Implementation of Tite Liner technique for maintenance and rehabilitation of a Colombian oil pipeline

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Abstract. One of the greatest challenges for petrochemical industry is corrosion prevention, mitigation and control, a phenomenon that generates a high negative impact due to materials degradation and that in recent years has increased as a result of multiphase fluids processing. Thus, there are different mechanisms of damage by internal corrosion that are generated during transport of multiphase fluids with high content of corrosive agents such as carbon dioxide, solid particles and sediments increased because of transport conditions. The technique Tite Liner was used for maintenance and repair of a Colombian oil pipeline with severe integrity problems. Equally, design and tuning of physical and chemical properties of the coating material was carried out, since they remained unchanged during thermofusion welding process, the initial compression for insertion in the system, the subsequent expansion to fit the pipeline internal dimensions and the system start up at high pressure. The experimental analysis displayed an improvement in the operational conditions of the line. This led to a decrease in the operating expenses of the pipeline, directing those assets in the physical recovery of other industrial equipment inherent to the hydrocarbon transportation process.

1. Introduction

New technologies have now been developed in Oil & Gas industry to control corrosion, erosion and CO₂ corrosion problems in pipelines that transport fluids with high corrosive potential. One of the main technologies developed for this purpose is the use of Liners, which correspond to pipes made of different materials that are used to rehabilitate, reinforce or replace sections of metal or plastic pipes that have deteriorated during their operation.

In this category are thermoplastic Liners, which have been widely used to mitigate corrosion, reduce use of inhibitors, reduce pumping costs and avoid replacement of a system, reducing losses associated with stops and unscheduled interruptions in hydrocarbon transport systems [1]. One of the most efficient techniques on the market is the one called Tite Liner®, which was developed in 1985 by United Pipeline Systems and consists of the insertion of a polymeric Liner inside a steel pipe, with diameters ranging from 2 inches to 52 inches and lengths that can reach 1,000 m according to pipeline conditions such as bends, diameters and soil [2].

A main characteristic of the Tite Liner technique is that, in addition to being used in new pipes, it is also possible to use it in old pipes that present significant wall thickness losses in order to rehabilitate...
them for a new period of operation, avoiding the component and/or system replacement. In these cases, the coating remains adhered to the internal walls of the pipe, forming a physical barrier that mitigates the chemical and electrochemical phenomena on the internal walls of the pipe caused by the products used in the operation [3].

This coating system is highly reliable for highly corrosive chemical products or processes used in Oil & Gas industry since its use can avoid damage caused by salt encrustations and flow rates generated in transport, optimizing the resources and increasing the reliability of the different units. There are different factors that must be taken into account during the selection process of the Liner’s manufacturing material, such as the type of fluid transported, exposure time and system temperature, among others.

In case of the type of fluid transported, it must be taken into account the affectation degree that can be caused on the chemical resistance of polymeric materials, since partial or total degradation of the Liner may occur. This degradation is produced by breaking of the chemical bonds of the polymeric chain, decreasing its ductility; or in the cases in which chemical absorption of the fluid occurs in the free spaces of the material volume, the result is expansion of the material and stiffness loss [4,5].

For its part, the influence of the system temperature in the selection process is critical because the cost of manufacturing and maintenance of Liner increases at higher temperatures. In addition to this, mechanical properties such as tensile strength, elongation, and yield strength are also strongly affected by this variable. Among the materials most frequently used in Liners manufacture are: ethylene butyl acrylate, polypropylene, fusion–bonded epoxy, medium or high–density polyethylene, different polyamides and polyvinylidene difluoride, among others [6].

High–density polyethylene (HDPE) is one of the materials with the greatest use potential for rehabilitation of metal pipeline pipelines susceptible to different damage mechanisms and fluids with solids, chlorides, acidity and CO₂ content that increase the degree of corrosivity [7]. HDPE is produced at low pressure by polymerization of ethylene with alpha–olefin, and its crystallinity and density can be controlled during the process. In market there are different grades of polymer used as Liners, commercially designated as ASTM PE–3408, ISO P –80 and PE–100 [8]. HDPE Liners manufacture is carried out through the process called thermofusion, which consists of heating the HDPE pipes ends or fittings to a certain temperature and applying a linear pressure with respect to the pipe axis to achieve the mixture and perfect union of the pieces [9].

