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Review of Marine Pipe Repair Methods in Indonesia

Abstract

Marine pipelines face numerous hazards that can result in their deterioration. These hazards encompass internal rusting due to corrosive substances, wear from solid particles in the moving fluid, outer corrosion, and collisions with anchors impacting the pipeline's surface. When deterioration and leaks occur in the pipeline, it leads to considerable product losses and substantial economic repercussions, as well as environmental contamination. Hence, it is crucial to identify methods for repairing marine pipes and to understand the conditions under which each technique is applicable. Since the inception of marine pipes, various techniques have been employed to remedy pipe flaws. Although the types of flaws remain constant, repair techniques have evolved to minimize time expenditure and enhance safety and operational reliability. The degree of impact varies based on the nature of the damage, the operational environment (land vs. sea), working pressure and temperature, length of pipe, type of fluid, etc. Given all these factors and the vast expanse of marine pipelines, it's vital to be knowledgeable about and proficient in the range of pipe repair methodologies. Accordingly, this article presents an overview of different marine pipe repair techniques along with the necessary tools and equipment.

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1. Introduction

In contemporary times, advanced nations depend on pipelines for the transportation of oil and gas products, water, and industrial waste, as well as for transmitting electricity through cables and other myriad industrial functions. Consequently, marine pipelines are established and utilized globally, steadily becoming prevalent due to social industrial growth and increasing profit aspirations. For approximately half a century, marine pipelines have been installed in various regions around the globe, significantly contributing to the economies of nations. These pipes consistently encounter maintenance challenges, including ruptures, fissures, erosion, and corrosion. In our country, corrosion is one of the predominant issues facing the plumbing sector. Both internal and external corrosion diminishes the effective lifespan of pipelines. Furthermore, external damage can occur from impacts with objects, necessitating pipe repairs. There are multiple methods available for pipe restoration. In certain instances, plumbing operations may be halted to excise the damaged segment and replace it with a new one. When the damage is minimal or if we prefer to maintain plumbing services, alternative repair techniques come into play, which will be detailed in the subsequent sections.

Steel, being the predominant material utilized in pipe manufacturing, is significantly affected by environmental erosion factors present in water or soil, rendering it susceptible to damage or corrosion. Any unwanted leakage of materials arising from these factors can generate irreversible consequences for both the environment and the economy of the affected locality. Contaminants such as industrial waste, sewage, or petroleum leaks can lead to soil pollution and can interfere with the daily lives of residents if they infiltrate the region's water supply. The hazards of gas explosions from leaking pipes further illustrate the potential dangers associated with pipe deterioration. Given that these issues can result in catastrophic events, extensive and prompt reconstruction and repair of pipelines is crucial from economic, technical, and ecological perspectives. The challenges outlined are particularly significant for a vast nation like Iran, characterized by substantial oil and gas reserves and an extensive network of aging marine pipelines. This article will first evaluate and categorize the various types of defects. Subsequently, it will discuss the considerations necessary for repairing a segment of piping.

2. A Review Of The Defects And Damage

Damage to pipes is connected to the conditions of installation and operation. Table 1 displays categories of damage and corresponding scenarios. As mentioned, steel piping is the predominant type utilized across multiple sectors of the oil and gas industry. The primary motivations for selecting high-strength steel include its relatively lower cost and the convenience of making connections. Nonetheless, despite these advantages, steel pipes are susceptible to corrosion during their operational life due to the environmental factors surrounding them, such as saline water or the presence of acidic gases in the flowing fluid. Internal or external corrosion, longitudinal or radial cracking, erosion, buckling, the emergence of gouging and dent defects, as well as rupturing are among the most frequent issues that can arise throughout a pipe's service life. [1].

Table 1. Damage categories and scenarios

Phase	Damage Category	Specific Damage Scenario
Installation	Dry buckle	Dry local buckle
		Dry propagating buckle
	Wet buckle	Wet buckle
	Loss of coating	Buckle/Stinger impact
Operation	Hydrate	Hydrate
	Localized damage, no leak	Internal/Eksternal corrosion
		Goude/Dent/Buckle
		Overstressing
		Fatigue damage
		Trawling/Anchoring
		Object dropped from the ships
		Ship sinking/Ship grounding
		Shipwrecks and debris
		Earthquakes/Tsunamis
		Mass gravity flows and turbidity currents
		Pin-hole leak
	Localized damage, minor leak	Seismic fault/Submarina landslips
		Liquefaction /Scour
		Rupture
	RUpture, local	Eartquakes/Slope stability
		Rupture

