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MICROSTRUCTURAL ANALYSIS OF A POWDER WIRE CLAD LAYER CONTAINING TUNGSTEN NANOPOWDER

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The main principles of using wires with tungsten nanopowder for arc cladding are considered. Special features of production and application of tungsten-modified wires are analyzed. The microstructure of the high-strength layer obtained by cladding wires with different tungsten nanopowder contents is investigated. Microhardness of clad specimens is determined.

Keywords: tungsten nanopowder, powder wire, arc cladding, cladding roller.

INTRODUCTION

Currently a promising direction in development in surfacing and restoration technology is use of nanopowders within combined welding materials. Of the main advantages of these materials attention should be given to the fundamental possibility of forming an object surface with prescribed properties. Practical use of nanopowders within the composition of welding material is so far a quite complicated and difficult process.

A representative of combined welding materials is powder wire making it possible to resolve the problem of surfacing alloys that are difficult to shape and are not amenable to drawing (high-chromium cast iron, alloys containing tungsten, etc.). Powder wire is one of the most promising welding and surfacing materials since it makes it possible to prepare metal of almost any composition and also to conduct welding and surfacing of steels and alloys with the main properties. The structure and properties of surfacing metal may vary due to addition to a charge of appropriate components. In particular such components may be nanopowders and nano-materials [1].

The properties of surfacing metal (surfacing layers) mainly depend upon dendrite geometric parameters and shape, whose formation proceeds as a result of welding bath crystallization [2].

A change in surfacing grain dimensions is accomplished by modification. One of the most effective and widespread modification methods for this is introduction into a welding bath melt of prepared crystallization centers, i.e., refractory elements or chemical compounds of particles having an ultra- or nano-size. Introduction into a molten welding bath followed by crystallization of nano-dispersed metallic particles in turn facilitates an increase surfacing metal strength properties [3, 4].

Currently processes for modifying surface metal layers are used extensively in joining and additive technology. In view of this, modification of surfacing layers with ultra- and nano-size modifiers is an important scientific and practical task. Use of a modifier with these particle dimensions makes it possible to control a surfaced metal crystallization process, and to obtain a surface with a prescribed structure and properties. In this case formation of a fine-grained surfaced metal structure (instead of coarse-grained) will make it possible to improve mechanical and operating properties of components, structures, and installations as a whole [5].

The main disadvantage of surfacing metal modification is the fact that nanostructured powders during action within an electric arc may warm up within the arc space above their melting temperature. As a result of this nano-structured powder particles dissolve in the high-temperature zone of a molten welding bath and consequently they will not cause grain refinement during solidification.

The aim of the present work is development of an effective method for modifying surfacing metal using powder wire containing tungsten nanopowder.

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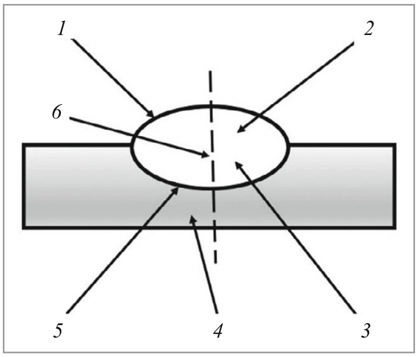

Fig. 1. Layout of test cladding layers areas: *1*) cladding roller; *2*) area of "granular" dendrites; *3*) recrystallized dendrite region; *4*) basic metal; *5*) fusion zone of cladding roller and basic metal; *6*) microhardness measurement line.

METHODS OF STUDY

Modification of technology was implemented by introducing powder wire as a supplementary material in the tail part of a welding bath according to a scheme presented in [6]. In this case tungsten nano-powder concentration within wire was varied in the range from 0 to 1 wt.% with a step of 0.2%.

The base used was powder wire PP-AN170M. Surfacing was performed on the surface of steel 10KhSND specimens.

One of the stages in creating powder within whose composition there is a nano-structured modifier, i.e., tungsten powder, was planning and preparation of a new unit for forming such surfacing material [7].

