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Study Changes in the Structure and Phase Formation in the Welded Joints of the Alloy 47 Crnimo

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Abstract

Structure welds usually consists of several zones: a zone of the weld zone and heat affected zone of the base metal. During welding zone occur recrystallization processes, flow rate and completeness of which depend on the distance to the suture. The seam zone about these processes have time to go to the full, and therefore the structure consists of equiaxed austenite grains. During welding seam and the heat affected zone softening than the original tape as supplied. Therefore, weld molded portion includes a weld zone, a portion of softening the heat affected zone and the base metal of cold. Therefore, the aging of each of these sections is strengthened with various intensity. With increasing aging time to 3 hours. The variation in the strength of the weld metal and base metal is substantially eliminated.

Key Words: *Welding, Alloy, Metal, Aging, Argon.*

Introduction

Alloys elastic elements besides high technological and operational, in particular elastic properties, should allow welding or brazing the various solders. Because along with the methods of thermal and mechanical-thermal treatments to spring alloys in the manufacturing technology of elastic-sensitive elements are frequently used treatment with concentrated flows of energy, such as welding Tuyakbaeva, Akhmetzhanov and Iskakov (2005).

The main feature of age-hardenable alloys is that they are reinforcing particles isomorphous phases. During welding, the material is subjected to considerable thermal diffusion effects that may affect the allocation process of the hardening phase during aging. Therefore welding precipitation hardening alloys has its own idiosyncrasies. One problem when welding age-hardenable alloys - the tendency to form cracks occurring at different stages of production of welded products Hansen (1962).

Main Body

The elements of welded metal and welded joints can occur dangerous local stress concentration zones, which have received or are plastic deformation to one or another degree, such zones identified passive fluxgate method of control, require clarification of their size and location methods of metallographic analysis and solid-symmetry that is of great scientific and practical interest.

To determine the changes in the structure and phase formation in the welded joints of the alloy 47CrNiMo we studied the structure and an assessment of the mechanical properties of welded joints of the alloy in the state of delivery, in the hardened state and after aging. Since the question of influence of welding on structure and mechanical properties of the alloy 47CrNiMo not yet fully resolved, which prevented a complete disclosure of the potential of this alloy.

Aging of the samples at 700^0C within 4-5 hours was carried out in a vacuum with a residual pressure not higher than 1 Pa

For the study were selected TIG, electron beam, laser and electro-contact types of effects (Table 1). Modes of melting with and without melting, in the latter case, the surface conditions were simulated heat treatment. Test samples were cut from the tape thickness of 0.1-1 mm, previously quenched in water from a temperature 1250^0C. The tape was cut into square cards with the face size of 100 mm square. Then the simulated thermal deformation welding cycle using the settings for the contact, argon arc, electron beam and laser welding. They use a continuous and impulsive modes.

Using the welding method allows for high-impact short pulses of high energy quickly melt a microscopically small volume of metal and cool it as fast as possible into the interior of the heat sink rest of unheated metal. The cooling rate in this case can be up to 106-1010 ° C/s. Also a method of melting fine-focus high energy pulse stains on the metal surface (point method) was used as a continuous process and surface hardening moving beam (traveling beam method), or movement of the sample with variable speed relative to a stationary beam.

Table 1. Types of installations, types and modes of high-impact, used in the work

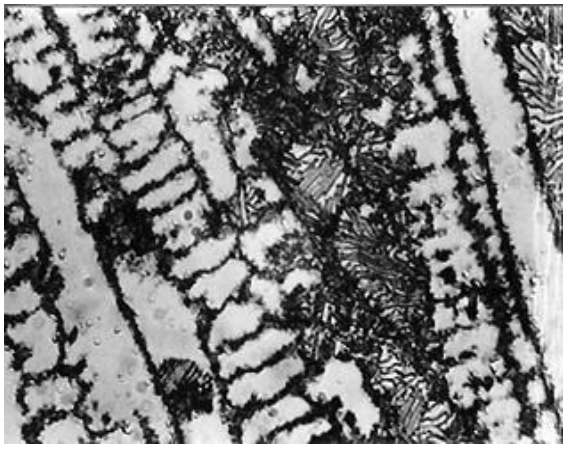
№	Modalities	Profiles	Style installation	I, A	I_l, A	U, kV	υ, m/s	ν, imp/s	P, N
1	Electrocontact	1 2 3 4	MR-4	2650 5200 4600 3900	- - - -	- - - -	$6,67\cdot10^{-3}$ $25\cdot10^{-3}$ $6,67\cdot10^{-3}$ $25\cdot10^{-3}$	9 25 25 25	370 500 750 750
2	Argon	1 2 3 4	ASTE -7	20 24 15 26	- - - -	- - - -	$11,1\cdot10^{-3}$ $11,1\cdot10^{-3}$ $6,4\cdot10^{-3}$ $13,9\cdot10^{-3}$	- - - -	- - - -
3	Electron Beam	1 2	A306.13	- -	$7\cdot10^{-3}$ $13\cdot10^{-3}$	30 30	$13,9\cdot10^{-3}$ $13,9\cdot10^{-3}$	- -	- -
4	Laser Continuous The laser pulse action	1 2	Expert. setting QUANT-15	30 -	- -	- -	$3,33\cdot10^{-3}$ $1,25\cdot10^{-3}$	- -	- -

