ELECTRON BEAM WELDING OF BODIES OF DRILL BITS WITH MODIFYING OF WELD METAL BY ZIRCONIUM

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The influence of weld metal modifying in EBW of new designs of drill bits was studied. It is known that application of zirconium inserts-modifiers allows preventing cracks in welded joints of 40KhN and 14Kh3MNA steels.

Keywords: *electron beam welding, drill bit, zirconium, weld modifying, cracks, microstructure, hardness*

It is commonly known that the only effective method for search and exploration of oil and gas fields is a deep drilling. The principal difference of deep drilling for oil and gas from other kinds of drilling consists in depth of wells. The updating equipment and technology for deep drilling, sufficient increase of efficiency of drill bits and decrease of their cost price are the tasks put before many leading companies-manufacturers of drilling equipment. In the complex structure of drilling system the bits are the component on which efficiency of the whole drilling process greatly depends. Therefore much attention is paid both to modernization of existing designs of bits and also to the development of new ones. The result of this work is the increase of average drifting for one modern bit by 122 % as compared to the similar value for bits of design of 1984.

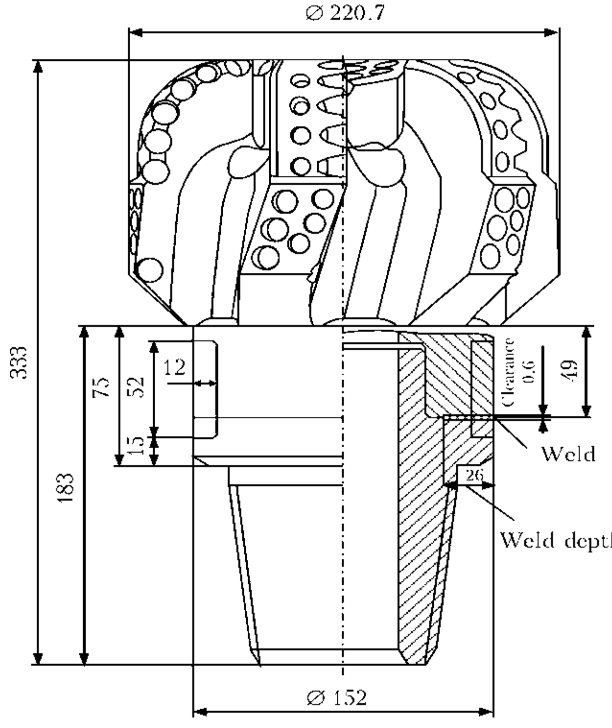

Figure 1. Scheme of general view of bit manufactured of steels 40KhN and 14Kh3MNA

As far as drill bits are operated under very rigid conditions, the selection of steels for their manufacture should be strictly differentiated for each single element of a bit, i.e. from bodies of slide rolling and materials of bearings to bodies of legs and bits.

The steel used for manufacturing of a bit leg should provide high strength and ductility combined with a good wear resistance. Many leading companies-manufacturers of drill bits abroad use steel AISI 4815H (analogue of the steel 15Kh3MA) or AISI 9315H (analogue of the steel 19KhGNMA) to manufacture legs.

At the same time, for new designs of drill bits the manufacture of their body part is planned of steel 40KhN (Figure 1), and joining with the steel 14Kh3MNA of nipple part should be performed by a

