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ANALYSIS OF REMEDIATION OF MANIFOLD LINE DAMAGED BY LONGITUDINAL CRACK IN THE PIPING ELBOW OF OIL AND GAS WELL COLLECTOR

ANALIZA SANACIJE CEVOVODNOG SISTEMA SA PETLJAMA OŠTEĆENOG PODUŽNOM PRSLINOM U CEVNOM KOLENU NA SABIRNIKU NAFTNIH I GASNIH BUŠOTINA

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- manifold
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Ključne reči
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- sanacija

Abstract

The paper deals with damage mechanisms affecting the piping and piping elements during working life of the well collector as an integral part of the upstream plant. An initiated crack has propagated in the vertical piping elbow and caused leakage. The damaged elbow has a sensitive cut, and a new elbow is welded onto the pipe by GTAW and SMAW processes. Necessary NDE was performed after repair welding activities showing that remediation of the line is properly conducted. The line is successfully put into service.

Izvod

U radu su prikazani mehanizmi oštećenja koji utiču na cevovode i elemente cevovoda tokom radnog veka bušotinskog sabirnika kao sastavnog dela uzvodnog postrojenja. Inicirana prslina se širila i izazvala curenje na vertikalnom delu cevnog kolena. Oštećeno koljeno ima osetljivi rez, a novo koleno je zavareno na cev postupcima TIG i MIG. Zahtevana IBR su obavljena posle radova reparaturnog zavarivanja, čime se pokazalo da je sanacija linije provedena na odgovarajući način. Linija je uspešno puštena u rad.

INTRODUCTION

Generally, a large number of classifications of oil and gas plants exist, and within the framework of these classifications is a classification of plants according to the plant position in sense of treating the raw material. According to this, oil and gas plants can be classified into upstream, middle stream, and downstream. In this paper we are dealing with problems of upstream plant operation, /1/.

Upstream plants are process plants where rough treatment of raw material takes place and in the first step it generally includes purification of raw material (oil and gas) from sand and small stones in gravitational separators. Further rectification of raw material takes place through desalinisation, dehydration, and sweeting processes, while final purification (especially) of gas take place in processes that include the removal of ethane and mercury. After finishing previously mentioned processes, oil and gas are transported by pipelines to appropriate downstream plants (refineries), /2/.

Generally, upstream plants are designed so to include (to be surrounded with) as much as possible oil and gas, as well as water wells, positioned at what is a possible shorter distance from the plant. The plant is usually connected with the wells in two ways.

One way is a direct connection of the plant with the well and by rule includes connecting the plant with the closest (surrounding) wells by direct trunk lines. Another way is indirectly, where the plant is connected to well collectors via direct trunk lines. Namely, for the well located far away from the plant to be directly connected to the plant, but on the other side (most often) the closest to the plant compared to other wells, a well collector is built, used for collecting oil and gas from the other wells, that are farther away.

The line from the well with a built collector and lines from surrounding wells are introduced in the main manifold from where the mixed flow goes to the main pipeline toward the plant, or to the test separator vessel (for required quality control), and then to the upstream plant. The main manifold is connected to the wells by direct trunk lines and the regulation of flow and pressure entering the manifold is regulated by an appropriate system of valves. Additionally, the flow and pressure between the main manifold and main pipeline, in the test separator, is regulated by a system of valves. The line between the manifold and pipeline consists of many piping fittings (T-reducers, elbows, pipe reducers), valves of different types and purposes, /3/, problems related to the operation of these lines is not fully researched in literature and the main goal of this paper is to analyse the remediation of these lines with a long time service.

Classifications of pipe elbows

As previously mentioned, lines to the well collector, connecting the main manifold, and the pipeline which further leads the flow toward upstream plant, consist of many piping fittings. Among other things, this line consists of piping elbows. A piping elbow is an element mainly used for con-

necting two pipes. It is a pipe fitting that enables the change of pipe direction. Generally, piping elbows can be classified according to several criteria such as:
- instruction angle;
- link type;
- size and span;
- material and manufacturing process.

