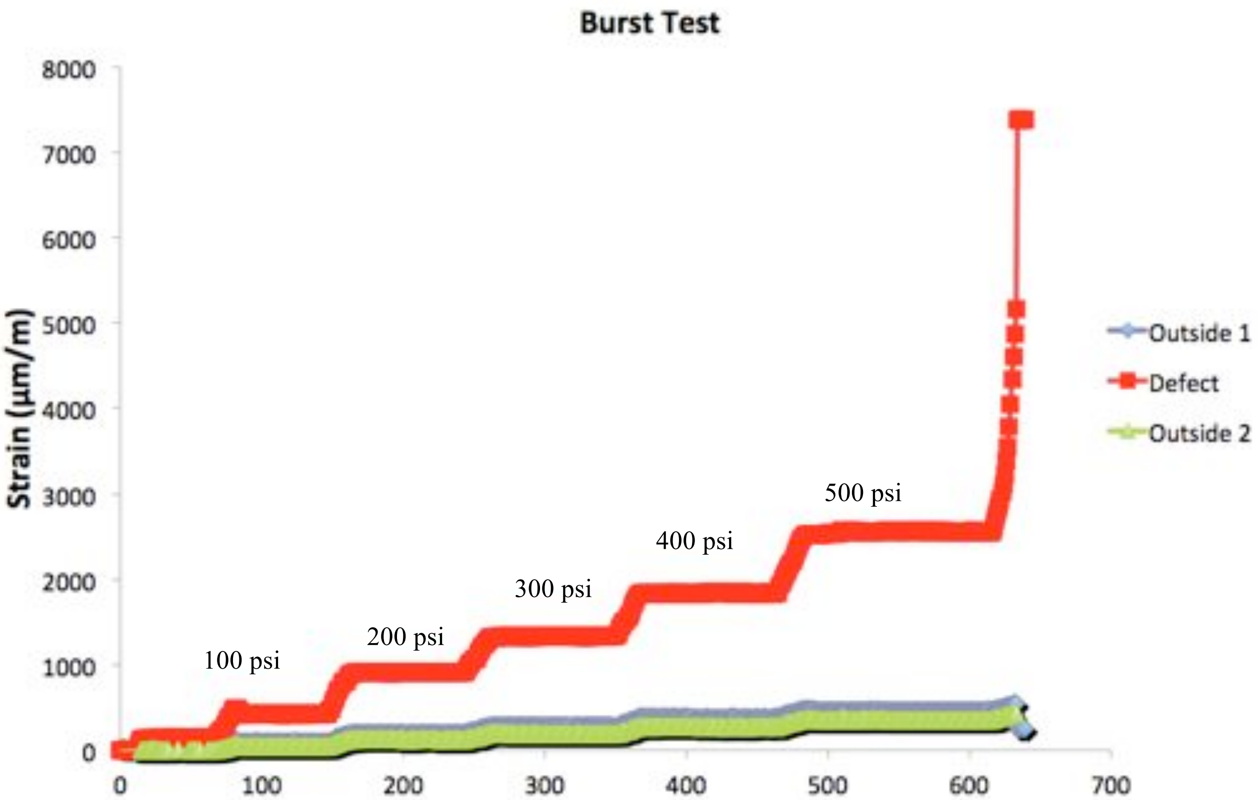

Figure 3. Pipe test pipe burst test

The effectiveness of the repair can be evaluated by comparing the burst pressure 3.8MPa (552psi) of the repaired pipes with the predicted burst pressure of an unrepaired pipe. The burst pressure of an unrepaired pipe can be calculated by the ASME B31G criterion (1991) or using the RSTRENG technique, both well established methods for assessing corroded pipelines (with the ASME B31G criterion known to be overly conservative). For the defect analyzed in the study, these methods (which do not take into account the circumferential length of the defect) result in a predicted burst pressure of 4.89MPa (709.2psi) and 3.44MPa (498.9psi) for the ASME B31G criterion and the RSTRENG technique respectively.

Figure 4 displays the repaired test sample.

