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Case Study of Stress Corrosion Cracking (SCC) on Natural Gas Pipeline and Types of Repairs

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***Abstract*—Oil and gas pipelines are prone to various deficiencies, including stress corrosion cracking (SCC). This case study explores the methods and best practices for repairing a 34-inch distribution network of gas transmission and supply pipelines that serve various consumers along the Libyan coastline. It also highlights the vital importance of this facility in powering key industries, such as power plants, steel mills, and cement factories. The focus is on preventing and addressing SCC, including the use of split sleeving, repair clamps, and non-destructive testing (NDT) techniques**.

***Index Terms*—SCC, natural gas pipeline, split sleeving, repair clamp, heat-affected zone (HAZ), weldability.**

I. Introduction

Stress corrosion cracking (SCC) poses a significant challenge to natural gas (NG) pipelines. This case study focuses on the repair of a 34-inch cross-country pipeline transporting NG at high pressures (30–100 bar) over 820 kilometers. The pipeline, made of low alloy steel API X52, is buried in trenches 1–1.5 meters deep and monitored using a Supervisory Control and Data Acquisition (SCADA) system. It plays a critical role in supplying natural gas to power stations, steel factories, and cement plants [1].

Figure 1: Sirte Oil & Gas Co Natural Gas Station of at Marsa El-Braga [1].

Recent studies [7], [9] have emphasized the importance of advanced material analysis and finite element modeling in predicting SCC susceptibility, which aligns with the findings of this case study.

The study explores the causes of pipeline failure, particularly stress corrosion cracking, and compares three types of repair techniques: pipe sleeves, repair clamps, and composite wraps. SCC occurs due to a combination of tensile stress and corrosive environments, leading to cracks that compromise the integrity of the pipeline [2].

2. Discussion and Results

2.1 Pipeline Failures and SCC

Pipeline failures can occur due to corrosion, external interference, fatigue, ground movement, and material or construction defects. Stress corrosion cracking is particularly insidious because it results from the combined effects of mechanical stress and a corrosive environment. SCC leads to leaks or ruptures, depending on the severity of the cracks and the pressure in the pipeline [2].

Research by [5] and [10] has shown that hydrogen embrittlement plays a crucial role in SCC propagation, particularly in high-strength steels like API X52 used in this pipeline.

2.2 Repair Techniques

2.2.1 Pipe Sleeve

Pipe sleeves are used for non-leaking defects such as pitting corrosion and stress corrosion cracking. These sleeves are fabricated according to API RP 1107 and ASME PCC-2–2008 standards. They are installed at a pressure below the failure threshold and welded onto the pipeline for a permanent repair [1], [2].

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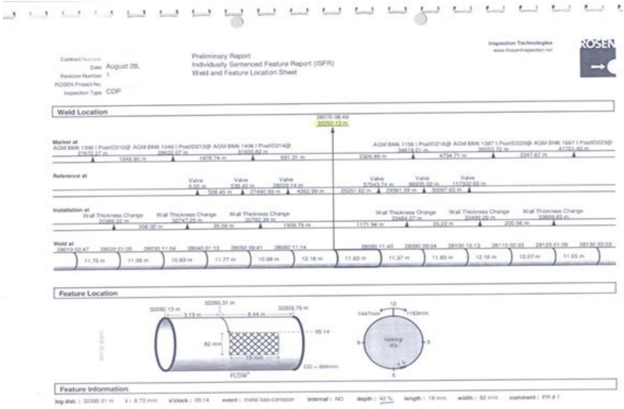


Figure 2- Rosen Co. Inspection data showing external corrosion [1] [2].

Figure 3: External Axial Stress Corrosion Cracking, determined by Rosen Smart Pig [1] [2]

Figure 4- Pitting Corrosion, Defect Location determined by Rosen Smart Pig [1] [2]

Figure 5: 36 " Inch Fabricated Split Pipe Sleeve- [1].

Figure 6-Welding Technique considering the cooling time [1].

2.2.2 Split-Clamp Repair

Split clamps are repair fittings commonly used for temporary repairs on both onshore and subsea pipelines. However, in this case, the clamp was modified and confirmed as a permanent repair solution. By integrating the clamp as a permanent part of the pipeline, future rework was avoided, effectively making the clamp an integral component of the system. These clamps are designed to seal leaks caused by corrosion or damage. Once fully torqued onto the pipeline, the clamp can be welded to provide a long-term solution.

