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REHABILITATION OF CORRODED PIPELINES THROUGH PRESSURE-CONTAINING SLEEVES REPAIR

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Abstract: Pipelines are safe and reliable facilities for the transportation or transfer of hydrocarbons between borders of geographically distinct operating units. However, defects occur that can affect its integrity during the life of the pipeline. In the present work, the pressure-containing sleeves repair technique is presented as an important alternative for the rehabilitation of corroded pipes. Special attention will be directed to the two most important caution for a successful repair by in-service welding on a pipeline that has had an extensive region of severe external corrosion. They are the risk of hydrogen-induced cracking (HIC) and the risk of burn through (or burnout) pipeline wall.
Keywords: Corrosion, pipeline, in-service welding, pressure-containing sleeves.

INTRODUCTION

In general, damage to a pipeline (or any other static equipment) can be defined as the transformation that occurred in the microstructure of its material or alteration in its design geometry, resulting from its working conditions. Thus, if no repair activities are carried out and the damage mechanism continues to act, the initial damage will evolve (by the accumulation of new damages), until it becomes a defect (when it jeopardizes the functionality of an oil or gas pipeline, for example). The result will be the structural failure of the equipment, with the consequent loss of containment of the transported fluid [1].

Among the various damage mechanisms that can affect the integrity of a pipeline throughout its life, corrosion processes that lead to loss of wall thickness is one of the most recurrent. And, consequently, inspections, structural integrity assessments and repairs are increasingly common activities for the inspection and maintenance teams of pipelines in operation, since a failure that leads to the loss of containment of an oil pipeline, for for example, it would cause oil leakage, forced interruption of the operation/transfer of hydrocarbons and damage to the environment [2].

Among the various repair techniques possible for the rehabilitation of corroded pipelines, one can mention the replacement of the section, the repair with composite material or the installation of pressure-containing sleeves repair. The latter consists of in-service welding (that is, with the pipeline in operation), of structural elements to reinforce a pipeline or pipe. This structural element consists of two gutters that fit over the entire circumference of the tube [3].

However, three important risks must be considered before deciding by pressure-containing sleeves repair: (i) the risk of cold cracks induced by hydrogen absorbed during the welding process, (ii) the risk of electric arc welding penetrates through the pipe wall and, lastly, (iii) the risk of unstable decomposition of the product carried by the temperature and pressure reached inside the pipeline or pipe [4].

In the present article, only the first two situations will be considered, since evaluating the risk of unstable decomposition of products would be outside the scope of this work.

The risk of hydrogen-induced cracking (HIC), it is associated with three controlling factors (diffusible hydrogen, susceptible microstructure and tensile stresses). Thus, this risk can be reduced by controlling hydrogen during welding (using low-hydrogen consumables, for example), as well as controlling the microstructure in the heat affected zone (HAZ). This, in turn, is performed by controlling the hardness of the material, since the increase in hardness contributes to the formation of cold cracks and the hardness depends on the chemical composition of the material and the cooling rate in the welding. The hardness value normally accepted as the upper limit to avoid HIC in carbon or low-alloy steel welds is 350 Vickers [3, 4].

Regarding the risk of burnout, studies have determined that the risk of burn through pipeline wall is imminent when the temperature on the internal surface of the welded pipe reaches values above 1,260 ºC. Thus, lower values were arbitrated as a safety margin: 980 ºC for low hydrogen electrodes and 760 ºC for cellulosic electrodes [3, 4].

In practice, the use of a Welding Processure Specification (WPS) is mandatory. A WPS specifies the type of consumable and the welding energy or heat input is limited, in addition to the use of numerical simulation in software to assess the risks already mentioned, that is: hydrogen-induced cracking (HIC) and burn through pipeline wall. In Figures 1.a and 1.b, there are examples of cold cracking and pipe drilling.

GOAL

To present control parameters for the technique of rehabilitation of corroded pipelines by pressure-containing sleeves repair, in sections of pipeline with high loss of thickness, to restore the mechanical strength of the material.

MATERIAL AND METHODS

Pipeline operating companies usually have their own procedures and standards for pressure-containing sleeves repair activities [3, 4], in addition to meeting specific international standards, such as ASME PCC-2: Repair of Pressure Equipment and Piping and API 1104: Welding of Pipelines and Related Facilities.

