STUDY OF EFFECT OF INITIAL AND SUBSEQUENT HEAT TREATMENT OF CONSTRUCTIONAL STEELS ON PROPERTIES OF JOINT WELDS PRODUCED BY ELECTRON BEAM WELDING

Исследование влияния предварительной и последующей термической обработки конструкционных сталей на свойства сварных швов, получаемых с помощью ЭЛС

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Absract:
The effect of modes of electron beam welding on geometry of joint welds of constructional steels has been analyzed using steel 40X as an example. Microstructure and microhardness distribution in joint welds have been investigated. Necessity of preheating and subsequent heat treatment of metal in order to avoid hot cracking at electron beam welding has been determined.
KEYWORDS: EBW, CARBON STEEL, CONSTRUCTIONAL STEEL

1.Introduction

There is a need in production of joint welds by electron beam welding (EBW) of parts made of constructional carbon steels and alloyed steels that are considered to be conditionally weldable and hardly weldable materials. The chemical composition analysis of these steels has shown that some of them have a strong tendency towards origination of welding defects such as cold and hot cracking. The main method of cold cracking prevention is initial heating that can be successfully performed at EBW, first of all, due to a wide range of opportunities of electron beam heating. In order to prevent hot cracking, the main cause of which being low-melting sulfides, modifying agents that bind sulphur into high-melting compounds are used in electric-arc welding methods.. The modifying agents are added into a molten weld pool together with filler materials. However, there is no such opportunity at deep alloying EBW that does not use grooving and fillers, which is the main economic advantage of this method as compared to electric-arc welding methods. This makes search and development of technological methods of hot cracking prevention urgent.

2.Objective

The objective of this work has been finding of an optimal initial state of material, its initial and subsequent heat treatment modes in order to produce high-quality joint welds in constructional steels by means of EBW. The work presents the research results on the effect of an initial structure, initial and subsequent heat treatment modes and EBW parameters on geometry, structure, mechanical properties and chemical composition of joint welds in constructional carbon steels and alloyed steels.

3.Results

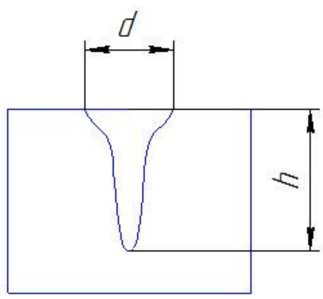


Fig. 1 – Schematic representation of the joint weld depth and width

The effect of EBW modes on geometry of joint welds of 40X constructional steels has been analyzed. Microstructure and microhardness distribution in joint welds have been investigated.

Electron beam welding of samples made of constructional steels has been performed in vacuum at a residual pressure of $5 \cdot 10^{-3}$ Pa. Welding modes for 40X steel have been as follows: an accelerating voltage of 60 kW, a beam current of 110 mA, a focusing current of 695 mA, a welding rate of 10 mm/s. Welding of the samples has been performed without preheating.

