Wear resistance increase of pipeline valves by overlaying welding flux-cored wire

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Abstract

Leakage of valves leads to an explosive hazard, as well as business losses. To improve the operational reliability of valves in the practice of using various methods of surface hardening, the main of which is surfacing, are used. For this purpose, a new composition of the cored wire was developed, that provides reception high-chromium steel weld metal alloying system Fe-Cr-Mo-Nb. The proposed cored wire provides a comprehensive strengthening of the weld metal due to the formation in the martensitic structure not only chromium carbide, niobium and molybdenum but also intermetallic phases such as Laves that provide this metal high wear resistance under abrasive wear and perception static pressure with high contact load. The results of field trials have shown a significant increase in the service life of valves of pipelines.

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Keywords: isolation valves; overlaying welding; flux-cored wire; hardness; wearability; structure

1. Introduction

The main reason of pipeline valves failure is the damage to the sealing surfaces as a result of scoring on the friction under considerable pressure contact surfaces with low velocity slip [1, 2]. To improve the operational reliability of valves in the operation practice, various methods of surface hardening, the main of which is overlaying welding, are used [3].

As surfacing materials for valves made of carbon steel, the wire type 08Kh18N10T, 20Kh13, bars V3K cobalt alloy (stellite) and other materials are used. The practice of using these alloys showed that the most workable cobalt

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material is stellite, which is used for hardening of the valve, even in those cases that do not require any high corrosion resistance or heat resistance [4].

At the same time stellite overlaying welding requires the prior and concomitant heating of the deposited articles to 700 °C, which significantly worsens the conditions of workers and makes it difficult to manufacture large-size parts with a mass of weld metal of several tens of kilograms. Furthermore, stellite is an expensive material containing scarce elements such as cobalt and tungsten.

2. The objective of research

The study subject is steel 20Kh13, 13Kh25T, 10Kh17N9S5GT (PP-AN133) produced by standard wires, and an alloy obtained by welding, developed by flux-cored wire PP-20Kh14M2B [5]. The chemical composition and hardness of the weld metal, the resulting test materials are given in the Table. 1.

Table 1. The chemical composition (in %) and the hardness of weld metal

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>Ti</th>
<th>Ni</th>
<th>Mo</th>
<th>Nb</th>
<th>S</th>
<th>P</th>
<th>Hardness HRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.14</td>
<td>0.56</td>
<td>0.38</td>
<td>12.18</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.027</td>
<td>0.023</td>
<td>40-42</td>
</tr>
<tr>
<td>0.11</td>
<td>0.71</td>
<td>0.54</td>
<td>22.49</td>
<td>0.21</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.022</td>
<td>0.018</td>
<td>22-28</td>
</tr>
<tr>
<td>0.10</td>
<td>1.44</td>
<td>5.62</td>
<td>17.71</td>
<td>0.14</td>
<td>8.47</td>
<td>–</td>
<td>–</td>
<td>0.031</td>
<td>0.024</td>
<td>28-34</td>
</tr>
<tr>
<td>0.18</td>
<td>0.44</td>
<td>0.27</td>
<td>14.2</td>
<td>–</td>
<td>–</td>
<td>1.86</td>
<td>1.25</td>
<td>0.024</td>
<td>0.021</td>
<td>52-54</td>
</tr>
</tbody>
</table>

3. Methods

Overlaying welding by selected wires was carried out with the help of automatic device ADG-502 in samples of steel 20 50 × 200 × 10 mm. Constant current is of reverse polarity. Argon was used as protective atmosphere.

Tests were carried out on the stand, simulating the operation conditions of a pair of friction sliding valves. Here ring samples of 100 mm diameter were used. One sample (top) with the sealing belt 5 mm wide and 6 mm high made on the lower surface of the sample, which was fixedly secured, a reciprocating motion with an amplitude of 10 mm and a speed of 0.005 m / s. Tests were carried out in air at a temperature of 20-30° and the axial pressure on the sample to 50 MPa, measured by pressure gauge and generated by the hydraulic cylinder.

Investigation of wear resistance of the deposited metal was carried out on friction machine II 5018 at dry friction on a "drive - block" (disc material is steel U7, the hardness is 63 HRC; the force exerted on the sample is 600 N, the disc rotation speed is 0.26 m/s). Quantitative depreciation was assessed by the change in mass of the sample using a high-accuracy weighing machine with an accuracy of 0.5 mg. The topography of the sample surface after the wear test, the bone was investigated using an optical interferometer Zygo NewViewTM 7300.

Metallographic examination of the deposited metal was carried out by an optical microscope Carl Zeiss AxioObserver A1m. The microstructure was revealed by chemical etching in the reagent composition: CuSO₄ - 4 g; HCl - 20 ml; H₂O - 20 ml. Electron microscopic studies were performed on the foil using a transmission electron microscope EMW-100L and JEM-2100 “JEOL” with energy-dispersive analyzer Inca-250. Durametric tests were performed using hardness Shimadzu HMV-2, MET-UD and TC-2.
4. Results and discussion

Tests on steel 20Kh13 to score resistance showed that scoring on the friction surfaces occur at pressure of 20 MPa for friction 300-400 cycles and at pressure of 50 MPa - for 10-15 cycles (Table 2).