Figures 7: Pipe section leak caused by Stress Corrosion Cracking [1].

Figure 8- Installation of Split Repair Clamp and Bolted up & Torqued [1].

Figure 9- Converted the Temporary Clamp into Permanent by welding [1] [2].

2.2.3 RES-Q™ COMPOSITE WRAP

The RES-Q™ composite wrap is a carbon-fiber-based solution for repairing non-leaking defects. It is applied over damaged sections of the pipeline to restore lost strength and prevent future damage. Composite wraps are effective for pitting corrosion and SCC but are not suitable for leaks [3].

Figures 11: Composite Wrap Repair for Non- Leaking defects [3].

Figure 12- Applied to a pipeline bend [3].

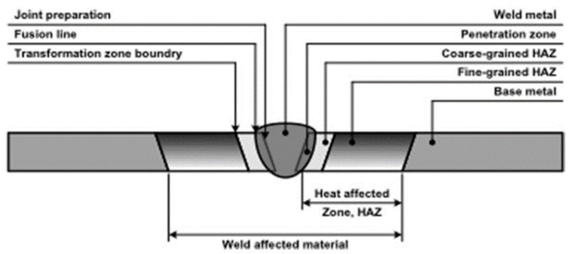
2.2.4 COMPARISON OF REPAIR METHOD EFFECTIVENESS

2.3 NON-DESTRUCTIVE TESTING (NDT) AND INSPECTIONS

NDT techniques such as ultrasonic inspection, magnetic particle inspection, and dye penetrant testing are critical in identifying defects in the heat-affected zone (HAZ). Inspection pigs, equipped with high-precision magnetic sensors, are used to detect flaws such as external corrosion, scratches, pitting corrosion, and stress corrosion cracking in gas pipelines. This information is crucial for planning repairs [2]. Recent advancements in NDT, as discussed in [11], have improved crack detection accuracy, particularly in submerged pipelines.

2.4 HEAT-AFFECTED ZONE (HAZ)

The HAZ is the area of the pipeline that has been exposed to high temperatures during the welding process but has not melted. The size of the HAZ is influenced by the heat input, duration of exposure, and the thermal diffusivity of the base material. Larger HAZs are more susceptible to defects such as hydrogen embrittlement and phase changes, which can lead to cracking. Managing the HAZ is critical in preventing further damage after repairs [4].



Figures 13: Illustration of HAZ Based on Process Parameters [4].

Repair Method	Application	Suitability	Durability	Leak Sealing	Cost	Standards
Pipe Sleeve	Non-leaking defects	High	Permanent	No	Cheep, due to Local Fabricated	API RP 1107, ASME PCC-2
Split-Clamp	Leaking/Non-leaking defects	Moderate to High	Permanent (when welded)	Yes	A pit costly due to overseas purchased	Customized, practical use
RES-Q™ Composite Wrap	Non-leaking defects only	Moderate	Long-term	No	Costly due to overseas purchased	TDW Specifications

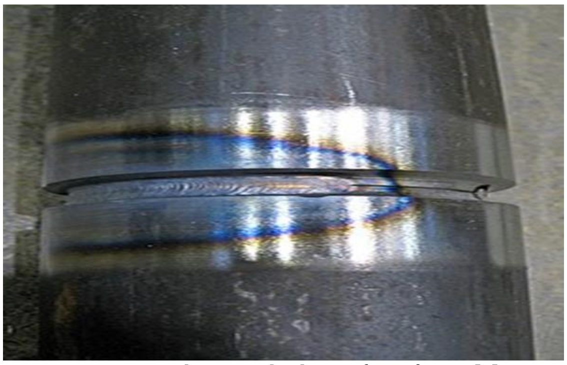


Figure 14 - Oxidation Dark Blue Surface of HAZ [1].

2.5 POST-WELD HEAT TREATMENT (PWHT)

Post-weld heat treatment (PWHT) is recommended to relieve stresses in the HAZ and improve the overall integrity of the repair. PWHT involves heating the repaired area to a specific temperature range (510°C to 650°C) and then cooling it slowly to prevent cracking. This process is particularly important for high-strength low-alloy steels and quenched and tempered steels, which are more prone to hydrogen-induced cracking [4].