According to the direction angle of the elbow, elbows are divided as: 90-degree; 45-degree; 180-degree elbows (return elbow), (in special constructions 60-degree and 120-degree elbow) and any angle elbow. Elbows according to link type are usually classified into following categories:
- welded elbows - attached to the piping system by welding;
- threaded elbows - with threaded connections, appropriate for the requirement to dismantle the component;
- flange elbows - connected to the piping system by flange, appropriate in the need for constant disassembly events;

Elbows according to length are usually classified as:
- short elbows - reasonably of small size, generally utilised in pipelines where area is limited;
- long elbows - of longer length, suitable for scenarios calling for a bigger bending span.

According to the material and manufacturing process, elbows can be divided into following categories:
- malleable iron elbows;
- pressed elbows;
- stamped welded elbows;
- welding elbows;
- high pressure elbows;

The malleable iron elbow is the most common threaded elbow. Specifications of malleable iron elbows are relatively small, and commonly used specifications range from ½ to 4 inches. According to their different surface treatment, they are divided into two types: galvanized and non-galvanized (Fig. 1).

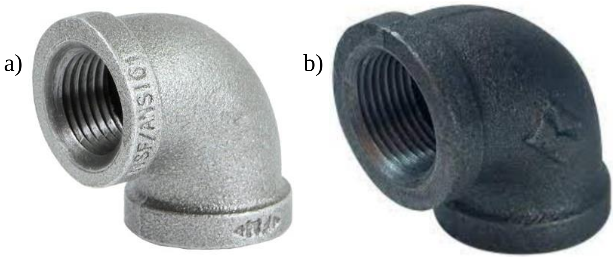

Figure 1. Malleable iron elbow: a) galvanized; b) non-galvanized.

Malleable steel pipe elbows have low strength and hardness, but good plasticity and toughness. They are used for parts with small loads and high impact and vibration, mainly for heating, upper/lower water- and gas pipes.

Pressed elbows, also known as stamped elbows or seamless elbows are formed by pressing high-quality carbon steel, stainless acid-resistant steel, and low-alloy steel seamless pipes in a special mould.

The bending radius of the long radius elbow is 1.5 times the nominal diameter ($R = 1.5{\times}D_N$), used in places where the pressure is high, or the flow rate is high. In the low-pressure fluid or where the elbow is limited, the short radius elbow with a bending radius equal to the nominal diameter ($R = D_N$) is used (Fig. 2).

Figure 2. Pressed elbows: a) long radius; b) short radius.

Usually, these elbows are made in the range ¾ inch up to 24 inches. The wall thickness range is the same as that of seamless steel pipes. Pressed elbows are generally stamped and processed by professional manufacturers or processing plants with standard seamless steel pipes. Both ends of the elbows should be bevelled before leaving the factory.

Stamped (and welded) elbows are formed by stamping a half-ring elbow from a plate through a die and then welding the two half-ring elbows together. Its bending radius is the same as that of a seamless pipe elbow, and its specification range is over 200 mm in nominal diameter (Fig. 3).

Figure 3. Stamped pressed elbow.

Welding elbows are usually made in two ways. One is to use a steel plate as the raw material, then cut and roll it and weld in the processing plant. Most of them are used for the matching of steel-coiled pipes. The other way of manufacture is to use pipes as raw material, and then form them by assembling and welding. Its specifications are generally above 200 mm. Operating temperature cannot be above 200 °C and can be produced at the construction site (Fig. 4).

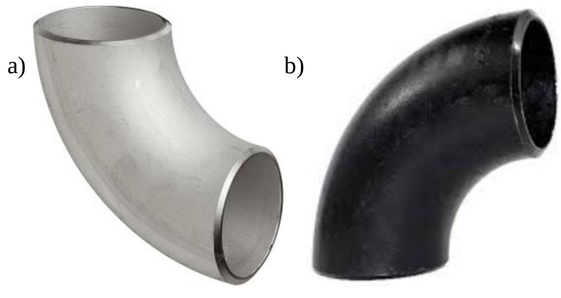

Figure 4. Welding elbow: a) white; b) black.

High-pressure elbows are forged from high-quality carbon steel or low-alloy steel. According to the form of pipe connection, both ends of the elbow have machined threads or grooves. Processing precision is very high, and it is required that the thread on the nozzle and flange can be closely matched and can be freely screwed in without loosening (Fig. 5).

Figure 5. High-pressure piping elbow.