It should be noted that initially tungsten nano-powder was prepared by technology described in [8]. For this wire grade BA 0.31 mm in diameter and 50 mm long. The voltage supplied to the high-voltage electrode was 31 kV. Powder was prepared by conductor electric explosion. This method makes it possible to vary powder fineness, and to change both physical (diameter, length exploded section of wire, gas pressure within the unit) and also the electrophysical parameters (working voltage, capacitance, contour inductance, and as a consequence energy introduced into wire during electric explosion) [9].

The modification process includes the following. Filler wire within whose composition there is nano-structured tungsten powder, was fed into the tail part of a welding bath. Wire was melted in a stream of superheated welding bath molten metal directed beneath the arc into the tail section. Nanostructured powder from melted filler wire was fed to the tail part of the welding bath without crossing the arc space, i.e., almost without loss, and in a solid condition transferred into the welding bath molten metal where there was mixing. Particles of nano-structured tungsten powder serve as additional crystallization centers of surfacing metal solidification, i.e., weld metal is modified.

A study of various sections of deposited layers was accomplished in accordance with the scheme presented in Fig. 1. Microstructural analysis of wire by a light metallography method in a Neophot 21 microscope with image recording by a Genius Vilea Cam camera for surfaced rolls. Microhardness was measured in a PMT-3M microhardness meter.

RESULTS AND DISCUSSION

Microstructural analysis of a surfacing layer was accomplished by a procedure provided in [10]. It was established that the structure of specimen surfacing layers obtained with a different tungsten content within the surfacing is more complex and consists of two regions: "granular" dendrites and misorientated dendrites (Fig. 2).

However, in spite of the similar composition with an increase in nano-powder content within a wire charge grain size decreases. Experimental results for determining grain size in relation to tungsten nano-powder concentration within a wire charge are provided in Fig. 3*a*.

Analysis of experimental data made it possible to describe the dependence obtained by an empirical equation

$$d = 31.59 \times \exp(-1.55/W), \quad (1)$$

where d is grain size ìm; W is tungsten nano-powder content within wire, wt.%.

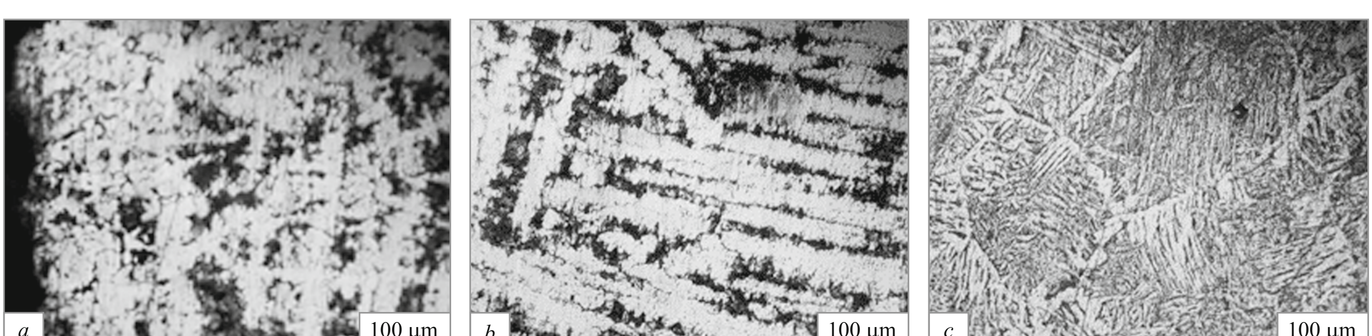

Fig. 2. Cladding and basic metal microstructure: *a*) region of "granular" dendrites; *b*) region of differently orientated dendrites; *c*) basic metal.

