MAGNETICALLY-IMPELLED ARC BUTT WELDING OF PIPES OF STEEL X70

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The paper gives the resuels of investigation of weldability of pipes of ∅168 × 7 mm from X70 steel for application in pipelines for various purposes, as well as the results of metallographic and mechanical property investigations of welded joints.

Keywords: *press welding, magnetically-impelled arc, pipe steel X70, pipelines, joint formation, technology of welding*

Over the recent years the investigations are carried out at the E.O. Paton Electric Welding Institute of the NAS of Ukraine for welding pipes and pipelines of up to 219 mm diameter and up to 16 mm wall thickness [1]. Results of investigations showed the feasibility of practical application of magnetically-impelled arc butt (MIAB) welding for pipes and pipelines. The MIAB welding process is characterized by a high efficiency (time of welding is 20–50 s), minimum consumption of pipe parent metal equal to wall thickness, moreover, the auxiliary welding consumables and consumable gas are not required.

The aim of the present work is to investigate the weldability of steel X70 using the MIAB welding method. Pipes of 168 mm diameter and 7 mm wall thickness were used for investigations. This selection was due to demands of different branches of industry and construction for the development of new highly-efficient methods of welding of small-diameter pipes and pipelines. Steel X70 refers to low-carbon steels with the following chemical composition, wt.%: 0.03 C; 0.156 Si; 1.45 Mn; 0.004 S; 0.004 P; 0.07 Cr; 0.14 Ni; 0.20 Mo; 0.02 V; 0.30 Cu; 0.033 Al; 0.022 Ti; 0.062 Nb; 0.012 As.

Peculiar features of joints formation in MIAB welding, and also main parameters, defining the quality of joints, are described in works [1, 2]. Main technological parameters of welding steel X70 pipes of ∅168 × 7 mm are the following (Figure 1): time of welding is 34.7 s; upsetting force — 247 kN; pipe shortening — 7.5–7.9 mm; consumed power — 28.7 kW.

To perform the mechanical tests, the sections were cut out from the pipe welded joint. Formation of welded joint on external and internal sides of the pipe is given in Figure 2.

Results of mechanical tests showed that strength and ductile properties of welded joint are at the level of characteristics of the parent metal (Table 1, Figure 3).

Structure of HAZ metal in MIAB welding is mainly similar to the structure of similar joints of pipes made

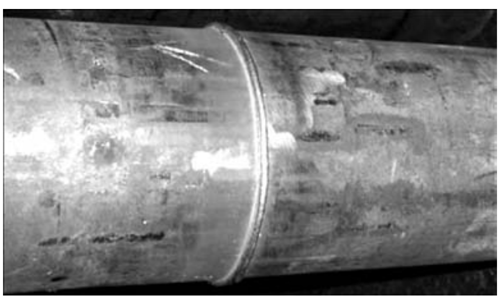

Figure 1. Welded joint of steel X70 pipes of ∅168 × 7 mm

Table 1. Mechanical properties of parent metal and welded joint of steel X70 pipes

Test area	σ_y, MPa	σ_t, MPa	KCV_{+20}, J/cm^2
Parent metal	448.9–469.1 / 460.6	528.8–566.8 / 551	248.4–265.7 / 256.5
Welded joint	411–440 / 425.5	511–556 / 533.5	124.8–283.4 / 204.1

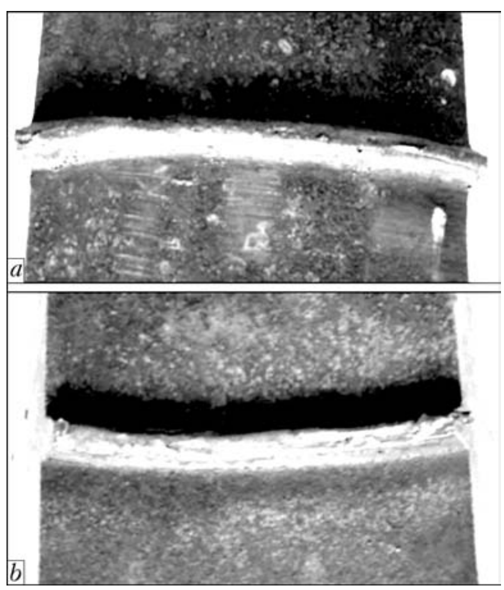

Figure 2. Formation of welded joint on external (*a*) and internal (*b*) sides of pipes

