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RTR Piping Technology in Oil and Gas Industry

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Abstract: **The corrosion and breaking of pipes in the upstream oilfield activities are due to salty water, carbon dioxide, and hydrogen sulfide gas emitted during the exploration and production of oil and gas. Also, the upstream activities involve high pressure and temperature that causes deformation and eventually tearing and leakages of oil and gas pipes. This causes huge financial losses and risks to the industry. The cost to repair the leakages and associated failures adversely affect the oil plant's production. To overcome this challenge, Saudi Arabia explored the technological solutions that can bring long-term solutions to the persistent leakages. The nonmetallic Reinforced-Thermosetting-Resin (RTR) piping has been considered a perfect replacement for the carbon steel piping in upstream oilfield. The RTR is made of composite materials resistant to high temperatures, high pressure, corrosion, and deformation from harsh environmental and operational conditions. The increased adoption of RTR pipes in the upstream sector has increased the lifecycle of pipes due to their resistance to corrosion and deformation by high temperature and pressure. The composite materials are lightweight, locally available, and cheap to acquire, with superior fatigue resistance to outstanding conditions than the conventional carbon steel pipes.**

Keywords: **(RTR) piping, salty water, carbon dioxide, carbon steel pipes.**

1. INTRODUCTION

Saudi Arabia is well known for oil exploration, production, and processing. These are energy-intensive activities that involve high temperatures, high pressure, and corrosion that conventional metal pipes cannot withstand. The persistent high pressure, temperature, and corrosion can compromise metallic pipes' structure, stiffness, and corrosion resistance, leading to leakages and related consequences in the oil industry if not addressed in time (Moser & Folkman, 2008). The oilfield and offshore operations require unique pipe designs and high quality to withstand corrosion, high temperature, and high pressure experienced during oil exploration and processing activities. To address this challenge, a comprehensive research was conducted on suitable materials that can manufacture high-performance pipes (Moser & Folkman, 2008). The current study explores the characteristics of Reinforced-Thermosetting-Resin (RTR) pipes that make them suitable for high-pressure and temperature oilfield and offshore operations.

2. BACKGROUND

The upstream oilfield operations are cost prohibitive due to corrosion, high pressure, and high that subject the conventional metallic pipes to structural failure and, subsequently, oil and gas leakage. Therefore, the upstream sector of the oil and gas industry needs reliable and fast systems that address the corrosive nature of the upstream oil field activities. The upstream oilfield delivery pipes must use corrosion, heat, and pressure-resistant materials. The Reinforced-Thermosetting-Resin (RTR) pipes are considered an appropriate replacement for conventional carbon steel pipes. RTR pipes are made of non-metallic and flexible material that can prevent frequent leakage, coating failure, and high maintenance costs experienced with carbon steel pipes (Moser & Folkman, 2008).

The RTR pipes provide both operational and economic relief to the oil and gas industry in Saudi Arabia because they are operationally flexible, cheap, and strong. The RTR pipes have resistive characteristics that can withstand adverse environmental conditions in Saudi Arabia (Moser & Folkman, 2008). Due to the resistive nature of the composite materials, the Reinforced-Thermoset-Resin (RTR) pipes, which are made of composite structures, have increasingly been adopted in upstream oilfield activities in Saudi Arabia.

3. RTR PIPE TECHNOLOGY

The RTR pipes have gained considerable popularity in the oil and gas industry over the years due to the technology used to solve persistent challenges such as corrosion, leakages, and the impact of high temperature and pressure in the upstream sector. The technology adopted in manufacturing the RTR pipes makes them resistant to corrosion and enhances the flexibility and stiffness to overcome adverse environmental and working conditions (Fahrer, 2012). The RTR has compositional variations, great design, and flexibility to withstand the impact of nature and tough working conditions.