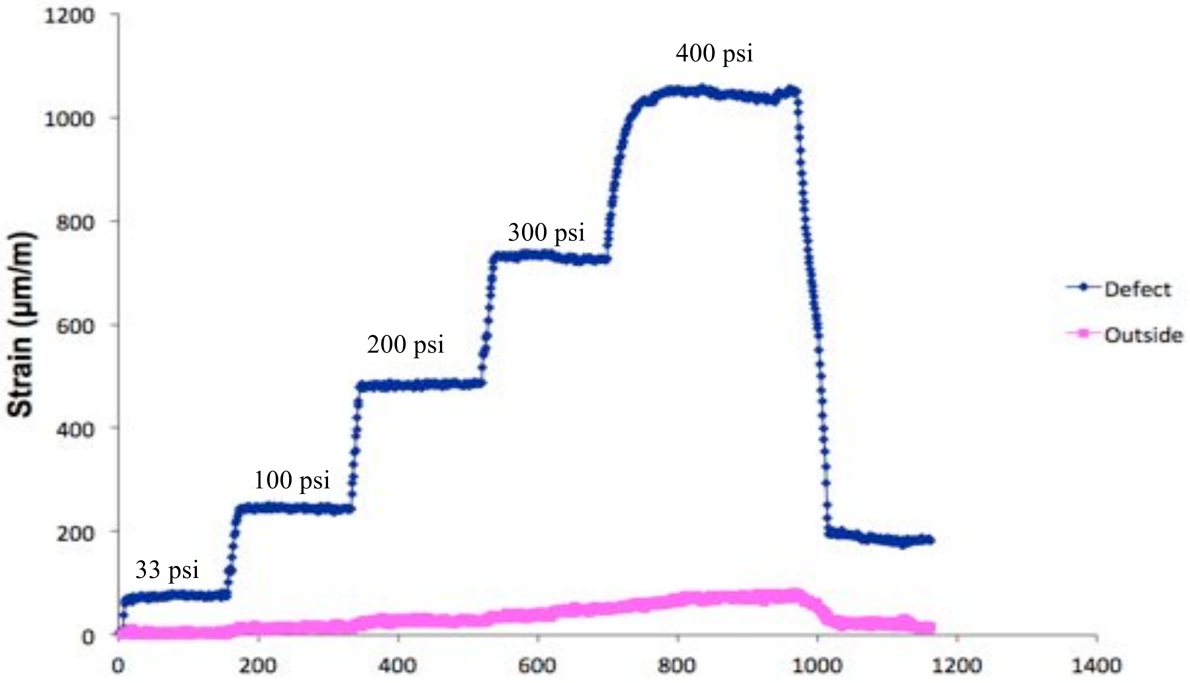

Figure 4. Hydrostatic test on the wrapped pipe

Table 1 present the average strain measured in the unrepaired and in the repaired test pipes. Comparing the burst test (unrepaired pipe) result with repaired pipe a considerable diminish of the strain in the defect area is measured. In the defect area an average reduction of 44.6% is reported and in the outside area the strain lowered 78.3% in average.

Table 1. Average measured strain values of unrepaired and repaired test pipe

Pressure (psi)	Strain (µm/m)(1)			
	Unrepaired		Repaired	
	Defect	Outside	Defect	Outside
100	422	41	242	8
200	910	137	476	23
300	1330	193	729	49
400	1831	275	1042	68

(1) : average values

According to ISO 24817 (2006) the repair thickness has to measure 1.6 mm (0.063 in.)

4. CONCLUSIONS

Test results showed that the repair system allowed the pipe to reach the original operational pressure. This repair withstood pressures above those that ruptured similar specimens that were not repaired. However, only one of the repair systems was approved in all strength verification tests for both internal and external defects. This system operated during a minimum of four hours under a hydrostatic pressure test and was also able to withstand ten pressure cycles of zero-to-design pressure without showing any visual damage.

The presented test indicated that further studies are necessary to better describe the stiffness of the repair systems and the behavior of the interface between composite sleeve and the metallic tube.

5. ACKNOWLEDGEMENTS

The financial support of Rio de Janeiro State Funding, FAPERJ, and Research and Teaching National Council, CNPq, are gratefully and acknowledged.

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