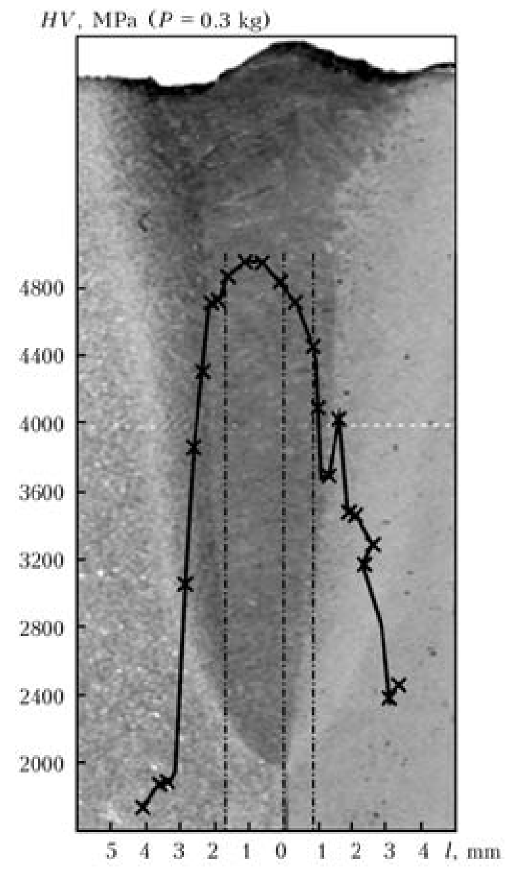

Figure 2. Cross section and distribution of microhardness in welded joint of steels 40KhN and 14Kh3MNA

circular weld. Selection of steel 40KhN is predetermined by need in increase of structural strength of a bit to increase speed of drilling. From the practice of arc welding of steels with increased carbon content the tendency of their welded joints towards crack formation is well known. The steels of the type 40KhN have tendency to reversible temper brittleness [1]. The prevention of cracks in arc welding of these steels is achieved by preliminary and postweld heat treatment which allows increasing ductility of welded joints. For the same purpose the welding methods of steel 40KhN with high concentration of energy are more challenging which provides less weakening of welds.

It is known that frequency of rotation of bits is a key factor in achieving the high speeds of drilling. At the modern market the bits demonstrating reliable operation at the frequency of rotation of up to 500 rpm and more are already available. The production of these bits should provide minimal design deviations in geometry of ready-made products from the drawings. Applying arc welding during joining of composite parts of a bit into single one, the residual deformations result in deviations of sizes which does not allow using them at high frequency of rotation. Thus, this problem also urgently requires highly concentrated sources of heating in welding production of drill bits.

The purpose of this work was the investigation of weldability of steels 40KhN and 14Kh3MNA and development of principal technology for EBW in production of new designs of drill bits.

The nature of brittle fracture of welded joint is predetermined by effect of two main factors: heat and load influence of welding. The local fracture affects base metal in direct vicinity of a weld, at the distance of one or several grains from it, i.e. in those places where steel was overheated to the temperatures exceeding 1200–1300 °C. To minimize overheat, i.e. to decrease the time of duration of area of near-weld zone