Metallographic and Electron-microscopic studies it was found that during welding, regardless of the initial structural state in the bond formed structural heterogeneity, does not eliminate the final heat treatment - aging (Figure 1a). Structural heterogeneity after aging due to the occurrence of uneven discontinuous

allocation incoherent α-phase in the different parts of the welded joint, which leads to a decrease in the overall level of mechanical properties.

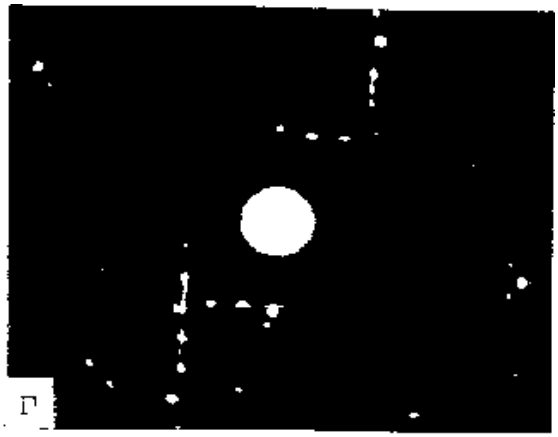
Microdiffraction analysis of the pictures (figure 1, d) showed that the particles in the discontinuous weld decay in the form of lamellar precipitates (Figure 1c) are incoherent α-phase based on chromium (solid solution of nickel in chromium). Figure 1d shows microdiffraction picture of α-phase. When the aging temperature is increased to 1000°C causes the change of the decay mechanism. In this case, the excess α-phase is released in a continuous mechanism.

a



b

c



d

a- general view of the connection, x30;
b - weld structure, x1000;
c - intermittent release of α - phase in the weld, x2250
d- micro diffraction pattern in Fig. 1, c.

Figure 1. Structure of welded joints of the alloy 47CrNiMo.

The development of macro and microstructural heterogeneity in the welded joints of the alloy 47CrNiMo depends on the type and welding conditions. The minimum size of the weld and heat affected zone are formed by electron beam and laser welding, which leads to higher values of mechanical properties. If the electron beam welding width depending on the welding conditions is in the range 0.10-0.25 mm, then when it reaches the TIG welding to 0.50 mm.

In TIG welding sample thickness less than 0.2 mm are observed burn marks and strong buckling. Therefore, to use TIG for products with a thickness of less than 0.25 mm is not recommended.

Unlike other types of welding resistance welding is characterized by small time welding at high welding currents and efforts to ensure local melting of the metal.

Welds produced by contact welding with melting and in the solid state, have low ductility compared to other types of welding (Table 2), which is associated with hardening of the material in the contact zone during welding, and at its final over aging heat treatment (aging). Mechanical properties of the weld joint obtained by contact welding, determined primarily only the properties of the weld.

Table 2. Mechanical properties of welded joints of the alloy 47CrNiMo depending on the initial structural state

№	Heat treatment and the type of welding	**Mechanical properties**		
		$\sigma_{0,2}$, MPa	σ_B, MPa	δ, %
1	Delivery condition (50%)	1340	1415	1,4
2	Delivery condition + AAW	625	825	2
3	Delivery condition + aging at 700°C, 4 hours	1010	1210	0,45
4	Delivery condition + AAW + + aging at 700°C, 4 hours	888	888	0,2
5	Hardening of the 1250°C, 2 min	501	926	13,6
6	Hardening of the 1250°C, 2 min + CW	499	631	6,9
7	Hardening of the 1250°C, 2 min + aging at 700°C, 5 hours	914	1200	4,0
8	Hardening of the 1250°C, 2 min + CW + aging at 700°C, 5 hours			0,08

*AAW - argon arc welding
*CW - contact welding

Mechanical properties at resistance welding with melting higher than resistance welding in the solid state. This is due to the fact that the welding in the solid state is not smooth transition zone is formed and a common molten core pronounced chemical inhomogeneity.

