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Investigation of Valves with a Weld Microstructure Layer Resistant to the Hydrogen Sulfide Corrosion

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Abstract

This paper discusses the characteristics of surfacing used in valves, gas and oil pipelines. For the study a sample was provided, made of structural steel with the inner part covered with a protective cladding of stainless steel alloy. With the help of optical and electron microscopy study of the microstructure of a sample covered by a protective cladding, the authors determined its structure, chemical composition, and the presence of non-metallic inclusions. Composition of inclusions was specified by metallographic techniques or by spectral analysis. Similarly, the protective deposited layer was studied. All conclusions drawn from our empirical research are presented in the final part of the article.

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Keywords: oil and gas recovery; isolation valve; weld overlay; microstructure.

1. Introduction

The problem of corrosion-resistance has become especially severe once oil and gas fields with high hydrogen sulfide content were found. More than 20 % of Russian explored fields contain gas with hydrogen sulfide and carbon dioxide. According to the Federal Service for Environmental, Technological and Nuclear Supervision, more that 350 000 km of infield pipelines are in operation and nearly 20 000 incidents of sealing loss that lead to leakage and harm the environment are registered annually. Almost 90 % are caused by corrosion of pipelines and isolation valves [1-2]. Thus, the problem of resistance to hydrogen sulfide corrosion has become an issue of vital importance.

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Despite the fact that numerous modern technologies allow production of metal with predesigned properties [3-5], the most widely used technique is covering an element that comes in contact with aggressive substances with a protective overlay. An overlay is usually represented by a stainless alloy or corrosion-resistant nickel product. Examination of such an overlay is the principal goal of the current research.

2. Research Methodology

LLC “Innovations and technologies” Research and Development Enterprise [6] provided a cylinder isolation valve made of low-alloy structural steel used for weld-fabricated constructions. Fanuc M-20iA/10L automatically operated robot welded an overlay onto the sample. The weld overlay was mechanically processed by milling (Fig. 1).

Polished sections were cut out perpendicularly to the product’s axis and used for macrostructure analysis. The sections were treated with 5% nitric acid alcoholic solution. The presence of weld overlay is clearly distinguished in the valve’s macrostructure. The weld overlay is the light layer on the inside surface of the sample (Fig. 2a), the dark layer is the base metal (hypopearlitic steel, Fig. 2b). The overlay is characterized by an even width of 1.7-2.0 mm.

Along the welding line, in the base metal zone, a hardened layer with bainite structure is clearly distinguished (Fig. 2b). The hardened layer resulted from a localized temperature increase in base metal during welding. Weld overlay’s structure is columnar due to the fabrication method used. (Fig. 2a). The coaxial-circles method suggested by 5639-82 GOST (All-Union State Standard) was applied to calculate grain’s size (7.2).
Non-metallic inclusions were registered in the sample’s microstructure. Silicate inclusions are typical for low-alloy structural steel used for weld-fabricated constructions and were found in the sample (Fig. 3). Composite silicate inclusions (MnO-SiO2) of 15-20 microns were found in the surface layer of the sample (Fig. 4). A large percentage of inclusions are triggered by 0.4 % silicon doping.

Fig. 3. Hardened layer adjacent to weld overlay, ×120

Fig. 4. Non-metallic inclusions in the sample, ×120

Impurity percentage was evaluated in accordance with the method III1 of 1778 GOST (All-Union State Standard). Experiment results are listed in the Table 1.

Table 1. Examination of non-metallic impurities in metal

<table>
<thead>
<tr>
<th># Sample</th>
<th>Grade</th>
<th>One-dimensional oxides</th>
<th>Non-deformable silicates</th>
<th>Sulphides</th>
<th>One-dimensional nitrides and carbonitrides</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,0</td>
<td>2,0</td>
<td>-</td>
<td>1,0</td>
<td></td>
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<tr>
<td>2</td>
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<td>1,0</td>
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</tr>
<tr>
<td>3</td>
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<td>1,0</td>
<td>2,0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1,0</td>
<td>1,5</td>
<td>0,5</td>
<td>1,0</td>
<td></td>
</tr>
<tr>
<td>5</td>
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<td>1,0</td>
<td>2,0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1,0</td>
<td>2,5</td>
<td>1,0</td>
<td>1,5</td>
<td></td>
</tr>
<tr>
<td>Average grade</td>
<td>1,0</td>
<td>2,2</td>
<td>0,5</td>
<td>1,4</td>
<td></td>
</tr>
</tbody>
</table>
JEOL JSM-6460 LV scanning electron microscope was used to examine chemical composition of the weld overlay and non-metallic inclusions (Fig. 5). Chemical composition data is shown in the Table 2.

![Fig. 5. Weld overlay microstructure, ×500](image)

**Table 2. Chemical composition of weld overlay (average values)**

<table>
<thead>
<tr>
<th>Element</th>
<th>Cr</th>
<th>Fe</th>
<th>Ni</th>
<th>Nb</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content, %</td>
<td>21,26</td>
<td>5.46</td>
<td>61.20</td>
<td>3.09</td>
<td>8.98</td>
</tr>
</tbody>
</table>

Spectral analysis of non-metallic inclusions (Fig. 6) detected aluminum, manganese, sulfur and calcium oxides (Table 3).

![Fig. 6. Non-metallic inclusions in weld overlay: (a) spectrum 1, ×3000; (b) spectrum 2, ×3000](image)

**Table 3. Chemical composition of inclusions in weld overlay**

<table>
<thead>
<tr>
<th>Area</th>
<th>Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O</td>
</tr>
<tr>
<td>Spectrum 1</td>
<td>30,24</td>
</tr>
<tr>
<td>Spectrum 2</td>
<td>-</td>
</tr>
</tbody>
</table>
3. Conclusion

Having conducted metallographic examination of the valve sample, we found neither macrostructural, nor microstructural defects. Overlay material had been welded evenly over the sample, welding quality was satisfactory. The size of base metal grain and non-metallic inclusions comply with requirements for the chosen type of fabricated products.

Acknowledgements

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References