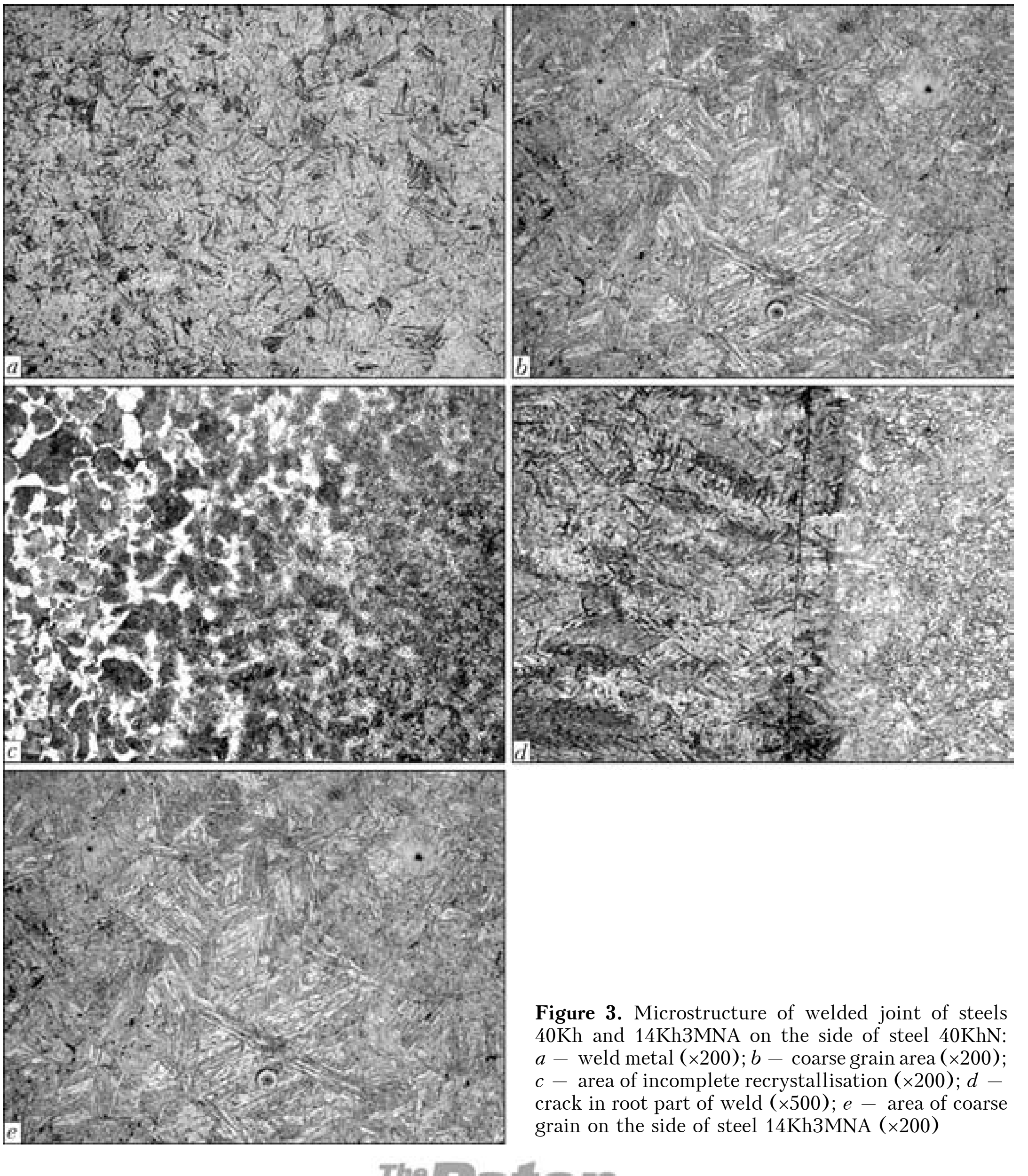

Figure 3. Microstructure of welded joint of steels 40Kh and 14Kh3MNA on the side of steel 40KhN: *a* — weld metal (×200); *b* — coarse grain area (×200); *c* — area of incomplete recrystallisation (×200); *d* — crack in root part of weld (×500); *e* — area of coarse grain on the side of steel 14Kh3MNA (×200)

adjacent to the weld at the temperatures of more than 1200–1300 °C, such concentrated heat source as electron beam is required.

The investigations carried out earlier [2] clearly showed that application of EBW allows sharp reducing of overheat in near-weld zone, delaying growth of austenite grains, preventing propagation of macrocracks from one areas of welded joint to other due to «tempering» of defects of physical character (dislocations, secondary boundaries) and eliminating possibility of their ordering into the boundary. Taking this into consideration, one can expect positive results as for quality of welded joints of dissimilar steels, one of which is 40KhN.

The principal technology of EBW was practiced on the flat models of welded joints of steels 40KhN and 14Kh3MNA of 30 mm thickness. Depending on the sizes of bits the required penetration depth should be 15–26 mm. The optimal shape of a weld is characterized by practically parallel walls with small convergence to the root in combination with a design penetration depth (Figure 2). It was provided by a certain heat input of welding which, for example, was 970 kJ/m for 16 mm depth. Directly before EBW

