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Study of technological conditions for welding austenitic steels

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ABSTRACT: This article provides a study of technological conditions for welding austenitic steels

KEYWORDS: austenite, structure, welding, steel, technology, heat resistance

I. INTRODUCTION

Austenitic steels and alloys have a complex of positive properties, so the same steel can sometimes be used to manufacture products for various purposes that are corrosion-resistant, cold-resistant or heat-resistant. In this case, the requirements for the properties of welded joints and welding technology will be different. However, the thermophysical properties of austenitic steels and the tendency to form hot cracks in the weld and heat-affected zone determine some general features of their welding.

II. LITERATURE SURVEY

The low thermal conductivity coefficient and high linear expansion coefficient characteristic of most high-alloy steels determine, at the same heat input and other equal conditions (welding method, edge geometry, joint rigidity, etc.), an expansion of the penetration zone and areas heated to different temperatures, and an increase in the total plastic deformation of the weld metal and heat-affected zone. This increases product warping. Therefore, for high-alloy steels, welding methods and modes should be used that are characterized by a maximum concentration of thermal energy, or the current should be reduced compared to the current when welding carbon steel. Heating the welding wire in its extension or the metal rod of the electrode for manual welding to high temperatures due to increased electrical resistivity during automatic and semi-automatic arc welding requires a reduction in the extension of the electrode and an increase in its feed rate. When manual arc welding, the length of the electrodes and the permissible welding current density are reduced. [1-2]

When welding austenitic steels, plastic deformation of the weld metal and heat-affected zone as a result of large coefficients of linear expansion and shrinkage, as well as the absence of polymorphic transformations, occurs to a greater extent than when welding pearlitic carbon steels. Under these conditions, during multilayer welding, the metal of the heat-affected zone and the first layers of weld metal can be strengthened under the influence of repeated plastic deformation, i.e., the phenomenon of self-hardening during welding is observed. [3]

The influence of this phenomenon on the properties of the weld metal is determined by the rigidity of the elements being welded. In relatively more rigid connections, where self-hardening causes an increase in strength characteristics, an increase in residual stresses is observed in some cases up to 450-500 MPa. [4]

Such relatively high residual stresses with the low relaxation ability of austenitic steels require the selection of a heat treatment regime that ensures a reduction in residual stresses, removal of self-hardening and the maximum possible homogenization of the structure of the welded joint. [5-6].

III. METODOLOGY

Among the main difficulties that arise when welding austenitic steels is the need to increase the resistance of the weld metal and heat-affected zone against crack formation. Hot cracks are intercrystalline fractures and are divided into crystallization and subsolidus cracks; the latter arise at a temperature below the solidus line, i.e., after the end of the crystallization process. The probability of the appearance of crystallization cracks is determined by the nature of the change in the plasticity of the alloys during deformation of the metal in the solid-liquid state.
Ways to increase resistance to the formation of crystallization cracks: 1) suppression of columnar crystallization and refinement of the crystal structure by alloying with modifier elements, as well as elements that promote the formation of high-temperature second phases during crystallization; 2) increasing the purity of alloys in terms of impurities that contribute to the formation of low-melting phases during crystallization in the composition range in which an increase in the amount of these phases reduces technological strength, and, conversely, increasing the amount of alloying elements that form eutectics in the range of alloy compositions close to eutectic. These paths narrow the temperature range of brittleness and increase the margin of ductility.
Technological measures to combat cracks are aimed at finding rational methods and modes of welding and structural forms of welded joints that reduce the rate of increase in internal deformations during the solidification process. Intergranular fracture of single-phase austenitic welds at temperatures below the solidification temperature under conditions of increasing stresses (subsolidus cracks) according to the scheme is close to fracture during high-temperature creep. A necessary condition for the formation of embryonic cracks of such destruction is intergranular sliding, which opens both steps in the boundaries and already existing microcavities formed as a result of the release of vacancies at the boundaries perpendicular to the action of tensile stresses.
To increase resistance to the formation of subsolidus hot cracks during welding, it is recommended:
1) alloying of alloys with elements that reduce the diffusion mobility of atoms in the lattice;
2) increasing the purity of the base metal in terms of interstitial impurities;
3) reducing the time the metal is at a temperature of high diffusion mobility (increasing the cooling rate of the weld metal) and reducing the rate of increase in elastoplastic deformations during cooling (limiting deformations by choosing a rational design of joints).
Metallurgical factors that contribute to increasing the resistance of the weld metal to the formation of hot cracks when welding austenitic steels:
1) formation of a two-phase structure in the high-temperature region during metal crystallization due to the release of primary ferrite, dispersed particles of the refractory phase or boride phase and chromium-nickel eutectic:
2) limiting the content of impurities that form low-melting phases in order to narrow the effective crystallization range.
To refine the structure, alloying of the deposited metal with elements that promote the release of high-temperature δ-ferrite during crystallization of the metal is used. The presence of δ-ferrite refines the metal structure and reduces the concentration of Si, P, S and some other impurities in the intergranular regions due to the greater solubility of these impurities in δ-ferrite, which reduces the risk of the formation of low-melting eutectics.
The amount of ferrite phase in the deposited metal after its cooling depends on the composition of this metal and the cooling rate in the region of high and medium temperatures. An approximate idea of the concentration of ferrite in an austenitic-ferritic metal is given by the Scheffler diagram.
The recommended content of the ferrite phase in the deposited metal is limited to 2-6%. When welding steels with a higher degree of austeniticity, for example, 08X18H12T, X14H14, etc., the limits of the content of the ferrite phase in the deposited metal are increased in order to ensure its presence in the weld, taking into account the mixing of the deposited metal with the base metal.