These types of elbows are suitable for petrochemical pipelines with pressures of 22 MPa and 32 MPa, and commonly used specifications range from ¼ to 8 inches. According to the previously mentioned classification of piping (pipeline) elbows, our attention here is focused on welding elbows /4-5/.

Design and material data of the manifold line

Operating problems of the manifold line analysed in this paper are related to the 20″ manifold line, which is nearing 20 years of continuous service. Main design data and materials for fabricating the manifold line are shown in Table 2.

Table 2. Design data of the 20″ manifold line.

No	Item	Value	Parameter
1	Pipe material	API5L-X65	ERW
2	Size	20	inch
3	Length	38.0	m
4	Wall thickness	14.27	mm
5	Corrosion allowance	7.30	mm
6	Elbows size	20	inch
7	Elbow thickness	14.27	mm
8	Design pressure	89.0	barg
9	Design temperature	100.0	°C
10	Operating pressure	33.1	barg
11	Operating temperature	69.0	°C
12	Test pressure	97.0	barg
13	Test method	Hydro-test	-
14	Fabrication class	A6	-
15	PWHT	No	-
16	Radiographic testing	100	%
17	Ball valves	2 pcs	A216WCB
18	Globe valves	2 pcs	A216WCB
19	Ring joint gaskets	8 pcs	SS-TP316
20	Flanges	8 pcs	ASTM-A694
21	Flanges	2 pcs	ASTM-A105
22	Olet (weldolet)	20″×8″ 1 pc	ASTM-A694
23	Olet (weldolet)	20″×4″ 1 pc	ASTM-A694
24	Design standard	ASME 36.10	Edition 2002

Damaged elbow of the long-time service manifold line

During long-time service (18 years) of the manifold line, used for transporting the mixture of oil and gas to upstream plant has a leak that has occurred on the vertical elbow due to appearance of a longitudinal crack (Fig. 6).

The longitudinal crack appeared on a 20″ piping elbow, belonging to a welding type. Also, it is highlighted that the elbow is such a pipe element type of non-uniform stress distribution and by rule, and the exterior part of the elbow is usually the most critical part. Taking into account the fact that piping elbows are pipe elements, used for changing the pipe direction, the external side of elbow is usually the area strongly affected by erosion, /6-8/.

Figure 6. Longitudinal crack in a vertical 20″ elbow.

This is particularly expressed when flow velocity is high and when the flow carries some solid particles as stones and sand. Considering that one of the causes of this leakage is erosion and that in a situation such as this, when leakage on the main manifold appears, it requires quick analysis of the problem and making decisions because the temporary shutdown of the well collector will decrease the production capacity of the upstream plant. In this case a plan of examination is adopted in the sense of making the decision whether this elbow can be repaired by cutting the area around the crack and inserting a new piece of material of the same shape and radius, or the elbow should be cut at positions where it is connected to the horizontal and vertical segment of the manifold line, /9, 10/.

This examination includes visual examination and ultrasonic thickness measurements of the area around the crack in the sense of establishing dimensions of a possible patch which should be butt-welded. On that occasion, detailed size measurements (length and width) of the longitudinal crack are performed also from the outer side of the elbow. The mentioned NDE examination is performed in detail, and a conclusion has been reached that the crack has propagated substantially and the thickness around crack has decreased.

a) b)

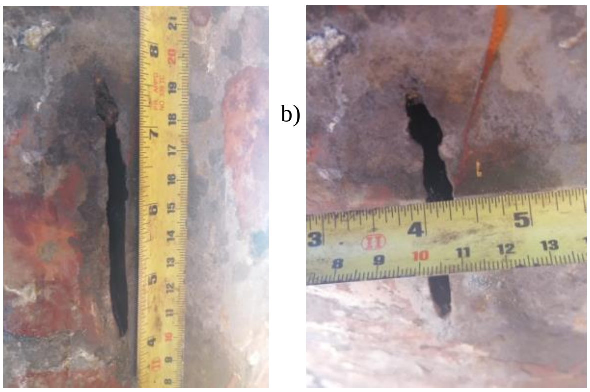

Figure 7. Dimensions of crack: a) length; b) width.