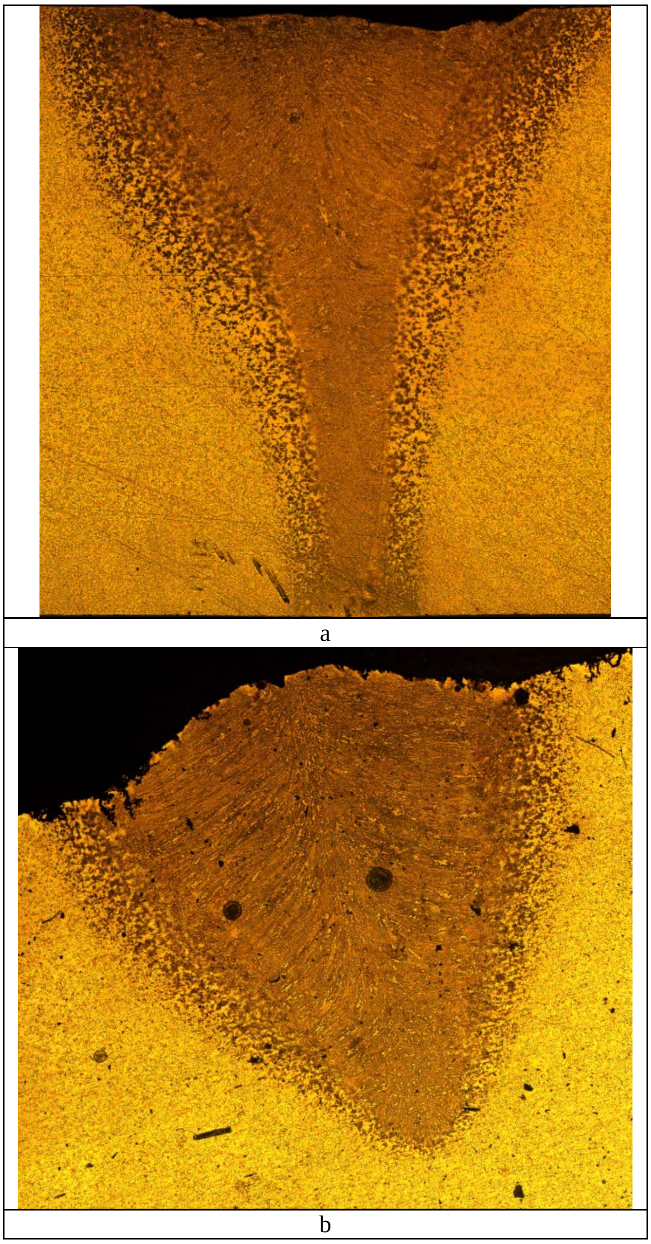
Geometry of the joint welds produced by EBW of the given constructional steels has been analyzed. The joint weld geometry is characterized by the following size factors: the depth h and the width d (Fig.1). The joint weld depth is defined as the longest distance between a joint weld surface and a point of maximum weld penetration of a base metal. The joint weld width is the maximum distance between visible weld lines at a transverse macrosection. Variation of the joint weld geometry (depth and width) for steel 40X depending on welding modes is presented in Table 1. The joint welds obtained by EBW of steel 40X samples have a depth of 9-12 mm and a width of 7-8 mm.

For metallographic tests on the joint welds produced by EBW samples with two planar parallel surfaces have been cut off using Micracut 151, a precision cutting-off machine. After that the samples have been exposed to grinding, polishing and etching. In order to determine the structure of 40X samples a mixture of 4% solution of nitric acid and ethyl alcohol has been used as an etching agent. Microstructure has been investigated using MI-1 microscope equipped with a CCD camera.
Study of microhardness of joint welds has been carried out using PMT-3 device. Loading on the penetrator has been 100g for steel 40X.

Table 1 – Variation of the joint weld geometry depending on EBW modes

Joint weld parameters			EBW modes	
Samples	Depth, mm	Width, mm	Focusing current, mA	Beam current, mA
1	8.0	5.4	650-660	100
2	6.7	4.9	650-660	80
3	3.9	5.5	660-670	80
4	6.8	3.8	633-643	90
5	6.5	3.8	633-643	90
6	5.0	3.3	633-643	95
7	5.5	4.2	633-643	100
8	4.0	4.4	633-643	70
9	4.2	4.7	633-643	50
10	5.3	5.3	633-643	60

Fig. 2 presents the microstructure of 40X joint welds in the test samples 1 and 7 after EBW. This figure shows that there are no cracks in joint welds. In sample 7 there are some pores.



a is the sample 1, b is the sample 7
Fig. 2 – Microstructure of 40X joint welds produced by EBW

Fig. 3,a shows the steel 40X microstructure: fine-grained, ferrite with small dark perlite inclusions. The microhardness is 1.1-1.2 GPa (Fig.4). Fig. 3,b shows ferrite-perlite structure of steel 40X. The ferrite microhardness (light phase) is 1.3-1.6 GPa, the perlite microhardness (dark phase) is 1.9-2.3 GPa.

Fig. 5 shows the microstructure of the joint weld of 40X sample obtained by EBW. The microhardness of the joint weld metal is 1.3-2.1 GPa.