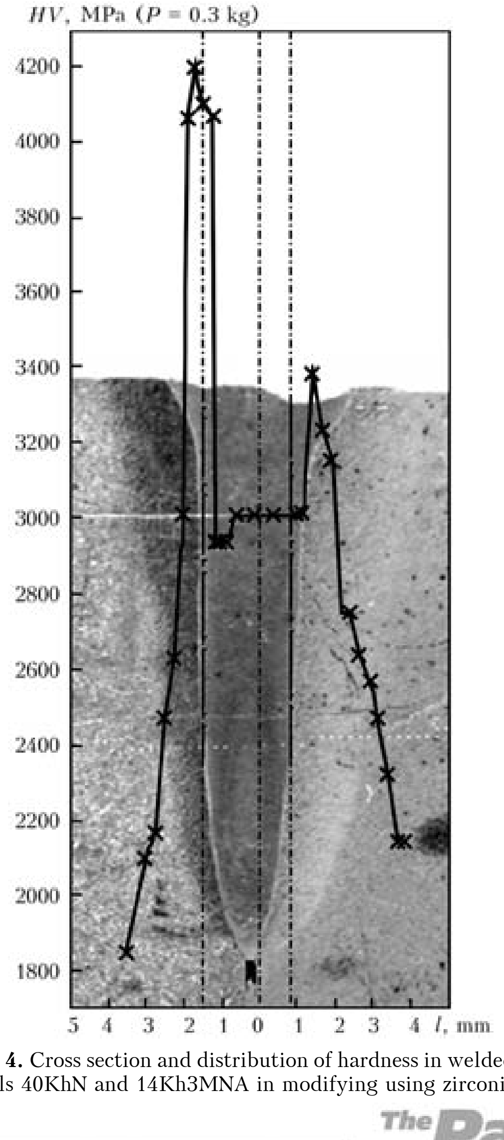

Figure 4. Cross section and distribution of hardness in welded joint of steels 40KhN and 14Kh3MNA in modifying using zirconium

the cleaning of a butt using electron beam was performed under the following conditions: speed of movement of electron beam v = 6 mm/s, welding current I_w = 12 mA, current of focusing lense I_f = 563 mA, circular scan of a beam A = 10 mm diameter. After welding and mechanical cutting of welds the structures of welded joints were investigated. The microstructure of weld metal is martensite one. It is characterized by ageing with acicular orientation at 60° angle. The hardness is rather high, i.e. of HV0.1-4810–5050 MPa (Figure 3, *a*).

The microstructure of base 40KhN metal is ferrite-pearlite with not high hardness HV0.1-1680–2180 MPa. The fusion line on the side of 40KhN is distinct, cracks and other defects along the fusion line are not observed. In the zone of overheat (on the area of coarse grain) the martensite structure with hardness HV0.1-4810 MPa (Figure 3, *b*) is observed. The microstructure of fine grain area is also martensite with somewhat lower hardness than that of coarse grain area – HV0.1-4410 MPa. In the area of partial recrystallisation (Figure 3, *c*) ferrite and pearlite are observed in the structure. Hardness drops smoothly with increase of ferrite and pearlite content in structure.

The width of HAZ on the side of 40KhN is from 0.3 mm in the root part up to 2 mm in the upper part of a weld. In a number of cases the cracks were observed in welded joints (Figure 3, *d*).

In the coarse grain area on the side of the steel 14Kh3MNA the structure of mostly lower bainite is observed which preserved orientation at the angle of 60° (Figure 3, *e*). The hardness of this structure is lower than martensite one and is HV0.1-3790–4180 MPa. At some distance from the fusion line the areas of ferrite component appear in the structure and the hardness respectively falls down to HV0.1-2470 MPa. The width of HAZ on the side of steel 14Kh3MNA is somewhat wider than HAZ on the side of 40KhN and amounts 0.5 mm in the root part, and in the upper part of a weld it is up to 3 mm.

Lamellar-acicular structure of welded joint of steels being investigated with large drop of hardness predetermines low ductility of joints with formation of cracks in them. To transform lamellar-acicular structure and improve strength properties of joints, the weld modification was applied using inserts to the butt in a form of a foil 0.1–0.2 mm thick of steel Kh18N9T, titanium and zirconium. The efficiency of this method was proved earlier in the development of technology of EBW of large-size drill bits.

In this case the best results from the point of view of preventing cracks formation in welded joints were obtained using inserts of zirconium. Inserts in a shape of rectangles of foil 4 × 10 mm in size and 0.1 mm thick were located along the whole length of a butt with a 30 mm gap. The conditions of EBW were preserved the same as in welding of butts without inserts.