For corrosion-resistant steels, increasing the primary ferrite content to 15-25% improves performance due to the greater solubility of chromium in ferrite than in austenite, which prevents the depletion of boundary layers in chromium and maintains high resistance to intergranular corrosion. For heat-resistant and heat-resistant steels with a small margin of austeniticity and a nickel content of up to 15%, the prevention of hot cracks is achieved by obtaining an austenitic-ferritic structure with 3-5% ferrite. A large amount of ferrite can lead to significant high-temperature embrittlement of welds due to their pigmentation in the temperature range 450-850°C.

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Obtaining an austenitic-ferritic structure of welds on deep austenitic steels containing more than 15% Ni will require increased alloying with ferrite-forming elements, which will lead to a decrease in the plastic properties of the weld and embrittlement due to the appearance of brittle eutectics, and sometimes the σ-phase. Therefore, in the welds they strive to obtain an austenitic structure with finely dispersed carbides and intermetallic compounds and to alloy the welds with an increased amount of molybdenum, manganese and tungsten, which suppress the formation of hot cracks.
It is also necessary to limit the content of harmful (sulfur, phosphorus) and liquidating (lead, tin, bismuth) impurities, as well as gases - oxygen and hydrogen, in the base and deposited metals. To do this, you should use modes that reduce the proportion of base metal in the weld, and use steels and welding materials with a minimum content of these impurities. Therefore, for the manufacture of welding wires, it is advisable to use vacuum-melted steels after electroslag remelting or refining: the same applies to the base metal. The welding technique must ensure minimal saturation of the weld metal with gases. This is facilitated by the use of reverse polarity direct current for welding. When manual welding with coated electrodes, maintain a short arc and weld without lateral vibrations. When welding in shielding gases, to prevent air leakage, it is necessary to maintain a short electrode extension and select the optimal welding speed and shielding gas consumption.
High-alloy steels contain aluminum, silicon, titanium, niobium, and chromium as alloying additives, which have a greater affinity for oxygen than iron. If there is an oxidizing atmosphere in the welding zone, their significant loss is possible, which can lead to a decrease in the content or complete disappearance of ferrite and carbide phases in the weld structure, especially in metal with a slight excess of ferritizers. Therefore, it is recommended to use low-silicon, high-basic fluxes (fluoride) and electrode coatings (basic) for welding.
Short arc welding and preventing air leaks serve this purpose. Nitrogen, being a strong austenizer, simultaneously promotes structure refinement by increasing crystallization centers in the form of refractory nitrides. Therefore, nitriding of the weld metal helps to increase their resistance to hot cracks. Highly basic fluxes and slags, by refining the weld metal and sometimes modifying its structure, increase resistance to hot cracks. Mechanized welding methods, ensuring uniform penetration of the base metal along the length of the seam and constancy of the thermal cycle of welding, make it possible to obtain more stable structures along the entire length of the welded joint.
An important measure to combat hot cracks is the use of technological techniques aimed at changing the shape of the weld pool and the direction of growth of austenite crystals, as well as reducing the force factor resulting from the thermal cycle of welding, shrinkage deformations and the rigidity of the fastening of welded edges. When tensile forces act perpendicular to the direction of growth of columnar crystals, the probability of crack formation increases. With mechanized welding methods using thin electrode wires, transverse vibrations of the electrode, changing the crystallization pattern of the weld metal, reduce the tendency of the weld metal to hot cracks. Reducing the effect of shrinkage deformations is achieved by limiting the welding current, filling the groove with seams of small cross-section and using grooves of appropriate structures. This is also facilitated by good sealing of the crater when the arc breaks.
In addition to the listed general features of welding high-alloy steels and alloys, there are features determined by their service purpose. When welding heat-resistant and heat-resistant steels, the required properties are in many cases ensured by heat treatment (austenization) at 1050–1100°C, which removes residual welding stresses, followed by stabilizing tempering at 750–800°C. If heat treatment is not possible, welding is sometimes carried out with preliminary or accompanying heating to 350-400°C.
Excessive embrittlement of welds due to the formation of carbides is prevented by reducing the carbon content in the weld. Providing the necessary heat resistance is achieved by obtaining weld metal whose composition is identical to the base metal.
When welding corrosion-resistant steels using various methods, to prevent intergranular corrosion, an increase in carbon in the weld metal should not be allowed due to its contamination of the welding materials (graphite lubricant of the wire, etc.) and prolonged and repeated exposure of the welded joint metal to the critical temperature range. Therefore, welding must be performed at the lowest heat input, using mechanized methods that ensure continuity of weld production. Repeated excitation of the arc during manual welding, having an undesirable thermal effect on the metal, can cause it to become prone to corrosion.

The seam facing the aggressive environment should, if possible, be welded last in order to prevent its reheating, and subsequent seams in multi-layer seams should be made after complete cooling of the previous ones and measures should be taken to accelerate the cooling of the seams. Splashes falling on the surface of the base metal can subsequently become centers of corrosion and must be carefully removed from the surface of the metal, seams, as well as slag and flux residues, which, interacting with the metal during operation, can lead to corrosion or a decrease in local heat resistance.
During welding, the creation of an austenitic-ferritic structure in the weld metal to increase the resistance of the welds to intergranular corrosion is achieved by alloying with titanium or niobium. However, titanium, which has a high affinity

for oxygen, burns out in the welding zone by 70-90% (during manual arc welding, welding with acid fluxes). The titanium content in the weld metal must correspond to the ratio $\frac{Ti}{C} \geq 5$

IV.CONCLUSION

The results of the research performed provided the necessary basis for studying the technological conditions for welding austenitic steels.

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