

Development of Arc Welding Technology for Austenitic Steels in Reducing Media

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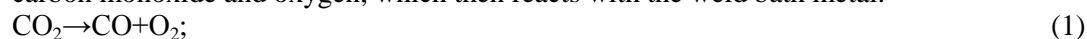
Abstract. The possibility of performing the arc welding of austenitic 08Kh18N10 steel in a carbon monoxide medium is considered. The thermodynamic substantiation of the proceeding chemical reactions is presented. It was established that the use of reducing media prevents the oxidation of weld metal. Comparative mechanical tests of welded joints made in various protective media were performed. The chemical and metallographic analysis of welded joints was done. It was established that the burnout of alloying elements during welding in a carbon monoxide medium does not occur. The studies conducted showed the possibility of using cheap carbon monoxide as a substitute for argon and helium in the welding of austenitic steels.

1. Introduction

Stainless austenitic steels are widely used in thermal power plants, pressure vessels, as well as in the automotive industry due to their high fracture toughness, good corrosion resistance, as well as the absence of the need for additional heat treatment [1]. Hygiene and environmental friendliness with a high level of elasticity and strength allow using steel data in the process of manufacturing equipment and various products for the chemical and food industries, medicine and household appliances.

Almost always in the manufacture of parts made of austenitic steels are used arc welding methods. The predominant welding with non-consumable electrode in argon or mixture of argon, carbon dioxide and hydrogen [2]. However, this welding method has a low productivity and high cost. The introduction of oxygen, carbon dioxide and others into the protective medium significantly affects the ongoing metallurgical reactions, mechanical properties, metal transfer, arc stability and other parameters [3]. The media used usually have oxidizing properties, or consist of inert gases. Quite often in the welding process, carbon monoxide is formed, which is considered a harmful impurity, due to its negative biological effects [4]. However, this gas has reducing properties, in relation to the oxides of most metals. It is therefore of interest to carry out welded joints in a reducing medium, mainly consisting of carbon monoxide.

The known reaction is the decomposition of carbon dioxide under the influence of a welding arc into carbon monoxide and oxygen, which then reacts with the weld bath metal:



Therefore, the welding of austenitic steels in a carbon dioxide medium may be allowed only if the product is not subject to the requirements for resistance to intergranular corrosion. The formation of carbon monoxide leads to restrictions in the use of this welding method in closed volumes.

It is also known that carbon monoxide heated above a certain temperature enters into active chemical reactions with atmospheric oxygen, being oxidized to carbon dioxide [5]. Therefore, to neutralize the harmful effect of carbon monoxide, it was proposed to heat the gas heated to protect the welding arc above the ignition temperature [6].

2. Materials and methods

To investigate the possibility of using reducing protective media, the weld-jointing of $\varnothing 76 \times 3$ mm pipes was performed. 08X18H10 steel, the analog of AISI 304 steel, was used. Arc welding in argon and carbon monoxide media was used. Sv-12Kh18N10T filler metal wire, analog of the Autrod 308LSi wire, produced by ESAB Company, was used. Microstructural studies were carried out on an optical and scanning electron microscope with simultaneous microchemical analysis. The welded joints were tested for tensile strength to determine the breaking strength. Corrosion resistance tests were carried out in accordance with GOST 6032-2003.

3. Results and Discussion

In the investigated steel, the combination of basic technological properties is ensured by the content of chromium and nickel in them. The possibility of oxidation of these elements in the investigated medium was studied. The source of oxygen may be the dissociation of carbon monoxide in the arc column, as well as passing it into the weld bath from atmospheric air. Reverse metal-oxide reduction chemical reactions are also possible. The direction of the reactions was defined by determining the isobaric-isothermal potential (the Gibbs Criterion) using the method described in [7]. Data given on the site [8] was used.

We shall consider the various ways of oxidation of nickel and chromium alloying elements during their interaction with carbon monoxide.



This reaction is reversible and proceeds with a noticeable release of oxygen at temperatures greater than 6000 K, that is, only in the anode and cathode zones of the arc. Accordingly, the amount of the decomposed monoxide will be very small. As will be shown below, this statement is confirmed by the results of chemical analysis



The isobaric & isothermal potential ΔG in the temperature range from 1100 to 3500 ° K decreases from 974 to 684 KJ, which makes this reaction practically impossible.



ΔG in the above temperature range is even higher, and increases with increasing temperature from 1442 to 1560 KJ. It is believed that the films of chromium oxide inhibit oxygen diffusion, thus decreasing the oxidation rate of the metal [9].