So, a final decision for solving this problem is adopted, taking into account also the location and type of crack (Fig. 7), cutting the damaged elbow and welding a new elbow onto the existing pipes.

Remediation of manifold line by welding a new elbow

After the performed NDE examinations and decision on cutting the existing, and welding a new elbow, we have approached the necessary activities in sense of conducting adopted decisions in a safe and reliable way.

Within this framework and before starting any activities in the sense of avoiding possible fire and/or explosion that can occur during cutting and welding, activities of cleaning and removing residue from the manifold line were performed. On that occasion technical water is injected in the line and held around 24 hours (with a constant feed) after which the line was drained, and nitrogen was injected.

After the cleaning and removal activities for needs of providing safety aspects, machine cutting has started without sparking in contact with the metal (Fig. 8).

Figure 8. Cutting of a damaged elbow in a safety manner.

In sense of providing the appropriate position for the new elbow, the existing elbow was cut at the middle of welded joint. After the cutting process, the damaged elbow was removed by crane, and bevels are prepared on surrounding pipes for welding the new elbow.

An appropriate WPS (welding procedure specification) was applied for welding the new elbow to manifold pipes. It included applying the GTAW procedure for the first two layers and the SMAW procedure for other weld layers of the carbon steel material. ER70S-6 wire was used as a GTAW filling material, and electrode E7016G for SMAW (Fig. 9).

Necessary NDE examinations of the new welded joints followed after the completed welding of the new elbow to manifold pipes. NDE examinations included penetrant tests and radiographic testing for checking the quality of the fabricated joints. Penetrant tests were performed also on root pass of the welded joint (Fig. 10), and on the final layer of welded joint (Fig. 11).

Radiography testing was used as a volumetric NDE method and interpretation of radiographs was conducted in a detailed way (Fig. 12). Radiography analysis has shown that the new welded joints were fabricated without defects /11/.

Figure 9. Welding of the new elbow to the manifold line.

Figure 10. Penetrant tests of welded joints: root pass.

Figure 11. Penetrant test of welded joints: final layers.

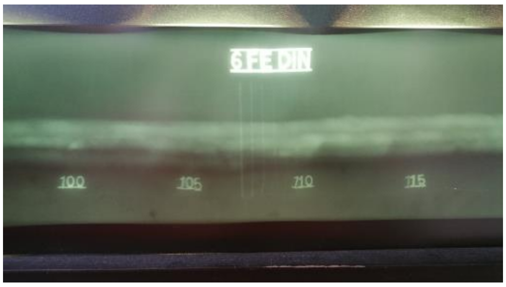

Figure 12. Interpretation of radiographs after welding.

Safety aspects conducted during the remediation process

After the detected leakage at the elbow and taking into consideration the fire hazard and explosive properties of the working fluid, were undertook all the necessary measures for conducting remediation in a safe and reliable manner, without harmful consequences.

For that occasion we provided a sufficient number of portable powder firefighting apparatus, uniformly distributed in the cutting- and welding area (Fig. 13).

Figure 13. Firefighting apparatus in the welding area.

Together with these firefighting apparatus with powder, a water pump and moveable tank were also provided as a water firefighting means (Fig. 14).

Figure 14. Water-based firefighting equipment.

CONCLUSIONS

The classification of oil and gas plants is done according to plant location in the sense of getting the final product, such as connection with upstream plants and the wells surrounding them. Classification of piping elbows is given in the sense of the most important parameters. Leakage has been detected on the vertically installed pipe elbow of the well collector, connected to the upstream plant. The leakage took place through a longitudinal crack that opened after a long operating time of the well collector manifold line. The crack has been analysed and it is concluded that the existing elbow should be cut out and replaced by a new elbow in the manifold line. The well collector was shut down for the necessary remediation which reflected on decreasing the total production of the upstream plant, creating a non-stable working regime. Emergency activities including cutting of the existing elbow and welding a new elbow were performed, respecting all necessary safety aspects. Following the welding procedures, necessary NDE was performed to check the required quality of the fabricated welded joints. It was proven that remediation of the manifold line was conducted in a proper way. The manifold line was successfully put into service after the conducted NDE. Measurements of the well collector working parameters and upstream plant working parameters confirmed that the plant operation has been restored to the required production capacity with a stable working regime.

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