RTR pipes are made using technology-based composite materials with high thermal, chemical resistance and ease of use. They include fiberglass reinforcements, thermosetting resins, and additives to obtain strength, chemical, heat, and corrosion resistance (Badeghaish et al., 2019). Several composites are involved in manufacturing the RTR pipes and have specific roles, as demonstrated in the table below:

Glass fiber types and functions	Resin types and functions	Additives in RTR pipes and functions
ECR glass Has good thermal and chemical resistance and high dielectric strength compared to other fiberglass types. It is more environmentally friendly because it is not made with boron trioxide and fluorine.	Vinyester resin This resin type withstands service temperatures over 1000 C and insulates the RTR pipes against high temperatures.	Fillers These components are used with resins and glass fibers to laminate the pipe with self-extinguishing properties to make them flame retardant. A typical example of fillers used in RTR manufacturing is antimony trioxide. The antimony trioxide coats other structural materials, such as resin, to form effective snuffing compounds.
Electrical glass (E-glass) It is one of the structural components used in the structural layer of the RTR pipes. It provides the strength and stiffness required by the RTR pipes to withstand working and environmental conditions.	Polyester Resin Are also called the isophthalic resin, with can withstand service temperatures below 1000C. This causes the RTR pipes to withstand temperatures in upstream oilfield activities.	Catalysts Catalysts are additives mixed with resins and other structural materials to control the polymerization reaction of the RTR pipes at ambient temperature.
Chemical glass (C-glass) It is a structural component wound around the RTR pipe to act as an initial barrier to corrosion. It has chemical resistance properties making it suitable for the RTR pipes used in the oil and gas industry.	Epoxy Resin This type of resin reinforces the physical and chemical properties of the RTR pipes, such as flexibility to avoid leakages at the connection points.	Accelerator and Inhibitors They are chemical compounds mixed with catalysts to reduce the polymerization time. Inhibitors mixed with resins reduce reactivity at ambient temperatures.

The thermosetting resins used in manufacturing the RTR pipes give out heat during the curing process; hence the pipes cannot melt or get reformed due to high temperatures in the upstream oilfield operations (Badeghaish et a., 2019). The primary composite materials used to make the RTR thermosetting resins include epoxy, polyester, phenolic resins, and E-type glass. The glass is a continuous strand or roving wound around the structure of the pipe using a centrifugal casting process (Fahrer, 2012). Furthermore, fillers are used to extend the resins in the RTR pipes; the fillers enhance the chemical and physical properties of the pipes. This causes the RTR pipes to be resistant to chemical corrosion and related effects (Fahrer, 2012). The reinforced resins, glass strands, and fillers give the RTR pipes high tensile strength, smoothness, and stiffness. The high tensile strength and stiffness features because the RTR pipes withstand the adverse working and environmental conditions in Saudi Arabia's upstream sector.

4. FABRICATION OF RTR PIPES

Several fabrication processes are involved when manufacturing the RTR pipes. They have different roles in ensuring the final RTR meets the required quality and performance. The processes include pressure molding, contact molding, centrifugal casting, pultrusion, and filament winding (Blaga, 1982). Filament winding involves mixing composite materials with the fillers to enhance the strength and stiffness of the RTR pipes. Moreover, filament winding ensures uniformity of the surface, and also increases the density of the product.

The biaxial winding is done using resins and glass fiber roving circumferentially and longitudinally to enhance the strength and stiffness of the pipes. Another method for making the RTR pipes involves helical winding of resin-impregnated continuous fiber roving at controlled helix angles to all selected directions but in a removable mandrel. After the winding of composite materials is mixed with additives, the pipes are then cured in a cross-linked method under heat (Blaga, 1982). The resulting product is a reinforced pipe with inner and outer layers. The smooth resin, acrylic, and glass fiber-rich surface of the RTR pipes makes the pipes corrosion and abrasion resistant.

5. PROPERTIES AND APPLICATIONS

The RTR pipes can withstand the upstream sector's adverse conditions because they can withstand high temperatures, high pressure, and corrosion. It has been the best choice for Saudi Arabia's oil and gas industry because all the above-mentioned adverse conditions are present during the exploitation and processing of oil and gas in the upstream sector (Blaga, 1982). Additionally, it finds its application in the oil and gas industry because it has a stronger structure and size that allows it to convey hundreds of cubic meters of sour crude oil for petroleum production at high pressure of up to 1200 psi and 660C (Blaga, 1982).