Fig. 5,b shows the structure of the joint weld using a 40X sample as an example. The joint welds have dendritic structure, dendritic crystals being elongated in the direction of heat rejection. Fig.6 shows microhardness distribution in 40X joint weld. Due to a great difference between the microhardness values of the light and the dark phases measurements have been taken in terms of the dark phase. The microhardness of the given phase in the joint weld zone is 2.8-3.0 GPa, which slightly exceeds the microhardness of the base metal. For the light phase the microhardness is 5.2-5.9 GPa. In the course of EBW quenching structures are formed, which leads to a great increase in the hardness of the joint weld material as compared to the base metal and serves as a disadvantage in terms of strength balance of separate parts of the welded structure.

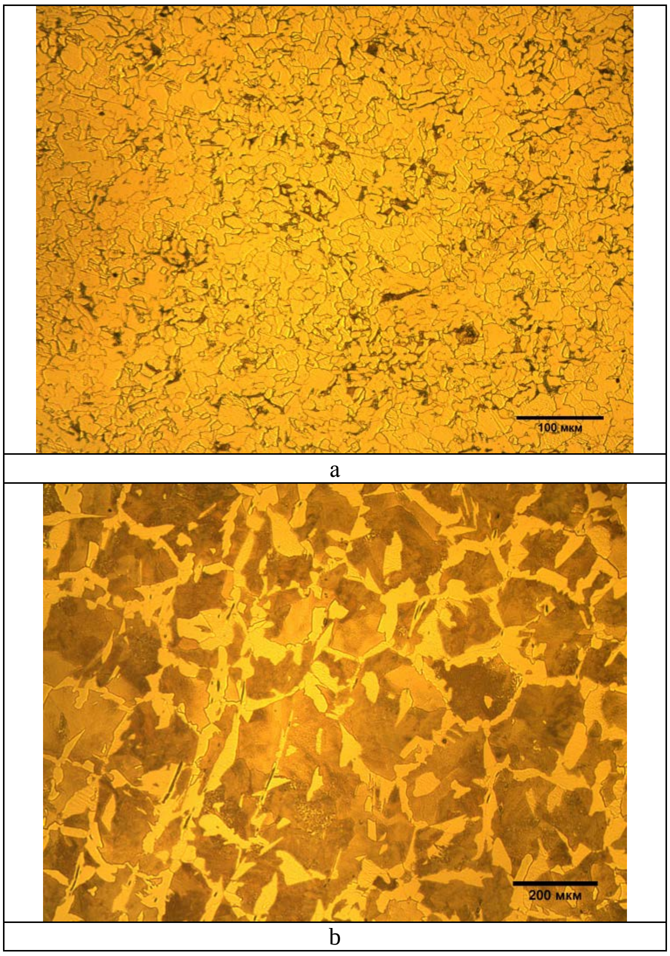


Fig. 3 Microstructure of the constructional steel 40X (a) and (b) in initial state

A heat-affected zone (HAZ) is small (0.6-1.5 mm) for 40X samples therefore it should not have a great effect on the joint weld strength. The microstructure of steel 40X in HAZ after EBW without preheatment is shown in Fig.7.