	Rupture,extensive length	Internal/eksternal corrosion
	Extensive damage, no leak	

Based on damage scenarios and risk assessments, it is clear that [1]:

a. The pipe installation contractor must have procedures fully developed and all necessary equipment ready for use in the event of a dry or wet buckle before deep water pipe installation operations start.
b. Operators must have fully developed procedures and all necessary equipment ready to use before starting operations to meet the following scenarios:

1. Hydrate formation
2. Local damage (i.e. dent or pinhole leakage).
3. Local Rupture
4. Rupture of a considerable length of pipe.

3. Effective Factors In Choosing The Repair Method

Numerous factors come into play when choosing a repair technique for marine piping. Once dimensionlessness is established, factors are assessed, and boundary conditions are determined, each will be incorporated into a pre-defined objective function to identify the optimal repair technique. Key influences in choosing repair methods include the following. [1-2]:

a. Repair time/period
b. Economic factors
c. Marine pipe specifications
d. Sea water conditions
e. Types and sources of failure
f. Environmental situation
g. Improve service capabilities
h. Strategic considerations

In the pipe repair process, the key temporal elements and considerations encompass the time spent on gearing up and getting ready, potential risks during the installation phase, and the effectiveness of communication among the operational teams. The principal financial aspects include the costs related to installation, maintenance, consulting, and the products used. Conditions of sea water, such as temperature, salinity, clarity, depth, and oceanic currents, influence pipe repairs. Additional factors affecting pipe repair are outlined in Table 2..

Table 2. Other effective factors in pipeline repair

Pipeline specification	Type and source of the defect	Environmental situation	Strategic consideration
Dimensions and pipeline	Internal/eksternal corrosion	Traffic situation	Sanctions
Chemical specification of the fluid	Longitudinal/circumferential or combined cracks	Seabed condition near repairing area	Currency exchanges
The remained time of the design life of the pipeline	Erosion	Weather condition	Product localization
Fluid pressure	Local or overall buckling	Distance between the defect and flange	After-sales service
Pipeline route maps	Denting, lamination	Position of the defect (closeto the platform,	Permanent warranty (product renewal)

Pipeline specification	Type and source of the defect	Environmental situation	Strategic consideration
		equipment, etc.)	
Pipe thickness at the defect point	Rupture	Specifications and condition of the pipeline cover in the area that defect has occurred	Restore production speed

Experience in carrying out similar projects, having qualified personnel and adequate equipment (type of float, equipment, technical characteristics, personnel, etc.), and product variety are the most critical factors in pipe repair services.

4. Types Of Composite Repair

Types of Composite Repairs Offshore pipeline repair procedures can be classified according to the repair method in terms of execution from inside or outside the pipe, water depth, and termination of pipe service. A general categorization of different repair methods is provided in Figure 1.