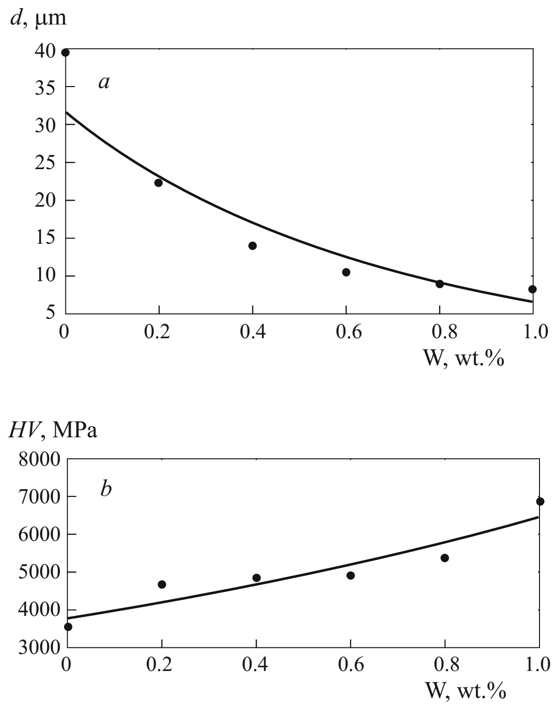

Fig. 3. Dependence of grain size (*a*) and cladding layer *HV* microhardness (*b*) on nanopowder tungsten concentration within cladding wire.

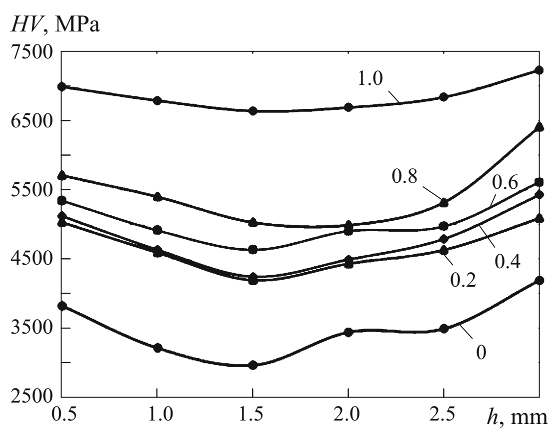

Fig. 4. Change in microhardness *HV* through cladding layer thickness within cross section (*h* is distance from surface). Figures on curves nanopowder tungsten content within cladding wire, wt.%.

In the test case tungsten nano-powder particles serve as prepared crystallization centers, i.e., they fulfil the function of a surfacing metal modifier. By changing tungsten concentration within a powder wire composition it is possible to control surfacing metal structure.

In order to evaluate the effect of nano-powder on the strength indices of surfaced layers microhardness of surfaced rolls was measured over a line *6* (Fig. 1) with a pitch of 0.5 mm. The distance from the deposited metal structure surface differed from 0.5 to 3.5 mm (Fig. 4). In all specimens microhardness distribution was identical in nature. The greatest microhardness for a surfaced roll is that around the melting boundary with basic metal. In this case at the fusion boundary microhardness indices are somewhat higher than at the surface that is due to different heat removal during crystallization *f* surfacing metal into the surroundings and basic metal.

A dependence is provided in Fig. 3*b* for the average value of surfacing layer microhardness on tungsten content. Analysis of these data made it possible to describe the experimental dependence obtained by an empirical equation

$$HV = 3776.8 \times \exp(0.54W), \quad (2)$$

where *HV* is surfacing layer microhardness, MPa; W is the tungsten content, wt.%

Addition of tungsten nano-powder to the composition welding wire makes it possible to refine grains, significantly increase hardness, and consequently surfacing layer strength properties.

CONCLUSIONS

Research has been conducted on surface layers prepared by wire arc surfacing with addition of tungsten nano-powder on steel 10KhSND. It has been demonstrated that the range of tungsten concentration in question (0 – 1 wt.%) within powder wire it is possible to reduce surfacing metal grain size by a factor of 2.7. In this case surfacing hardness increases by a factor of 1.9. Maximum value of microhardness are recorded at the surface of deposited metal and around fusion zones that is connected with features of structure formation during surfacing cooling (different heat removal conditions).

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