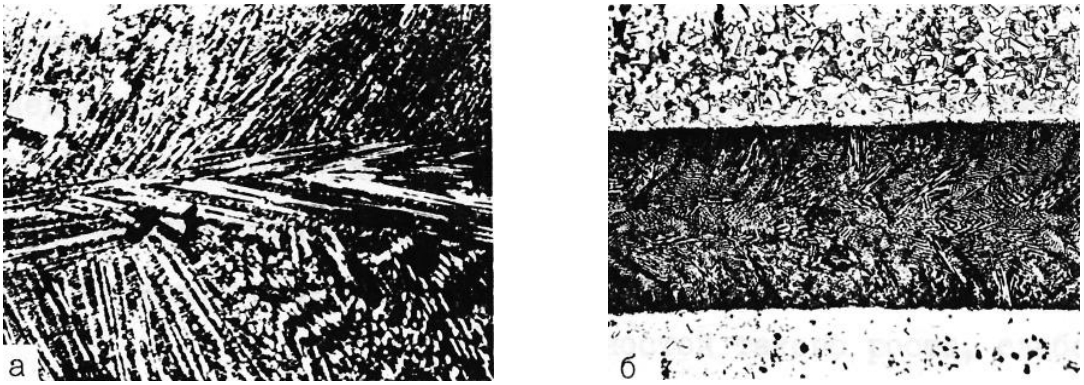
The results of mechanical tests show that the highest level of mechanical properties when using resistance welding is achieved under the following conditions: welding current I = 4600A, the speed of movement of the source $\upsilon=6{,}67\cdot10^{-3}$ m/s, the compressive force of the electrodes P=750N.

In the case of TIG welding, the highest level of compressive, tensile properties and ductility of the alloy is achieved by using the mode: the current I=20A, the speed of movement of the source $\upsilon=11{,}1\cdot10^{-3}$ m/s.

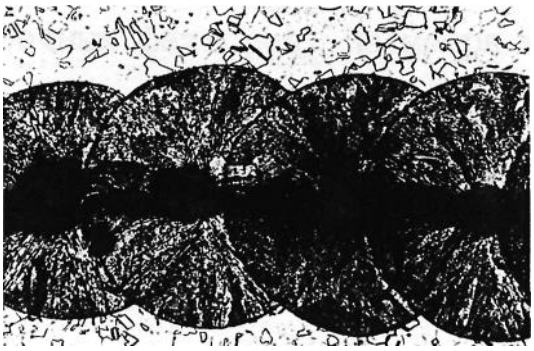
The highest resistance to damage under static loading welded joints have produced electron beam and laser welding in continuous mode, the macro- and micro-structural heterogeneity which is weaker than the argon arc welding.

When an electron beam exposure elastic and strength properties of the alloy above for mode 1 ($I_l=7\cdot10^{-3}$ A) in comparison with the 2 ($I_l==13\cdot10^{-3}$ A), and the process - almost identical. When various kinds of high-impact type alloys 47CrNiMo formed macro- and microstructural heterogeneity, consisting of a cast zone adjacent the zone and base metal. It is found that in all studied species of high-impact-hard enable alloys

with intermittent decay mode, the molten metal is crystallized to form a dendritic-cell structure regardless of the original structural state (Figures 2, 3).



a *b*



c

a - electron beam exposure, x50;
b - laser (continuous), x50;
c - laser (pulsed mode), x100.

Figure 2. Effect of the form of high exposure to the emerging nature of the structures in the cast zone.

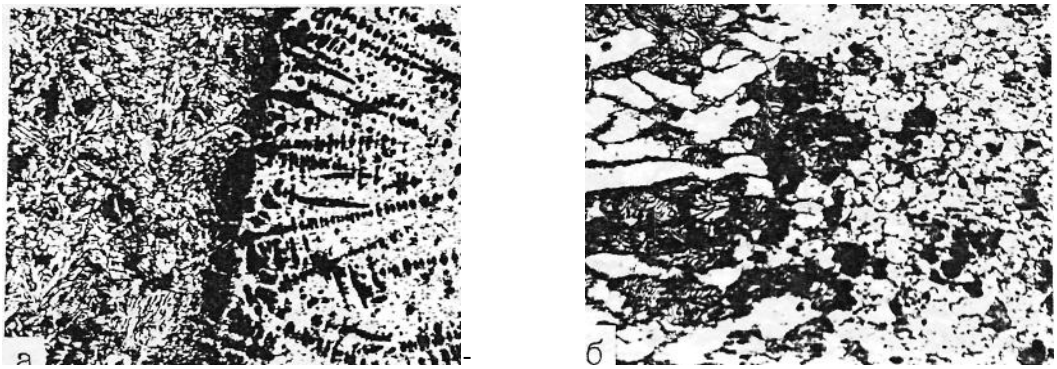
When the electron beam exposure in the central part of the cast area-oriented structure is not observed (Figure 2a). When a laser (continuous exposure) and electric contact surfaces influences the contact zone of columnar dendrite is not formed, and molded zone has fine-grained structure (Figure 2b).