Table 2. Results of tests on the weld metal to scoring resistance

<table>
<thead>
<tr>
<th>Brand of wire</th>
<th>Pressure, MPa</th>
<th>The number of cycles of reciprocating motion</th>
<th>The depth of score, mym</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sv-20Kh13</td>
<td>20</td>
<td>300-400</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>10-15</td>
<td>80</td>
</tr>
<tr>
<td>Sv-13Kh25T</td>
<td>20</td>
<td>5-8</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>400</td>
<td>none</td>
</tr>
<tr>
<td>PP-AN133</td>
<td>40</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>8-10</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>600</td>
<td>none</td>
</tr>
<tr>
<td>PP-20Kh14M2B</td>
<td>50</td>
<td>800</td>
<td>5</td>
</tr>
</tbody>
</table>

Samples of steel 13Kh25T had deep score marks after the first cycle of friction at a pressure of 20 MPa, and when paired with a solid metal on the surface formed growths very quickly. Samples cored wire weld AN133 during testing at pressures up to 20 MPa had burrs up to 400 cycles. However, testing at pressures above 40 MPa showed that the samples have score marks after 100 cycles. Samples of the deposited flux cored wire PP-20Kh14M2B, showed good resistance to scuffing. When tested up to 600 cycles at a pressure of 50 MPa there were no score marks on the samples. Further tests led to the emergence of very small scratches depth of 3-6 mym, the number of which is gradually increased.

Studies of wearability at dry friction of metal-to-metal showed that the wear of metal-cored wire PP obtained 20Kh14M2B up of 58 ± 2 mg. At the same time the wear of metal less wear of wire Sv-20Kh13 7 times, wire Sv-13Kh25T 13.5 times and cored wire PP-AN133 8.4 times (Fig. 1).

Fig. 1. Weld metal wear of metal to metal at dry friction

The study of the topography of the sample surface after tests showed that the predominant view of their wear is abrasive. A distinctive feature of profilograms worn surface of metal samples obtained by means of cored wire PP-20Kh14M2B is the smallest value of the mean-square value of roughness – 1.520 microns (rms), which is less as compared with samples from other surfacing materials studied in 5, 10 and 5 times, respectively (Fig. 2).
To identify the causes of differences in values scoring resistance and wearability of weld metal, obtained with coating materials researched, metallographic studies were conducted. They showed that the metal structure obtained with wire Sv-13Kh25T represents a ferritic structure (Fig. 3a). This structure does not have high strength; it is what determines the low rates of wear.
Metal obtained with flux-cored wire PP-AN133 has a ferritic structure with a small amount of austenite, and within and along the grain boundaries there is a large amount of silicide (Fig. 3 b). Such structural state of the metal causes an increase in wear resistance as compared to the weld metal obtained with wire Sv-13Kh25T.

The weld metal obtained with wire Sv-20Kh13 and flux-cored wire PP-20Kh14M2B, has the structure of high-chromium martensite (Fig. 3 c, d). Incorporation of ferro-niobium in the new cored wire PP 20Kh14M2B produces niobium carbides during melting and crystallization of the deposited metal (Fig. 4 a). Niobium carbides uniformly distributed in a matrix of the new type of deposited metal ensures a high wear under abrasive wear and high static pressure. Furthermore, niobium provides resistance weld metal to intergranular corrosion in the state after welding.

Molybdenum powder introduced into the flux-cored wire to increase the hardness and strength as the main strengthening phase for the metal together with carbides is Fe2Mo type Laves phase (Fig. 4 b). Molybdenum is also a surface-active element with respect to iron, and prevents carbide precipitation of intermetallics on the grain boundaries, which in turn increases the strength and ductility of the weld metal. Furthermore, molybdenum prevents grain growth during the crystallization process and improves the strength (resistance to hot cracking) of weld metal.

To carry out production testing of weld metal under operating conditions producing surfacing of sealing surfaces wedge Du600 of steel 20L developed cored wire PP-20Kh14M2B. Surfacing carried flux-cored wire diameter of 2.4 mm in the gas mixture Ar + 2.5% CO2 in the following modes: current - 300 A, voltage - 22-24 V, deposition rate - 20 m/h. Surfacing pendulum conducted by increments of 4-6 mm. The thickness of the deposited metal layer
is 3-6 mm, 1.5-2.0 mm plus - allowance for subsequent machining. Layer between the weld metal and the base metal is virtually absent, which significantly reduces the probability of occurrence of cracks in the fusion zone (see Fig. 5). Hardness is almost equally distributed over the height of the weld bead, and its values are stable are within 50-54 HRC, that fully satisfies the requirements to the hardness of the weld metal of the sealing surfaces of friction.

Fig. 5. The line between the main alloying metal Steel 20L and welded metal using wire PP-20Kh14M2B

5. Conclusion

The proposed flux-cored wire PP-20Kh14M2B provides comprehensive hardening weld metal due to the formation in the martensitic structure both chromium carbide, molybdenum NbC, niobium and Cr23C6, (Cr3Nb)C2, (Mo23C6 + Mo2C), intermetallic phases type Fe2Mo. The results of the production test demonstrated that the service life of valves, build-wire PP-20Kh14M2B compared to the previously used wire Sv-20Kh13 increases 2-3.5 times.

References