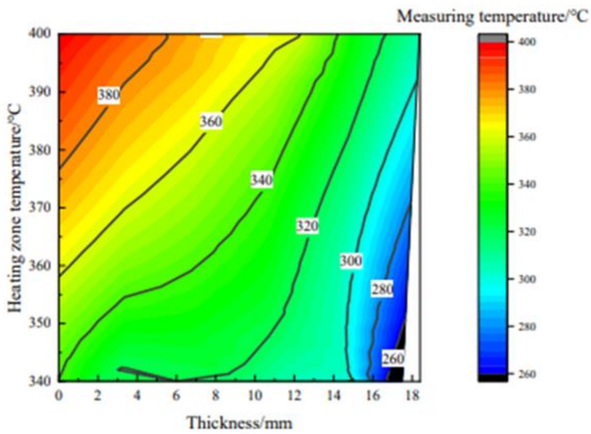


Figure 15- Temperature Levels of Heat Inputs, Vs Base Metal Thickness [2]

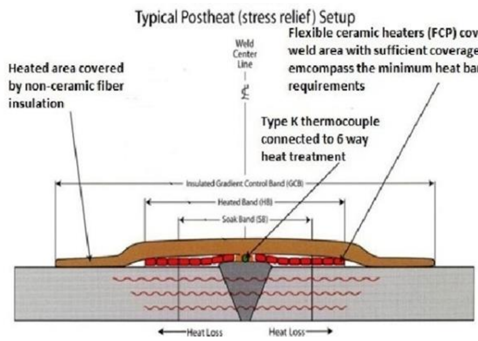


Figure 16: PWHT process for Stress Relief [1] [4].

3. ACKNOWLEDGMENT

This case study highlights the critical importance of employing effective repair techniques to address stress corrosion cracking in natural gas pipelines. Various methods, including the use of split sleeves, repair clamps, and composite wraps, combined with comprehensive non-destructive testing and post-weld heat treatment, have been instrumental in maintaining the long-term integrity of the pipeline system.

However, significant challenges remain, particularly in sections of the pipeline that are submerged in the sebkha area and pass below sea level. These underwater sections are exposed to both mechanical stress and temperature fluctuations, which can lead to recurrent cracking. The gas flowing through the pipeline at approximately 49°C (120°F) undergoes sudden cooling, putting additional stress on the metal structure and increasing the likelihood of cracks.

To prevent future issues, it is strongly recommended to redesign and install an optimized air cooler between the manifold and the main pipeline. This would enhance the cooling process, reducing thermal stress on the pipeline and mitigating the risk of further cracking.

The repairs completed during this case study were vital not only for maintaining the uninterrupted transmission of natural gas to essential facilities but also for ensuring cost-efficient energy supply. Natural gas, as a cleaner and more efficient fuel compared to heavy and light fuel alternatives, provides both environmental and economic benefits, reinforcing its value as a sustainable energy source.

Ultimately, while the immediate issues were resolved, ongoing monitoring and improvements, particularly in cooling system design and repair strategies, are crucial for maintaining pipeline integrity in challenging environments such as submerged and marshy areas.

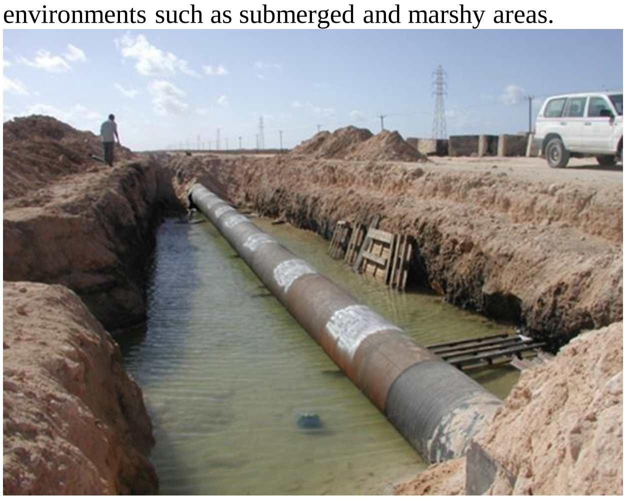


Figure 17: Immersed Pipeline Below sea level (sebkha area) [2].

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