Character dendritic structures formed during the crystallization of metals and alloys, significantly affects many physical and mechanical properties, in particular, the anisotropy of the properties, ductility, yield strength and toughness.

Of particular interest for the study area is adjacent to the casting area, ie, heat-affected zone, where there are significant structural changes, has a significant impact on the process of selection of the hardening phase, and thus the mechanical properties of the complex Shugaenko, Drapiko, Ziborova and Chernyakov (1985). The portions of the near zone can be cast melt grain boundary formation of microcracks, the migration of grain boundaries, resulting in grain growth. It is known (BE Sunquist, 1973) that an increase in grain size leads to a reduction of the volume fraction of discontinuous precipitation aging and thereby cause a reduction in the mechanical properties of the heat affected zone. Furthermore, within the grains slip lines observed indicating a deformed state of the material in this area. Part trimmed defects can probably heal through the subsequent aging complex reaction and recrystallization of intermittent γ′-selection phase. Note that the

electric contact, electron beam and laser exposure of grain growth in the was observed. Apparently, this is due to the fact that these kinds of feedback are highly localized heating that provides them with high rates of heating and cooling. There fore, grain growth does not have time to occur.

Most clearly manifested heat affected zone with a high energy impact on the deformed material. Figure 3 shows the structure of the cast zone and of the alloy as received, after exposure to argon-arc. Cast zone has a dendritic-cell structure (Figure 3a). The heat-affected zone (Figure 3b), there are several specific areas as we move away from the border deep into the fusion of the base metal. When the high-impact deformed metal is inevitable softening of the as a result of heating, the dislocation density in this region is reduced as compared with the parent metal. At the boundary alloying complete recrystallization occurred, that is under the influence of high temperature occurred structure refinement. As the distance deep into the base metal grain sizes increase, but inequigranular observed (Figure 3b) appears, this material portion undergoes the process of secondary recrystallization. Perhaps this is as follows: under the influence of heating temperature originate new grain to the grain boundaries of deformed metal or subgrain boundaries of strongly disoriented. New grains formed free from hardening, increasing the deformed structure due to its extinction, i.e. primary recrystallization process takes place. Thereafter, the boundaries of new grains continue to move, but at a lower speed. It is the stage of grain growth, when absorbed by other one grain, or in other words, passes the secondary recrystallization of the base metal.



a *b*

a – dendritic structure of the cast alloy welded joint area, x250
b – heat-affected zone of welded joint alloy 47CrNiMo, x400

Figure 3. Macro and microstructural heterogeneity in alloys with discontinuous type of decay.

The presence of macro and microstructure inhomogeneity causes the appearance of chemical heterogeneity. The chemical heterogeneity of cast metal band called nonequilibrium conditions of crystallization, the incompleteness of the processes of diffusion or convective leveling composition of the melt and equalizing diffusion in the solid phase. The cast metal develops normal or increased impurity segregation in the solidification direction, it is manifested not only in the bulk of the metal, but in each crystal, i.e. crystallite part solidifies primarily contains fewer impurities than the portion solidified later. The greatest amount of impurities accumulated in the center of the cast zone where joined growing towards each other crystallites. Research shows Chernyshova T. (1986), along with the normal segregation zone is formed in the cast cellular and dendritic segregation. This type of chemical heterogeneity is associated with the appropriate form of crystallite growth Chernyshov (1986).

In addition to these types of segregation in the cast zone has a layered distribution of impurities. It is caused by a change in the rate of growth of the crystallites due to uneven flow of heat into the liquid metal bath, periodically upsets the balance of income and removing heat and changing the cooling rate. To equalize the mechanical properties of the weld zone and the base metal is necessary to conduct a further heat or mechanical-heat treatment after welding with subsequent aging.

Findings

High quality welding in conjunction with a maximum output of the process for the web material provided to choose the right welding mode; highest resistance to fracture under static loading welded joints have produced electron beam and laser welding in continuous mode, the macro- and micro-structural heterogeneity which is weaker than in TIG welding; in place of welded joints premature failure is the boundary between the weld and the HAZ, the middle seam; welded joints obtained by welding by melting of the contact in the solid state, has low plasticity in comparison with other types of welding, due to the hardening of the material in the contact zone during welding, and at its final overaging heat treatment (aging); the mechanical properties of welded joint are determined, basically, only the properties of the weld; mechanical properties at the contact welding with melting higher than with solid state welding. This is due to the fact that the welding in the solid state is not smooth transition zone is formed and a common molten core pronounced chemical inhomogeneity; to align the mechanical properties of the weld and the base metal is necessary to conduct thermal and mechanical-thermal treatments, regimes are determined by the type of alloy.

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