The investigation of the welded joints of the nitrogen containing cast austenitic steel, obtained by the manual arc welding

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Abstract. A literature analysis showed, that in the world there are not the welding additives, which is contain in own composition more than 0,37% mass. N. The investigations of the welding joints of the austenitic cast steel 05Kh21AG15N8MFL with the nitrogen containing 0,57% mass with using the available welding additives was provided. The technology of TIG welding with using two industrial welding wires Sv-10Kh20N18M3AFS (0,24% N) and Sv-25Kh25N16AG7 (0,10% N) was developed. It was obtain the defect-free welding joints, having a high rate of the mechanical properties, resistance to the pitting corrosion in 3,5% NaCl, containing up to 0,4% ferrite.

1. Introduction

It is known, that the austenitic stainless steels with the high nitrogen equilibrium concentration (~0,5% mass.), have a high rate of the physical-mechanical properties, corrosion resistance and cold resistance [1-8]. Using them as a constructional material often not complete without the welding. So, it is important to get the defect-free welding joints. However, the welding thus steels is considered as a difficult technological operation, in operating which can grow up the hot cracks, lack of fusion, segregations of the second phases in the zone of thermal effect, pores, nitrogen loses [9].

Developed in IMET RAN the cast steel of austenitic class 05Kh21AG15N8MFL with 0,57% of nitrogen containing is the high strength, corrosion- and cold resistant material to manufacturing the difficult form construction elements [10]. It is overtrop applying in the Russia the cast austenitic steels as 12Kh18N9TL, 10Kh18N11BL, 12Kh18N12M3TL at the limit of liquidity in ~2 times, at percussive viscosity in ~ 4,5 times. It is not subjected to the cold brittleness. At cooling to ~70°C it has the percussive viscosity values ~2,3 MJ/m² [11-13].

In a literature there are the works about the welding the similar in the chemical compound nitrogen containing hot deforming steels 05Kh22AG16N8M and 05Kh22AG15N8M2F [14]. Welding joints was
obtained by the manual arc welding under flux (SAW) with using as the welding additive of a such metal, cutting to the strips (so-called «strip»). Welding joints have a high rate of the properties ($\sigma_{0.2} = 450 \div 465$ MPa, $\sigma = 800 \div 820$ MPa), however the weld wire with a such chemical compound do not producing, thus using the such welding additive costly, in main, by the showed possibility to obtain the welded joints of a given steel without the cracks and the gas pores, with a good rate of the properties.

Due to this the purpose of the investigation consist of the possibility obtaining quality high strength weld joints from the steel 05Kh21AG15N8MFL with available industrial welding wires applying.

In present time in industry are absent the additive materials, which have the similar compound with the nitrogen steels, in which strength rate is providing by the nitrogen concentration near 0,5%, which confirmed by our literature analysis and authors data [15-17]. Producing in the world additive materials contain in their compound no more than 0,37% of a nitrogen. Literature data analysis by the welding of the austenitic corrosion resistance steels with the high nitrogen concentration, analysis the proposed producer welding materials, also showed that, as rule, using weld additives is low carbon, contain 20-27% Cr and 2,5-9,5% Mo; the high nickel concentration in their compound (17-25% in steels and 32-60% in alloys) is required to providing the austenitic structure and the high crack resistance. The nitrogen concentration in the welding additives – a balance between the concentrations Cr and Mo (promoting the nitrogen solution, increasing the corrosion resistance and providing the solid solution strengthening) and between the concentration of obstructing to the nitrogen solving Ni. When choosing the material of the welding additives for testing in present work at obtaining welding joints of the steel 05Kh21AG15N8MFL with 0,5% N the next condition was formulated:

- the welding wire material must be austenitic;
- the mechanical properties rate must be the such or higher that the welded base metal to providing the high mechanical properties rate;
- a wire material must providing the corrosion resistance rate no low the base metal.

2. Materials and methods

Leaning on the aforesaid and known investigations experiments, the welding of the cast steel 05Kh21AG15N8MFL thickness of 22 mm was providing with using welding wires: Sv-10Kh20N18M3AFS and Sv-25Kh25N16AG7. The model chemical composition BM the welding wires metal showed in the table 1.

| Model | Chemical composition, % mass (Fe – and impurities – another) |
|-------|-------------------------------------------------------------|
|       | N | Si | Cr | Ni | Mn | Mo | V | Nb | C | S | P |
| 05Kh21AG15N8M2F | 0,55-0,6 | 0,1-0,2 | 21-22 | 7,8-9 | 15-16 | 1-2 | 0,3 | - | 0,04 | 0,008 | 0,012 |
| Sv-10Kh20N18M3AFS | 0,2-0,25 | 0,7-0,1 | 19,5-20 | 16-17 | 3-3,5 | 1-2 | 0,8 | - | 0,12 | 0,008 | 0,015 |
| Sv-25Kh23N16AG7 | 0,1-0,15 | 0,1-0,2 | 24,7-26 | 15-16 | 6,5-7 | 0,1-0,3 | 0,7 | - | 0,25 | 0,006 | 0,012 |

In this investigation was used the manual arc welding by non-melting electrode in the argon environ (TIG), as widely used and the available method. To obtain the welding joints with the high rate of properties, it was developed the welding technology, the mode of them showed in the table 2. Welding was provided at low currency and every welded roll was cooled by the welding wire to the room temperature. Thus, obtained welding joint was schematically looked, as showed at the figure 1.