Generally, efficiency of Liners in Oil & Gas industry is evaluated through the pipeline reliability, which corresponds to the probability that it will operate without failures during a period of time and conditions determined to avoid generation of accidents and human, economic and environmental impacts [10]. The life cycle of a Liner comprises the stages of construction, installation, start–up, operation and removal, which is why it is of great importance to implement an inspection plan that includes the use of non–destructive tests such as visual inspection, installation and real–time monitoring of pressure transmitters and the use of Smart Pigs for online inspections [6]. Taking this into account, this work presents the process of construction, installation, start–up, evaluation and control of a HDPE Tite Liner in a Colombian oil pipeline, in order to guarantee the integrity of the pipeline and reduce operational failures of the system to improve productivity.

2. Experimental

Before installing the Tite Liner system in the pipeline, hydrostatic tests were carried out to verify the real state prior to rehabilitation. Additionally, a sweep was carried out with a cleaning pig in order to rule out dents or mechanical damage in the existing pipe, and in case of any type of rupture, the repair was carried out.

To implement the Tite Liner system, the layout of the existing oil pipeline to be rehabilitated was established in order to identify curves, and there were defined areas where the excavations were carried out taking into account the topography conditions and areas of equipment location. In excavation areas a cut of the existing pipe was carried out, flanges were installed and threaded holes were made that
allowed ventilation and reduced the annular space between the external walls of the HDPE Liner and the internal walls of the pipeline [11].

The HDPE Liner was constructed through the thermofusion welding process shown in Figure 1, where the two ends were heated, pressed together and allowed to cool, confirming that the finished weld retained the same properties as the initial pipe. Once the system was built, the pulled head was installed at one end, also joined by thermofusion in order to hold it and take it to the other end.

Subsequently, the HDPE Liner was inserted using a pulling cable tied to a pig driven by compressed air, which ran through the pipe to be rehabilitated at constant speed, passing through a Roller Box that was responsible for reducing the external diameter of the Liner, guaranteeing that the diameter reduction was less than 10% so as not to plastically deform the HDPE Liner [6]. Once the insertion was completed, a cut was made to release the tension and allow the coating to recover its initial dimensions and adapt to the shape of the pipe to be rehabilitated, taking into account that the external diameter of the HDPE Liner is greater than the internal diameter of the pipeline.

To finish the process, the stub ends were installed by thermofusion, which were also manufactured in HDPE with the appropriate size to be coupled to the projecting edge of the carbon steel flanges present in the pipe to be rehabilitated as shown in Figure 2. In addition to this, a metallic separator was installed to avoid damage to the edges when making the connection between sections. Finally, in order to ensure the tightness and resistance of the installed system, pneumatic and hydrostatic tests were carried out following the Guidelines established by the ASME NM–1 standard [11].

**Figure 1.** Thermofusion welding process and construction of the insertion system.  
**Figure 2.** Stub end installation.

## 3. Results and discussion

Definition of the route and geographic location of the pipeline to be rehabilitated was carried out by georeferencing using the Google Earth tool as detailed in Figure 3. Taking into account this information together with the region topography, the strategic areas were identified for carrying out the cuts and welds by thermofusion of the HDPE Liner, following the procedures and safety guidelines in the use of available equipment and tools.

Along the pipeline to be rehabilitated, a total of 34 cuts were made for installation of the HDPE Liner, using metallic separator with variable thickness between 11 mm and 24 mm and a total of 70 stub ends (one at the beginning of the pipe, one at the end and two for each cut) that allowed to guarantee the tightness of the system and avoid leaks during the operation. The initial external diameter of the HDPE Liner was 212 mm, which was compressed to be inserted and finally obtain a size equal to the internal diameter of the pipe to be rehabilitated, equivalent to 202 mm. Figure 4 shows the number of thermofusion welds in each cut, 1,887 in total, as well as the length of the HDPE Liner installed, reaching a total installed length of 23,630 m.

It is important to highlight that the entire process carried out, including the design, identification of physical and chemical properties for material selection, identification of the system operating conditions, identification of cutting points, HDPE Liner installation and evaluation, pipeline start up and reliability monitoring was carried out by local personnel, who were trained to carry out all operations.
associated with the process. Thanks to this training of local personnel, it was possible to increase the technological knowledge available in the country, and based on the procedure developed in this work, the rehabilitation of other Colombian oil pipelines is projected through new personnel training, aiming to guarantee the reliability of the entire Colombian natural gas transportation network in medium and long–term.