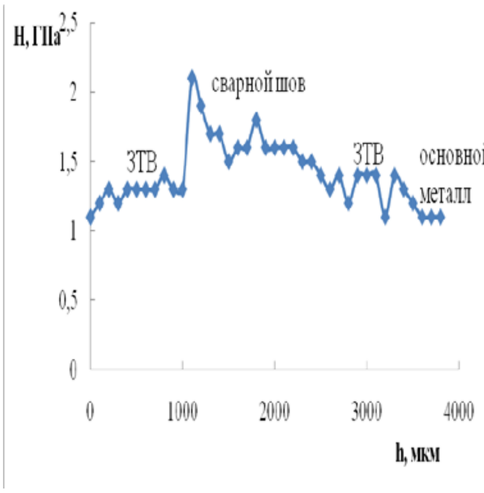
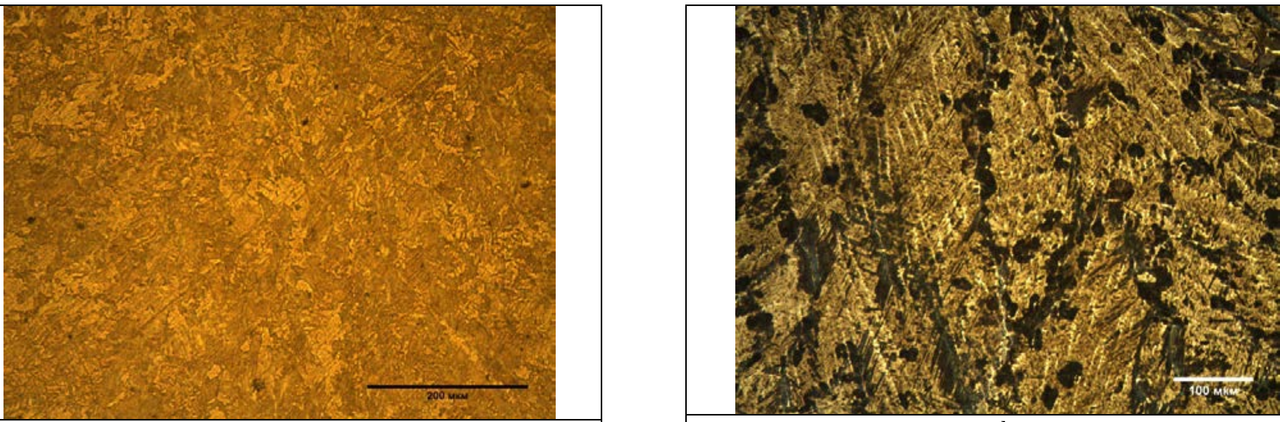


Fig. 4 – Microhardness distribution in 40X joint weld produced by EBW



a b

Fig. 5 – Microstructure of 40X joint welds obtained by EBW without preheatment (a) and (b)

The microhardness of the dark phase in HAZ is 2.1-3.0 GPa and the microhardness of the light phase is 1.3-1.5 GPa.

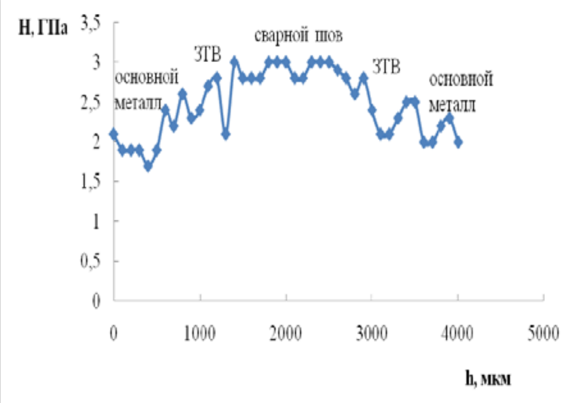


Fig. 6 – Microhardness distribution in the joint weld made of steel 40X obtained by EBW

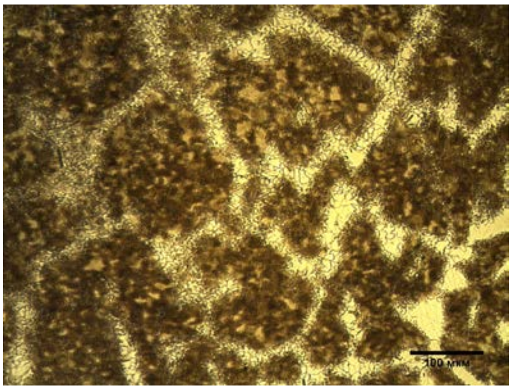


Fig. 7 – Microstructure of steel 40X in HAZ after EBW without preheating

4.Conclusions

Thus, in order to prevent formation of quench structures, which leads to an increase in microhardness of constructional steels after EBW, one needs to carry out preheatment and subsequent heat treatment of samples.

5.Literature

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