| Table 2. The mode of the manual arc welding in argon of the cast austenitic steel 05Kh21AG15N8M2FL under a developed technology. |
|---------------------------------------------------------------|
| Base metal / wire | Welding mode | Edges cutting |
| 05Kh21AG15N8M2F / 10Kh20N18M3AFS | I=70-100 A, U=8-10 V, welding velocity 3 m/c | V-looked |
| 05Kh21AG15N8M2F / 25Kh25N16AG7 | | |

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The microstructure of welded joints was examined on an Olympus light microscope and a Kyky 2800 scanning electron microscope with an Oxford Instruments X-ray Microscope Analysis Unit (MRSA). The nitrogen content in samples from different zones of welded joints was determined on the Eltra ONH-2000 gas analyzer (“Venta Lab”). Ferritometry was provided using IMP-2M ferritometer. Tensile tests were carried out according to GOST 1497-84 on Instron 3382 equipment; (test speed 1 mm / min). Impact bending tests were carried out according to GOST 9454-78 on Amsler RKP-450 (copra energy - 300 J). The microhardness of the various structural components of the welded joints (fusion line, weld, base metal, and heat-affected zone of weld) was determined according to GOST 9450-76 on Volpert 402MVD hardness meter (load 50g for 10 s). Corrosion tests on pitting corrosion – 3,5% NaCl at 20°C providing by GOST 9.912-89. A velocity of the potential change consist of 0,2 mV/s.

3. Results and discussions

Obtained under the developed mode the welding joints turned as qualitative, without the pores and cracks, under the radiographic and visual control data, and also by the microstructure investigations. In all WJ the microstructure of BM consist of the large austenitic cast grains, with the size 500-700 mkm, WJ have the characteristic cell-dendritic structure with the grains size 4-20 mkm (figure 2).

The chemical composition investigation of the metal joint showed, that the chosen welding mode is not to provide the manganese loses more than 0,3-0,7%. Also, it was established, that in the welding process practically not happened the nitrogen loses in the weld joints. Including, the nitrogen containing in the metal of the wires / in the welding joint to make:

1) 05Kh21AG15N8M2F / 10Kh20N18M3AFS: 0,24% / 0,22% N;
2) 05Kh21AG15N8M2F / 25Kh25N16AG7: 0,10% / 0,11% N.

A condition to obtain the austenitic structure of the welding joints was fulfill. The microstructure investigation of the base metal and the wire metal showed, that the influence of the thermal cycle of the multi pass welding are not provide to the δ-ferrite formation in the metal wire. The δ-ferrite containing in the welding wire (0,00%), then in the base metal (~0,40%).

Figure 1. Schematic picture of obtained welding joints.

Figure 2. Microstructure of the different zones welding joints:
   a) 05Kh21AG15N8M2F/10Kh20N18M3AFS; b) 05Kh21AG15N8M2F/25Kh25N16AG7.
The strength characteristics WJ was investigated on the bursting cylindrical samples, where the welding joint located in the center. The limit of liquidity of all welding joints higher than the base metal. It is due to more smaller the grain size of the metal joint (figure 3).

![Graph](image)

**Figure 3.** The mechanical properties of the base metal and its welding joints.

The thermal cycle of welding influence provide to the percussion viscosity declining of all the weld joints at +20 and at -70°C, with comparison to the base metal (KCV\^{+20} = 331 J/cm\(^2\)):

1) 05Kh21AG15N8M2F / 10Kh20N18M3AFS: KCU\(^{+20}\) (90 J/cm\(^2\)) and KCV\(^{-70}\) (31 J/cm\(^2\));
2) 05Kh21AG15N8M2F / 25Kh25N16AG7: KCU\(^{+20}\) (111 J/cm\(^2\)) and KCV\(^{-70}\) (51 J/cm\(^2\)).

However obtained indicators are settled to the criteria values of the percussion viscosity of the pipeline equipment, working under the pressure [18].

Fractographic analysis of the welded joints fractures after the tests on the distension and percussive bend showed, that in the fractures of all the samples prevails the viscous component. On the figure 4 are pictured the fractures of the samples of the welding joints after the distension tests.

All the welding joints have shown the resistance to the corrosive environment influence at the tests on the pitting corrosion due to the formation of the protective passivating film.

![Fractures](image)

**Figure 4.** Fractography of the fractures of the welding joints after the tests on the distension:
a) 05Kh21AG15N8M2F / 10Kh20N18M3AFS; b) 05Kh21AG15N8M2F / 25Kh25N16AG7.

4. **Conclusions**

1. It was developed the technology of TIG welding, allowing to obtain the non-defect welding joints of the austenitic cast steel 05Kh21AG15N8MFL with the nitrogen containing of 0.57% mass. with using the two welding wires: Sv-10Kh20N18M3AFS (0.24% N) and Sv-25Kh23N16AG7 (0.10% N).
2. Using mode of the welding allow to obtain the austenitic structure in all zones of the welding joints and practically does not lead to the changes of the nitrogen quantity in the metal joint.
3. The liquidity limit of the welding joints higher than the base metal. The strength limit is slightly lower (no more 11%).

4. The welding joints percussive viscosity after the welding thermal cycle influence has decreasing, however the obtained values has fit to the requirements of the criteria values of the percussive viscosity of the pipeline equipment.

5. The welding joints resistance to the pitting corrosion in 3.5% NaCl solution at 20°C was studied. It is shown that they not inclined to the corrosion in present environment due to the defensive passivating film formation on the surface.

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