![Figure 3. Geographic location of the pipeline.](image)

![Figure 4. Thermofusion welds and length of installed HDPE Liner.](image)

Table 1 shows the results of the pressure tests carried out on the pipeline after rehabilitation, where it is evidenced that the system is within the normal operating range. Additionally, the execution of pneumatic pressure tests allows to reduce the annular space between the internal wall of the carbon steel pipe and the external wall of the HDPE Liner, guaranteeing maximum adhesion between the two surfaces, while the execution of the hydrostatic pressure test allowed to guarantee the tightness of the system and the integrity of the pipeline with the new operating conditions [11].

| Test          | Pressure (psi) | Time (hours) |
|---------------|---------------|--------------|
| Pneumatic     | 110           | 1            |
| Hydrostatic   | 485           | 12           |
Generally, the maximum operating temperature established by the manufacturer and regulations for HDPE Liner is 40 °C (104 °F). When the material is operated above this temperature, it is possible that softening, deformation and bulging of the HDPE Liner may occur, which considerably affects the efficiency of the material [8]. However, in the case of the pipeline to be rehabilitated, the maximum operating temperature could be increased to 60 °C (140 °F) because the HDPE Liner did not replace any section of the pipe, but was inserted inside, so the presence of this metallic pipe helped to contain the pressure of the fluid and avoid deformations of the plastic material, thus expanding the operability range of the system [12]. Table 2 shows the maximum operating pressure values of the pipeline at 60 °C before and after rehabilitation, where the significant increase in the maximum pressure supported by the system is evidenced, which allows increasing the flow of the fluid transported and, in this way, increase the efficiency and profitability of the transport operation [8,13].

Table 2. Operational conditions of the pipeline.

| Material                  | Pressure (psi) |
|---------------------------|----------------|
| Carbon steel              | 190            |
| Carbon steel+HDPE Liner   | 400            |

Finally, Figure 5 shows the reliability projection of the pipeline if rehabilitation had not been carried out, calculated using the Weibull model based on failure data from the previous year. Additionally, in the graph it is observed that real reliability of the system was equivalent to 100% for the last 12 months from the moment in which the rehabilitation with the HDPE Liner was carried out, due to the fact that no type of failure has occurred which allows confirming the effectiveness of the implementation of the Tite Liner technique in the corrective maintenance of pipelines and hydrocarbon transport lines [14].

One of the greatest favorable aspects obtained in this work is the mitigation of the environmental impact produced by the Oil & Gas industry. This is due to the fact that Colombian geography forces the pipelines used to transport natural gas to cross various ecosystems on their route, which can be seriously affected by leaks of the multiphase fluid transported in the pipelines, as has been evidenced by other authors [15,16]. In this way, the appearance of leaks in the route between natural gas wells and processing plants is prevented by guaranteeing the reliability of the pipelines, mostly eliminating the effects on ecosystems to accomplish environmental responsibility goals.
4. Conclusions
Design of Tite Liner technology implies knowledge of the physical and chemical properties of the materials used in rehabilitation of multiphase fluid transport systems, and its implementation in this Colombian pipeline required the identification of system operating conditions, such as maximum operating temperature (140 °F) and pressure (close to 500 psi). From identification and analysis of these conditions, high-density polyethylene was selected as the material with the best benefit–cost ratio in execution of the rehabilitation process through the internal lining of the pipe, in contrast to traditional high–cost systems aimed to pipeline sections replacement. Additionally, the costs associated with the maintenance of the HDPE Liner are significantly lower compared to the traditional maintenance used in Oil & Gas industry for carbon steel pipes, since solid deposits are eliminated and the transport of more abrasive fluids is enabled thanks to its mechanical and chemical properties.

Through implementation of the Tite Liner technique, favorable results were achieved for the rehabilitated pipeline, increasing the maximum operating pressure that allowed guaranteeing the integrity of the system and increasing productivity. Additionally, after a year of continuous operation of the pipeline since the execution of the rehabilitation using the Tite Liner technique, the stability in the reliability of the system was evidenced, for which it was demonstrated that this technique was implemented properly and safely, since until currently there has been no type of failure. Thanks to the acquired reliability, it was possible to mitigate pollution of ecosystems that the pipeline passes through, which is caused by spills that occur when the pipes leak the transported fluid, in such a way that a positive environmental impact was obtained.

Additionally, the Liner installation process was carried out in its entirety by local personnel who were trained for this task, and these personnel were in charge of monitoring and calculating the reliability projections of the pipeline, allowing a decrease in dependence of national industry on services of foreign industry and contributing to technological development of the country. Similarly, thanks to the training of local personnel, it is possible to project the implementation of the Tite Liner technique in multiple pipelines located in the national territory, helping to improve the natural gas transportation and distribution system throughout the country to increase the life quality of inhabitants and contribute to social development.

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