Thus, the calculations performed showed that the oxidation of alloying elements during welding as a result of the reactions (3, 4, 5) is practically impossible.

Owing to poor weld shielding, the presence of oxide and organic films on the surface of the weld metal, oxygen can enter the arc zone, resulting in the formation of oxides of the alloying elements.



Consider the possibility of recovering the oxides of nickel and chromium under the action of carbon monoxide. The calculation results are presented in Table 1.

Table 1. Calculation result of the isobaric-isothermal potential

Temperature, oK	1100	1500	1900	2300	2700	3100	3500
Reaction	Isobar-isothermal potential, ΔG , KJ						

$\text{NiO} + \text{CO} \rightarrow \text{Ni} + \text{CO}_2$	-399	-338	-265	-211	-158	-93	-29
$\text{Cr}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Cr} + 3\text{CO}_2$	247	253	258	264	270	276	283

As shown in Table 1, chromium oxides will not react with carbon monoxide, and nickel oxides will be actively reduced, giving up oxygen and oxidizing carbon monoxide to the dioxide. Similar calculations for other alloying elements are presented in [10]. Thus, preliminary calculations show that the proposed medium will not cause the oxidation of the investigated steels during welding.

It is established that when welding in a carbon monoxide medium, a qualitative weld seam was formed, without pores, micro-cracks or other defects. The micro-structure of the weld is shown in Figure 1.

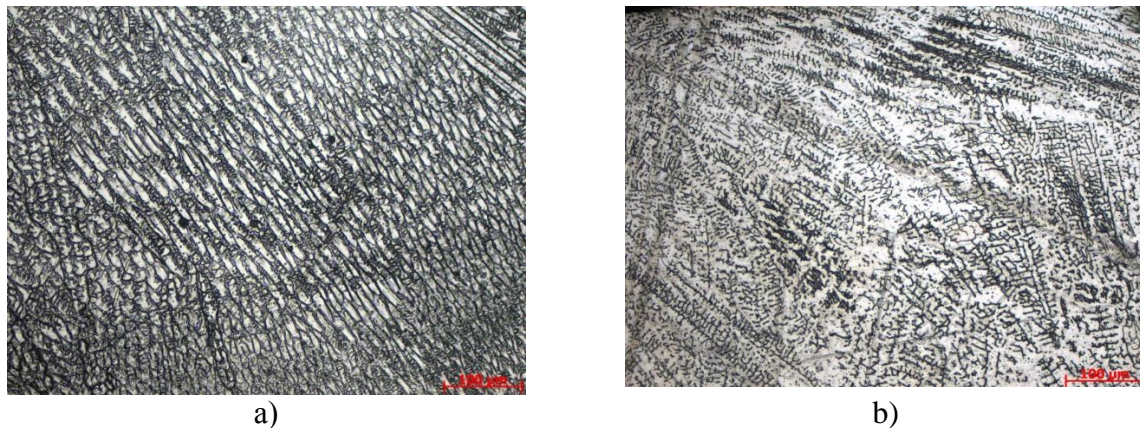


Figure 1. Micro-structure of a welded joint made in a carbon monoxide (a) and argon (b) medium

In the weld metal deposited in the carbon monoxide medium was observed the formation of secondary walls that do not coincide with the direction of the dendritic growth (Figure 2).

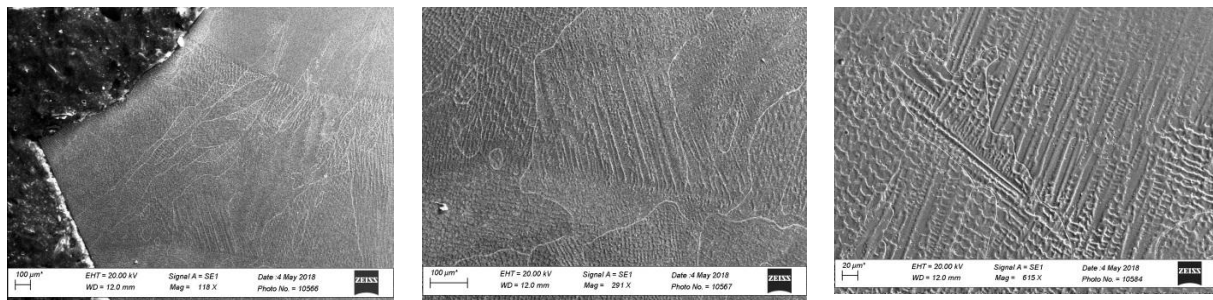


Figure 2. Secondary grains in the weld metal made in a carbon monoxide medium

In conventional argon-arc welding, the formation of these walls was not observed. It should be noted that in the listed steels was noted the formation of similar structures after recrystallization [11]. Additional research is required to establish the reasons for their occurrence in the welding process.