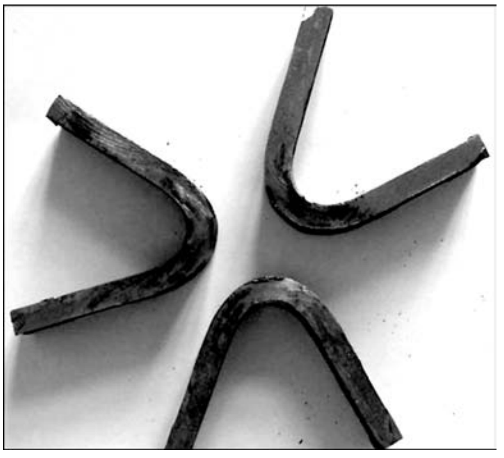

Figure 3. Results of bend tests of welded joint

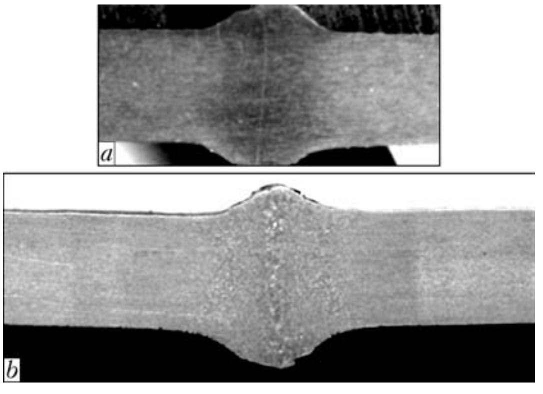

Figure 4. Macrosections of steel X70 welded joints made by MIAB welding (*a*) and FBW (*b*)

by the flash-butt welding (FBW), but there are differences in the formation of a central part of the joint. Analysis of macrostructure of joints of steel X70 pipes of ∅168 × 7 mm showed (Figure 4, *a*) that the HAZ width in MIAB welding is not more than 10 mm, and the width of area of normalization in a middle line is 2 mm. In FBW the width of HAZ and normalization area is 18 and 6 mm, respectively (Figure 4, *b*). Thus, in MIAB welding the HAZ is much narrower than in FBW that provides the formation of a finer-grain structure.

The area of welded joint of steel X70 was subjected to metallographic examinations. The microhardness of welded joint was measured in the LECO device

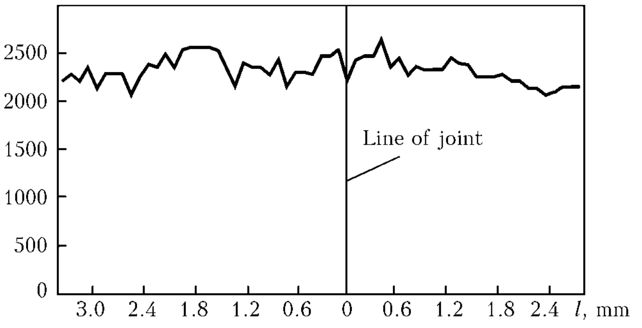

Figure 5. Distribution of microhardness of metal in welded joint zone

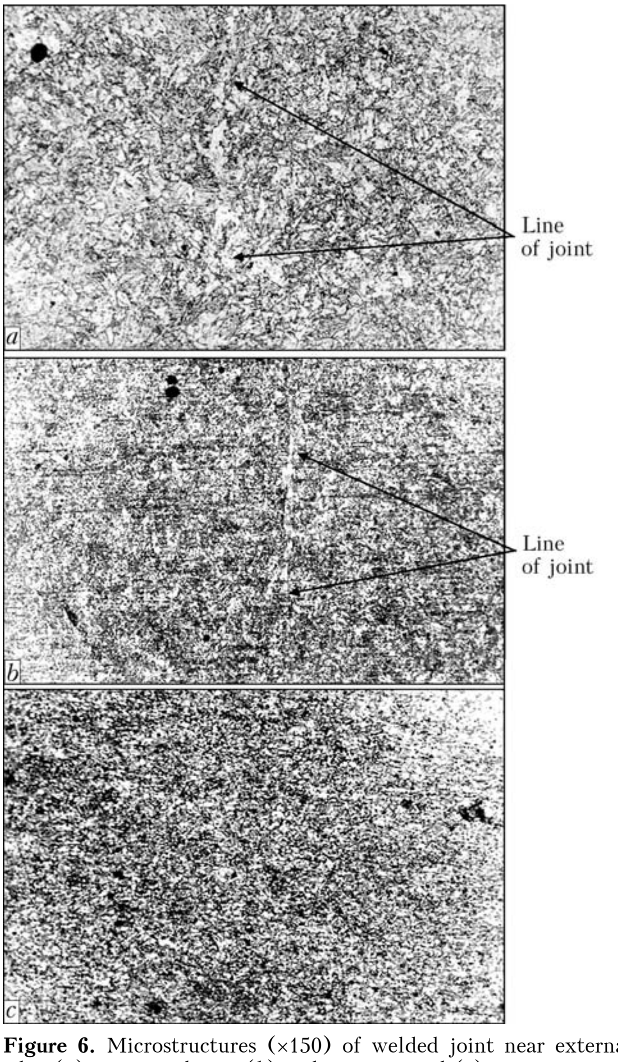

Figure 6. Microstructures (×150) of welded joint near external edge (*a*), in central area (*b*) and parent metal (*c*)

M-400 at 1 N load and 100 μm pitch. Sample was etched in 4 % HNO_3 solution in alcohol.