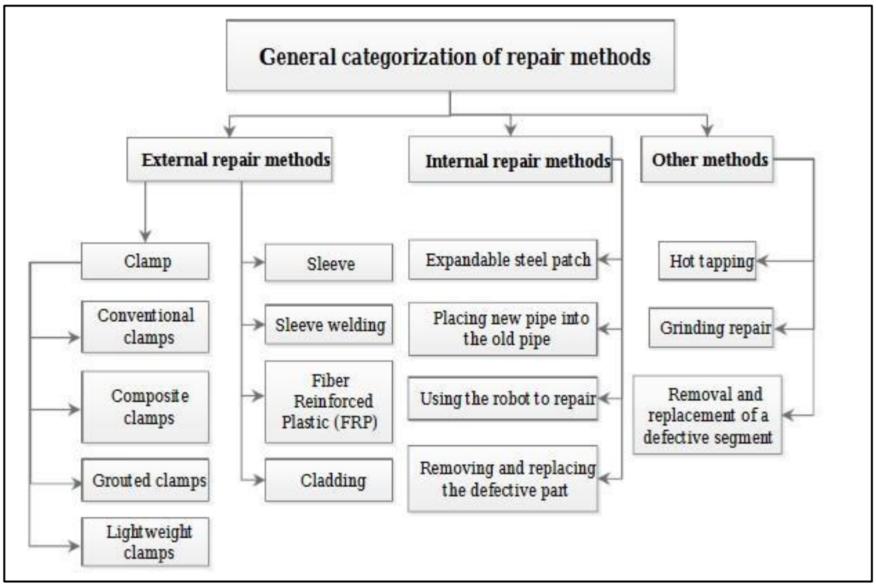

Figure 1. Categorization of Repair Methods

Figure 2. Conventional Clamps

Clamps serve as external mechanical connectors that mend compromised or leaking sections on pipes and offshore platform components. These connections are established by divers or ROVs (notably in deeper regions) to the affected area [3]. Figure 2 illustrates the components of the clamp designed for pipe repair. The sealing efficiency of the clamp is the primary functionality of this device [4]. The clamp assembly is primarily made up of two semi-massive structures. The mounting ring, the mechanism for opening and closing the hydraulic auxiliary arm, the holder for the hydraulic cylinder, the bolt tightness hole, the flange base, and other design features are all integral to the clamp structure. The mounting ring facilitates the easy lifting of the clamp into the correct position during underwater installation tasks. The mounting ring, along with the hydraulic auxiliary arm's opening and closing mechanism and the hydraulic cylinder holder, aids in the clamp's movement when submerged, enhancing its suitability for the underwater installation environment. The clamp is secured when the central bolt passes through the tightening bolt hole, achieving a longitudinal seal. The flange base serves the purpose of joining and securing the flange. The material characteristics of the clamp body match or exceed those of the pipe material [4]. Clamps uphold the structural integrity of the pipe and enable it to function at peak operating pressure. For the clamp to achieve complete watertightness, the pipe surface must be entirely smooth and free from excessive edges. Hence, any concrete or plastic coating on the pipe must be eliminated.

a. Clamp Composite

Figure 3. Composite Clamps

The composite clamp is composed of two sections of a half-cylindrical shell featuring a flange, which is positioned on the pipe and secured by bolts to hold the pipe in place, as illustrated in Figure 3-a. The primary elements of the clamp are distinctly represented in Figures 3-b and 3-c. A durable rubber seal is utilized to contain the pressurized fluid that leaks from the pipe within the annulus region between the pipe and the clamp. Various composite fabrication methods can be employed to create the clamp; however, vacuum-assisted liquid molding is deemed the most economical approach to achieving a favorable balance of quality lamination while maintaining affordability. Leak containment is ensured through the use of rubber seals tailored to the operating conditions and surrounding environment. The seal is arranged in a 'picture frame' layout, as depicted in Figure 3c. Consequently, each half-clamp features a fully enclosed semicircular annulus to trap the fluid escaping from the compromised pipe. Ultimately, the two half clamps are secured together using socket head cap screws. The flange is reinforced to provide adequate resistance against localized compressive forces exerted by the bolts during tightening, as well as to enhance the flange's stiffness to counteract its likelihood of opening during subsequent operational stresses [5].

b. Emphasis Grouted

Figure 4. Grouted emphasis

Grouted clamps serve the purpose of mending and reinforcing offshore structures, which include jacket members, caissons, and pipes. The primary reason these marine constructions necessitate repairs with grouted clamps is due to damages incurred from vessel collisions or items falling overboard, typically occurring during the installation or intense construction processes. Clamps may also be essential for prolonging the fatigue lifespan of node joints or structural elements and are positioned around these components. Subsequently, these sections are secured together, and after pre-tensioning the bolts, grout is injected into the gap between the clamp and the existing tubular structure. Some key benefits of grouted repair methods consist of: - Grout can easily adapt to typical fabrication flaws in clamps - Grout accommodates existing member survey tolerances - It swiftly restores full, and often enhanced strength to compromised parts - Structural repair clamps can be installed at any depth on the jacket [6]. The grout selected for structural refurbishment can vary in formulation based on the specific needs of the project. The grout formulation may include a blend of cement, aggregates, superplasticizers, and anti-washout additives. Figure 4 illustrates an example of these clamps utilized in the North Sea in 2007 for the repair of a jacket member. The cement type employed in this clamp is CEM1 42.5 [6].

c. Emphasis Lightweight

Figure 5. Lightweight Emphasis

Another type of external clamp is a lightweight clamp that provides a local seal on the pipe surface. STATS GROUP first put forward the idea of using this type of clamp. These clamps are produced in two types: Strap and Pinhole. Sealing certain areas of the pipe reduces the sealing area and, thus, the load that needs to be supported. So, these clamps are much lighter and easier to handle than traditional repair clamps that encapsulate the entire circumference of the pipe. The main advantage of using light clamps is that they save time. The rope clamp has three main components, as depicted in Figure 5 [7].