For the present article, a real case of successful repair in a buried pipeline was considered, where severe external corrosion was identified during inspection by an instrumented pig, of the MFL type (Magnetic Flux Leakage Pig) [7]. Table 1 shows the main design data for the pipeline. In turn, in Figure 2, you can see photographs taken during the field validation for the defect reported in the inspection. It can also be seen in Figure 2.b that corrosion sockets with a depth of up to 6.0 mm were identified on the external surface of the pipeline, when its nominal wall thickness was 7.9 mm.

For the repair, an EPS was used, whose welding parameters established a welding energy between 23.91 and 38.40 kJ/in, or 0.90 and 1.53 kJ/mm [8]. The welding energy can be determined through Equation 1 [4]:

$$\text{Heat Input [kJ/mm]} = \eta \times \frac{\text{Tension [V]} \times \text{Current [A]}}{1000 \times V_S\text{[mm/s]}} \qquad (1)$$

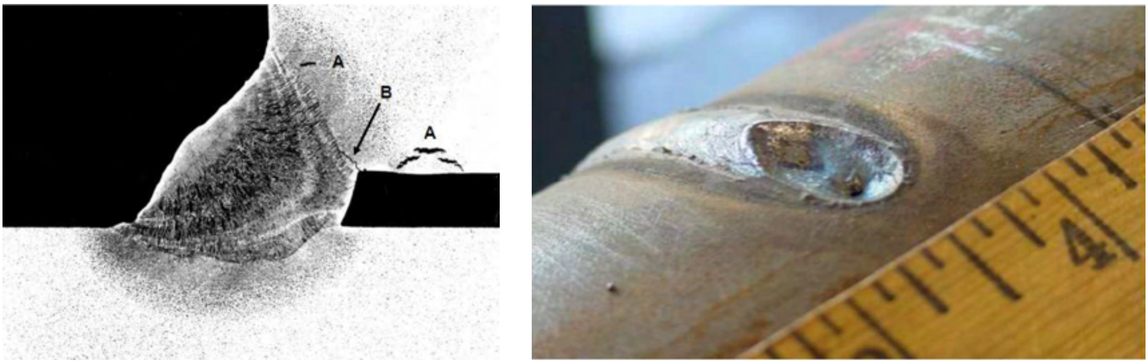
Where η is the thermal efficiency of the process and Vs is the welding speed.

For the thermal simulation, the PRCI software was used (from Pipeline Research Coucil International), which, through the EPS welding parameters, the welding energy, the chemical composition of the material and the design and operation data of the pipeline, estimated the resulting hardness in the HAZ and the temperature reached on the internal wall of the pipeline in the region of the weld.

RESULTS

In the thermal simulation, according to Table 2, a maximum temperature on the inner surface of the pipeline wall of 659 °C and a maximum hardness in the HAZ of 224.96 Vickers were obtained. The software also generated the curves illustrated in Figure 3.

In Figure 4, there is a photographic record of the moment when the longitudinal weld was performed for the installation of pressure-containing sleeves. As foreseen in the EPS, the root pass was carried out using the GTAW – Gas-Shielded Tungsten Arc Welding process.



a) *b)*

Figure 1 – Pipe faults: a) HIC at fillet joint of pressure-containing sleeves repair, b) burnout due to excessive heat input [5, 6].

Design Standard	ASME B31.4	Operating Temperature	90 °C
Construction year	2004	Year of Start of Operation	2005
Operating Pressure	9 ~ 42 kgf/cm^2	Coating	3LPP[1]
Design Pressure	90 kgf/cm^2	Material Specification	API 5L X60
Nominal diameter	14”	Nominal Thickness	7,90 mm
1) Triple layer in polypropylene.			

Table 1. Main Features of the Pipeline [8]

a) *b)*

Figure 2 – Photographs of the pipeline after trenching for validation: a) corrosion pits in the most critical region, b) measurement of the pit depth – 6 mm [8].