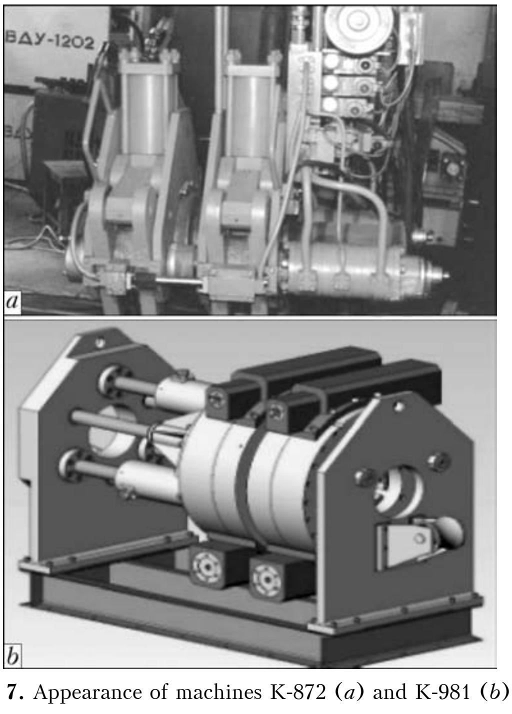

Figure 7. Appearance of machines K-872 (*a*) and K-981 (*b*)

It is seen in Figure 5 that there is a negligible increase of hardness in a ferrite band up to *HV* 2450 MPa in the joint, that is higher than the microhardness of the pipe parent metal. In FBW the decrease in microhardness at this region is usually observed.

The joint line represents an intermittent white band of up to 10 μm thickness in a central part of the welded joint and it is widened up to 30 μm to the edges of section sample (Figure 6, *a*). Microhardness of ferrite band of the joint line is *HV* 2050–2450 MPa. Structure of area in a central part of sample is fine-grained (number 8–9 by GOST 5639–82) ferrite-pearlite with hardness of *HV* 2470–2640 MPa (Figure 6, *b*). At the edge of sample the structure is coarser (number 7) with domination of a ferrite component and microhardness of *HV* 2190–2350 MPa (Figure 6, *a*). At the fine grain area the structure is fine-grained ferrite-pearlite with number 10–11 and *HV* 2270–2400 MPa.

The parent metal is fine-grained with domination of a ferrite component (grain number is 10) and *HV* 2130–2360 MPa (Figure 6, *c*).

At the coarse grain area the amount of a pearlite component is increased as compared with that of parent metal and other HAZ regions. This leads to a negligible increase in hardness at this region. Defects in welded joint were not revealed.

The carried out investigations showed that the structure and mechanical properties of joints of pipe steels X70, made by MIAB welding, are very similar to those of FB-welded joints. Therefore, the systems and methods of non-destructive testing and in-process control, accepted in FBW, can be similar.

The machines have been developed for MIAB welding of pipes and pipelines, providing welding in the field and stationary conditions (Table 2).

Machines K-980, K-872, K-981 (Figure 7) are designed for press welding of pipes and different-purpose pipelines and consist of welding head, hydraulic pumping station, control cabinet with a remote control panel, and arc power source.

Table 2. Technical characteristics of machines for MIAB welding

Type of machine	Diameter of pipes to be welded, mm	Wall thickness, mm	Welding efficiency, welds/h	Consumed power, kV·A	Mass, kg
K-980	50–140	3–10	80	80	3500
K-872	89–219	2.5–8.0	60	90	2500
K-981	120–250	3–10	50	160	4500

The suspended head K-872 is of a tong type, the characteristic feature of which is a separate clamping of pipes being welded. Machine by its design has a possibility of loading and unloading pipes being welded aside [3].

Machines K-980 and K-981 are of a continuous type, the characteristic feature of which is a separate clamping of pipes being welded. Design of machine of a continuous type provides a high accuracy of axial aligning of welded pipes and pipelines [4].

CONCLUSIONS

1. Main conditions of MIAB welding for formation of welded joints of steel X70 are defined.

2. Technology of welding of steel X70 pipes of ∅168 × 7 mm has been developed.

3. Welding equipment and technology of MIAB welding of pipes of up to 250 mm diameter and up to 12 mm wall thickness have been developed

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