6. THE GENERAL PROPERTIES AND PRINCIPAL APPLICATIONS OF RTR PIPES

The Reinforced-Thermosetting-Resin (RTR) pies can be broadly categorized into Glass Reinforced Polyester (GRP) and Glass Reinforced Epoxy (GRE) pipes. The primary difference is the matrix resin and additives used in making the pipes (Blaga, 1982).

The GRP is manufactured using polyester resin and additives, which forms approximately 70 percent of the pipe material. However, the two must be cured with chlorine-based additives to improve the fire-retardant characteristics of the pipe (Blaga, 1982). A suitable choice of resin matrix also increases the ability of the TRT pipes to resist aggressive fluids and chemicals at high temperatures of more than 1000C.

Polyester resin has been used in GRP because it is mechanically stronger than other resins. However, it has a relatively lower temperature resistance characteristic. It is preferred for making the RTR pipes because it is cheap, readily available, and has good corrosion resistance features. It can also be molded to fit in pumps, tanks, and other fittings to increase the thermal, corrosion, and chemical resistance of other equipment used in upstream oilfields (Fahrer, 2012). Due to these features, the RTR has widely been adopted in the upstream oilfield sector because it can withstand high temperatures, high pressure, and corrosive processes in upstream oilfield activities (Robertson, 1983). It has become a suitable replacement for carbon steel pipes in Saudi Arabia's oil and gas industry.

The GRE uses bisphenol-a-based epoxy and epoxy novolac resins to enhance the flexibility of the pipes. Still, the bisphenol-a-based epoxy resins are cheap and easy to handle during GRE manufacturing processes, making them a priority for manufacturers (Blaga, 1982). Meanwhile, the epoxy novolac can withstand high temperatures and high solvent resistance, thereby increasing the structural stability and stiffness of the GRE pipes. The epoxy resins can be cured using different agents to change the properties of the final GRE pipes.

The main curing agents for epoxy pipes are aromatic amines and aromatic anhydrides. The aromatic amines increase the resistance of GRE pipes to salts, acids, and severe caustic and solvent solutions (Blaga, 1982). On the other hand, the aromatic anhydride curing agent increases the brittleness, chemical and caustic resistance of the final GRE pipes. The temperature limit for anhydride-cured GRE is 750C, while those cured with GRE cured with amines have temperature limits of more than 1000C. However, both curing agents are not resistant to inorganic acids and strong oxidizers (Blaga, 1982). Despite the polyester resin-based RTR pipes generally having large diameters and custom-made, epoxy-based pipes are preferred for upstream oilfield activities because they are suitable and can be used for various functions (Yu et al., 2017). For example, the unlined epoxy RTR pipe has high resistance to the actions of the crude oil and paraffin build, and at the same time, they can withstand high pressure and temperature surges in the upstream oilfield processes (Yu et al., 2017). However, the unlined RTR pipes have lower chemical resistance than the lined epoxy RTR pipes. Hence, it only handles solvents and solutions with salt, dilute acids, and alkalis. The good chemical resistance of lined epoxy pipes makes them suitable for use in environments with highly corrosive solvents. It offers solutions to corrosion and abrasion-related problems in processes involving severe exposure conditions.

7. PERFORMANCE OF RTR PIPE SYSTEM IN SAUDI ARABIA'S OIL AND GAS INDUSTRY

Saudi Arabia has adverse weather conditions; it is a desert that experiences extreme temperatures and corrosive conditions. The adverse weather conditions have significantly influenced the choice of piping materials. As a result, modern piping systems such as RTR have been adopted to combat corrosion and extend the life of the piping system, reducing the running cost of oil and gas plants.