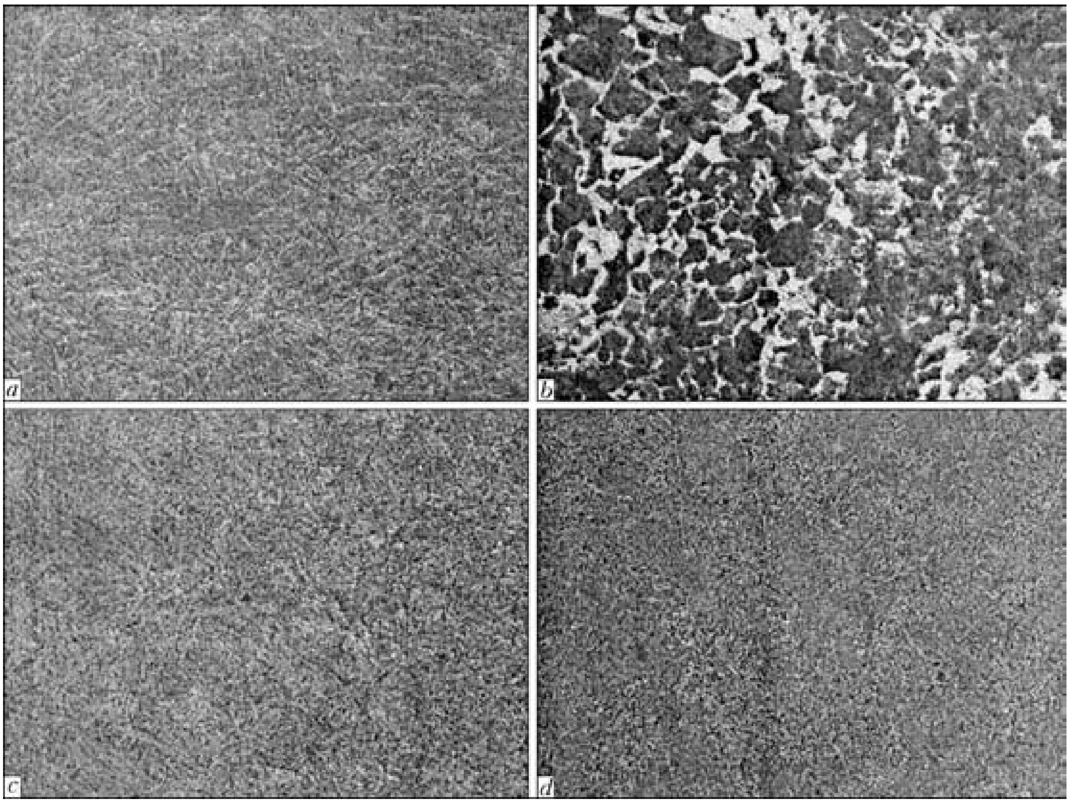

Figure 5. Microstrucutres of welded joint of steels 40Kh and 14Kh3MNA with insert of zirconium: *a* — weld metal (×200); *b* — area of large grain (×200); *c* — area of incomplete recrystallisation (×200); *d* — coarse grain area on the side of steel 14Kh3MNA) (×200)

The adding of zirconium into weld metal facilitates the formation of hard-to-dissolve carbides in austenite. Their influence on the properties of joints is revealed in a form of refining grains, decreasing threshold of cold-shortness and decrease of sensibility to stress concentrators [4].

The distribution of hardness on the transverse sections shows its decrease in average by HV0.1-800 MPa (Figure 4) which evidence the producing the more ductile welded joints.

The microstructure of a weld with insert of zirconium is bainite-martensite with hardness HV0.1-4410–4570 MPa (Figure 5, *a*). At coarse and fine grain area the microstructure on the side of steel 40KhN represents classical fine acicular martensite with hardness of up to HV0.1-4800 MPa (Figure 5, *b*). At the area of partial recrystallisation the areas of ferrite and pearlite structure (Figure 5, *c*) appear which decreases hardness down to HV0.1-2320 MPa. At the area of coarse grain on the side of 14Kh3MNA the microstructure is composed of mixture of upper and lower bainite with hardness of HV0.1-3750 MPa (Figure 5, *d*). The cracks in welded joints are not observed.

Thus, weld metal modifying using zirconium in EBW of steels 40KhN and 14Kh3MNA in designs of new types of drilling bits provides formation of welded joints without cracks.

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