CASE	Heat Input [kJ/in]	Maximum Internal Temperature [°C]	Maximum Hardness [Hv]
1	23,91	547	224,96
2	38,40	659	190,92

Table 2. Thermal Simulation Results in the PRCI [8]

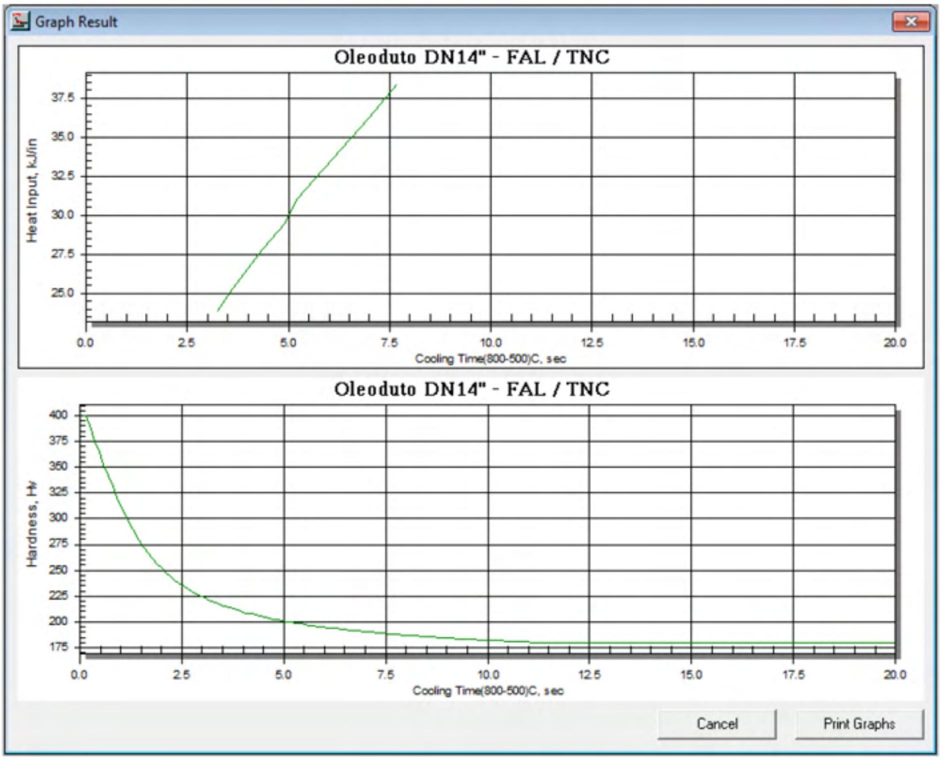


Figure 3 – Welding Energy and Hardness Curves from PRCI software [8].

Figure 4 – Longitudinal welding of the root pass for the installation of the pressure-containing sleeves using the GTAW process – *Gas-Shielded Tungsten Arc Welding* [8].

The filling passes were performed with a coated electrode (SMAW – *Shielded Metal Arc Welding*).

DISCUSSION

It can be seen from Table 2 that the internal temperature and hardness in the HAZ vary differently in relation to the welding energy used. Observing case 2, for example, while for the higher heat input, the estimated welding temperature on the inner surface of the tube was the highest, on the other hand, the estimated final hardness for the material obtained the lowest value. For case 1, with a lower welding energy, the lowest temperature was reached on the inner surface and the highest hardness in the HAZ.

The explanation for the behavior of the internal temperature in relation to the welding energy is trivial: higher heat input implies higher internal temperature in the pipeline wall. On the other hand, although the hardness behavior does not seem so obvious, it can be explained in terms of the cooling rate. For example, if a welding energy (heat input) of 30 kJ/in is used, according to the upper curve of Figure 3, the cooling time at transformation temperatures (t8/5 – cooling time from 800 to 500°C), will be equal to 5 s (five seconds). And, by the lower curve of the same Figure 3, the estimated hardness in the HAZ will be 200 Hv. Therefore, higher values of the welding energy will require a longer time for their cooling (that is, they will have higher cooling rates), which reduces the probability of martensite formation in the HAZ - which is attested by the lowest value obtained for hardness of material.

CONCLUSIONS

According to what has been exposed, it is concluded that the heat input of the EPS used did not pose a risk to repair by in-service welding (using the pressure-containing sleeves repair) for the pipeline in question. This is because welding in operation will be successful as long as a safe range is determined for the welding energy to be used in the repair. This interval, in turn, is limited at its lower value by the microstructure that does not offer a risk of cold cracking as a function of the hardness reached (HIC) and, at its higher value, by a heat input that does not burnout the pipeline wall in the welding.

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