The RTR pipes are suitable replacements for conventional carbon steel pipes due to their high-performance specifications and in-depth experience in various applications and advanced manufacturing processes. It has multipurpose functions due to its ability to withstand adverse environmental and operational conditions (Salibi, 2001). The degradation of the carbon steel piping with the adverse environmental and operational conditions causes huge financial losses to the oil and gas industry due to leakages and corrosion (Salibi, 2001). To minimize such losses, the oil and gas industries have resorted to affordable, non-corrosive pipe systems. The RTR pipe can operate in saline underground conditions, high temperatures of more than 1000C, and high pressure of more than 175 bars (Salibi, 2001). Therefore, it can operate continuously underground, undersea, and above ground.

8. LOADING CONDITIONS FOR RTR PIPES FOR OFFSHORE APPLICATIONS

The loading conditions are a critical aspect of determining the design of offshore pipes. Parameters like thickness and diameter play a critical role in determining the success of the pipes and avoiding huge impacts on the economy and environment (Yu et al., 2017). The offshore pipes are long to reach long distances to reduce the transportation costs of the oil and gas industry. Thus, the parameters must adjust depending on the length and the volume of petroleum it is supposed to transport. The following datasheet demonstrates the RTR parameters that make it suitable for dynamic offshore loading.

Nominal diameter	Unit/Size	3"	4"	5"	6"
Internal diameter	mm	74	101	127	152
External diameter	mm	102	135	162	191
Design pressure at 600C	Bar	55	43	37	32
Burst pressure at 200C	Bar	284	218	189	165
Burst pressure at 600C	Bar	210	161	140	122
Minimum bending radius at 200C	M	0.7	0.9	1.1	1.2
Weight in air empty	Kg/m	3.7	5.8	7.5	9.6
Thermal exchange coefficient at 200C	w/m. K	4.6	5.7	6.7	7.5
Maximum length on one reel	M	1800	1000	500	250

Offshore pipes experience different loading conditions based on the type of load, pressure, and temperature. The RTR is designed to ensure safety and sustainability during offshore loading conditions. The common failure during offshore operations is dynamic loading, fatigue damage accumulation, and long-term loading, which leads to deformation and corrosion of conventional carbon steel pipes (Yu et al., 2017).

9. THE ECONOMIC RELEVANCE OF USING RTR PIPES IN UPSTREAM SECTOR

The utilization of RTR pipes in Saudi Arabia's oil and gas industry has significantly increased the lifetime of the piping system, which is usually expensive to repair. This leads to cost savings on installing and maintaining the upstream systems (Cheldi et al., 2019). It has also eliminated the rework due to the leakages, bursts, and abrasions that largely affected the conventional carbon steel piping system.

The composite materials used to manufacture the RTR pipes are lightweight, easy to handle, and can handle large volumes of oil and gas at a time. This increases the productivity of the oil and gas plants, therefore, increasing their profitability. Moreover, the resistance to corrosion, high pressure, and temperature make it versatile. It can be used in all areas within the oil and gas industry, thereby reducing the costs of acquiring different piping systems for different sections (Cheldi et al., 2019). It expands the operation envelope of current materials to increase their deployment for cost savings and efficiency in the upstream piping systems.

10. CONCLUSION

The upstream oilfield operations are cost prohibitive due to corrosion, high pressure, and high temperature that subject the conventional metallic pipes to structural failure and, subsequently, leakage that has adverse cost implications in the oil and gas industry. The upstream sector of the oil and gas industry in Saudi Arabia has adopted reliable and fast systems that address the challenges resulting from the corrosive nature of the upstream oil field activities. The Reinforced-Thermosetting-Resin (RTR) pipes are an appropriate replacement for conventional carbon steel pipes. They are made of non-metallic and flexible material that can prevent frequent leakage, coating failure, and high maintenance costs experienced with carbon steel pipes. The RTR pipes provide economic and operational relief to the oil and gas industry in Saudi Arabia because they are operationally flexible, cheap, and strong. Furthermore, the RTR pipes have resistive characteristics that can withstand adverse environmental conditions in Saudi Arabia. Due to the resistive nature of the composite materials, the Reinforced-Thermoset-Resin (RTR) pipes have increasingly been adopted in upstream oilfield activities in Saudi Arabia.

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