1. Strap: this steel strap wraps around the pipe and provides mechanical restraint to the internal pressure acting on the clamp. It comes in two parts, which join geometrically from the seal

housing. The strap fits the pipe OD around the back of the pipe and then runs tangentially to the connection to the seal housing. Connection to the seal housing is by bolts installed directly in line with the load path, and the strap design maintains the load path in direct tension, minimizing weight.

2. Seal Housing: The seal housing is connected to a strap that completes the load support. Housings can be designed in a variety of configurations to provide the following:
   - Sealing plate for repair
   - Ported housing to allow hot tapping
   - Encapsulated housing that can accommodate pipe fittings

The connection to the strap is structural, and the connection to the seal cartridge is at the seal bore.

3. Cartridge Seal: The cartridge seal is a cylinder seal piston installed inside the seal housing. This cartridge seals the seal housing at the cylinder diameter and to the pipe at the compression seal diameter ('D' seal). The result is internal pressure (red), pressing the compression seal against the pipe [7]. The repair size accommodated with this design can vary but should be negligible about the pipe diameter (<25%). Pinhole leak clamps (Figure 6) have been developed to repair piping in oil and gas facilities. Installations can be performed with minimal disruption to the pipework or operation of the system in which they are installed. Designed for simple installation, pinhole leak clamps are designed to provide a fast and versatile solution for localized leak points. This clamp is used to repair pipes with a 2 to 48-inch diameter. The maximum pinhole size for pipes with a nominal diameter of 4 inches and below is 6mm, while for pipes with a nominal diameter of 6 inches and above is 12 mm. Critical features of pinhole leak clamps include:

- All sizes of pipe range 2' and above
- Pressure range: up to 153 Bar (900 lbs)
- Maximum pinhole size up to 12mm
- No preparation required
- Can be installed to leak directly
- Easy to install
- Xylan coating provides excellent corrosion resistance [8].

One type of clamp utilized in light clamps for urgent pipe repairs is the STOPKIT model from Brisma Afrika. It effectively halts various leakages (oil, gas, water) across pipe diameters ranging from 4 to 56, and is also compatible with certain geometries (aval pipes, elbows) and irregularities like welds. This item holds a patent for emergency and temporary systems and comes in multiple models (tailored to pipe and hole diameter) suitable for diverse settings (onshore, offshore, and subsea). It can manage pressures up to 80 bar for hole diameters under 10 mm (patch size 50x100 mm). For hole diameters reaching up to 50 mm, leaks can be sealed at pressures of up to 30 bar (patch size 100x100 mm). Installation can be completed without interrupting the pressure line [9]. The system functions by concentrating all necessary stress in the pipe at the defect site. The hoop tension required to halt the leaks is maintained by technical ties and screws (Figure 7). This robust rope fiber is resistant to temperature and stress. The specifications for these two types of clamps designed for offshore/subsea uses are detailed in Table 1.

d. Emphasi Swelded sleeve

Repairing corrosion damage, dents, and small cracks in pipes can be done by installing a welded sleeve around the pipe. The repair system consists of welding two half-pipe sections with an inner diameter equal to the outer diameter of the pipe around the damaged part, as shown inFigure & There are two types of sleeves used for this operation: Type A sleeves that are only seam welded without welding the ends to the original pipe, and Type B sleeves that are welded at the ends, contributing to full pressure containment around the damage [10].

Figure 6. Welded Sleeve Emphasis

5. Conclusion

Initially, this document examines the flaws and impairments found in marine conduits. Subsequently, all relevant parameters and their distinct sub-parameters associated with the enhancement technique are outlined. Following this, a range of appropriate repair strategies is presented in response to the identified flaws, along with a brief description of their applications. Based on the findings from this document, there are multiple approaches available for mending damage to offshore pipelines. An optimal choice can be made by evaluating the key factors influencing the enhancement and defining the objective function. In the Persian Gulf area, it is advisable to upgrade offshore platform components using pre-cured layered composite cladding to reduce installation time. The implementation of clamps is also suggested for notable defects.

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