Tensile tests on the expansion of flat samples cut across the weld were performed. In all cases, the disintegration occurred over the heat-affected zone. Significant differences in the mechanical properties of samples welded using various protective media were found. The tensile strength varied from 558 to 579 MPa.

To determine the resistance of the welded joint to inter-crystalline corrosion, rings 50 mm long were cut from the samples, in which the weld was centered. 8 samples of welded joints were made in different protective media. Of these, 4 samples were subjected to boiling in an aqueous solution of copper sulphate and sulfuric acid in the presence of copper chips for 8 hours. All the produced samples

were flattened until a 13 mm-gap was obtained. After that, the curved samples were inspected with a magnifying glass with a sevenfold magnification. Cracks were not detected in the samples. The results of the micro-chemical analysis of the weld metal obtained in argon and carbon monoxide media are presented in Figure 3.

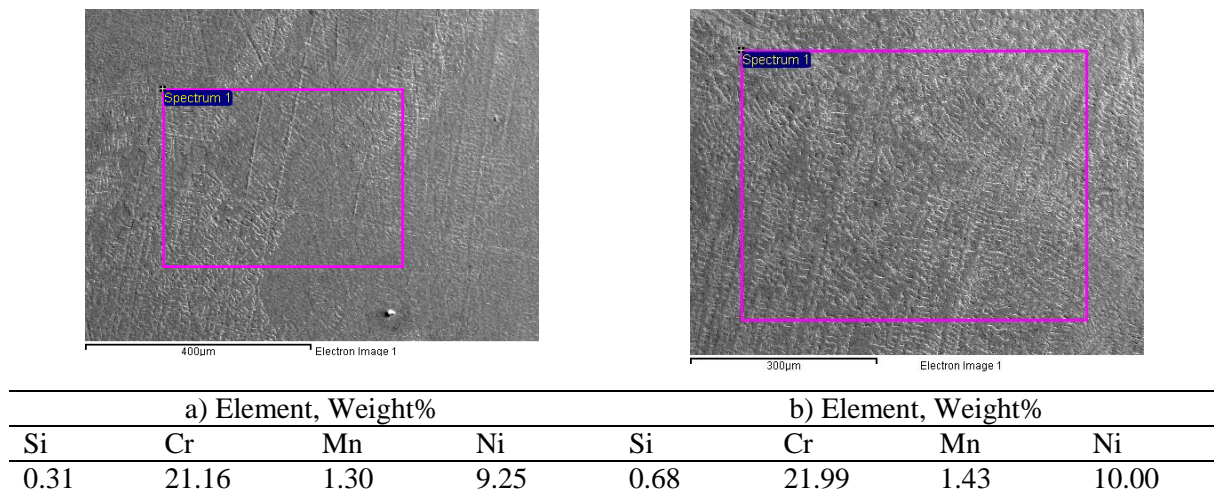


Figure 3. Composition of weld metal made in carbon monoxide (a) and argon (b) media

As can be seen from the data presented in Figure 3, weld metal made using different media has approximately the same composition. Due to a significant error in measuring carbon during the microchemical analysis, an X-ray fluorescence analysis of the chemical composition was performed using the X-MET 7500 analyzer. In general, the results presented in Figure 3 were confirmed. However, an increase in the carbon content from 0.072 ... 0.106 to 0.144 ... 0.171% by weight was noted. The increase in the carbon content in the weld metal by 0.07% seems to be due to the dissociation of carbon monoxide in the near-electrode regions, which was mentioned above. Increasing the carbon content negatively affects the corrosion resistance of the metal. It is believed that for this class of steels, to ensure corrosion resistance, the carbon content limit in the steel should not exceed 0.2%. The specified level of carbon in the metal was not achieved when using carbon monoxide as a protective medium.

4. Conclusion

Based on the studies conducted, it was proved that when carbon monoxide is used as a protective medium for the welding of 08X18H10 steel, the chemical composition of the weld metal is close to the composition of the weld metal made in argon-arc welding. At the same time, the required mechanical properties and corrosion resistance of the welded joint are also provided. The studies performed demonstrate the possibility of using carbon monoxide as a cheap alternative to the inert gases widely used in arc welding.

References

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