PECULIARITIES OF DEGRADATION OF METAL OF WELDED JOINTS OF STEAM PIPELINES OF HEAT POWER PLANTS

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The peculiarities of degradation of structure and damageability of metal of welded joints of the steam pipelines of heat power plants of long-term operation period (more than 250,000 h) under the conditions of creep and low-cyclic fatigue are given. It is shown that welded joints of steels 15Kh1M1F and 12Kh1MF are damaged mostly along the areas of fusion, overheating and partial recrystallization of metal in the near-weld zone and also in the places of joining pipe elements of different thicknesses. 13 Ref., 1 Table.

Keywords: *welded joints of steam pipelines, degradation, structure, creep cracks, fatigue cracks, carbides*

The revealing of peculiarities of degradation of structure of metal of welded joints of steam pipelines of heat power plants of long-term operation period (more than 250,000 h) under the conditions of creep and low-cyclic fatigue is challenging as the effect of initial stage of their damageability. The damageability of steam pipelines mostly occurs simultaneously by the mechanism of creep micropores formation and mechanism of fatigue microcracks formation [1–4]. Welded joints of steam pipelines, characterized by a considerably increased structural, chemical and mechanical heterogeneity, are respectively damaged more intensively (except of bends) than the base metal. The service life of welded joints of steam pipelines amounts approximately to 0.6–0.8 of the base metal life [2, 5–9, 11–12].

The damageability of welded joints of steam pipelines (Table) is provided by technological, design and service factors. During service life of welded joints of more than 250,000 h, the peculiarities of damageability, revealed by metallographic methods, are strictly different from the similar peculiarities of damageability of welded joints, life duration of which amounts to 60,000–200,000 h. [2, 10]. The metal structure of HAZ of welded joints of steam pipelines as well as that of weld and base metal is transformed at different intensiveness into ferrite-carbide mixtures, which are differed by grain size of α-phase; level of grains polygonization; rate of carbide reactions $M_3C \rightarrow M_7C_3 \rightarrow M_{23}C_6$; rate of coagulation of carbides of the group I; level of segregation of chromium and molybdenum in near-boundary zones of grains of α-phase; presence of places, where boundaries of grains of α-phase detach from coagulating carbides; local liquidation of grain boundaries of α-phase, which can be considered as an initial stage of primary recrystallizaiton [7, 9–10].

The change in metal structure of long-term operated steam pipelines is predetermined by physical and chemical processes, the intensiveness of which in metal of welded joints of steam pipelines is stronger than in their base metal [9–10, 13]. The presence of difference in gradients of chemical potentials of chromium and molybdenum across the section of crystals of α-phase causes their diffusion movement to the near-boundary zones of crystals, thus leading to segregation phenomena. The conditions for occurrence of carbide reactions $M_3C \rightarrow M_7C_3 \rightarrow M_{23}C_6$ are created. The release of carbon from M_3C and M_7C_3 results in formation of new carbides of the group II of Mo_2C and VC. In carbides the amount of molybdenum reaches to 50 %.

It was revealed that VC carbides almost do not coagulate at the service life of welded joints (steels 15Kh1M1F and 12Kh1MF) up to 300,000 h. It is rational to specify the capability of Mo_2C carbide to coagulation. The decrease in chromium and molybdenum in the nodes of the crystal of α-phase decreases the retardation effect of dislocations, which results in polygonization of grains of α-phase (formation of subgrain structure).

At the local clustering of dislocations near the grain boundaries of α-phase they can partially penetrate through the boundary and break up in other grain in the form of vacancies, interstitial atoms, and also can cut off the elongated carbides $M_{23}C_6$. The energy of grains boundaries grows to the level facilitating the formation of dislocations in the neighboring grains.

Types of damageability of welded joints of steam pipelines at their long operation (more than 250,000 h)

Damageability zone. Types of cracks. Direction of crack propagation	Metallographic peculiarities of damageability	Causes of damageability
Creep cracks		
Zones of fusion, overheating and partial recrystallization of HAZ metal, weld metal (WM) and rarely base metal (BM). The cracks are propagating from the outer surface of welded joints perpendicularly to the axis of steam pipeline element. Transverse cracks are formed in welded T-joints with a thinned wall of connecting pipe.	Along the boundaries of the contact of 3 or 2 coarse grains of α-phase, at the places of contact of grains with coagulating carbides $M_{23}C_6$. Along the grain boundaries of α-phase, where new products of austenite decay in the form of granular pearlite (area of partial HAZ recrystallization) are located.	1. Design, caused by high concentration of local stresses, in the zones of contact of steam pipeline elements of different thicknesses. Presence of undercuts. 2. Technological, caused by presence of original rejected structure or structure close to the rejected one, which is predetermined by an increased welding heat and heat treatment performed with violation of requirements of standard documentation; discrepancy of chemical composition as to requirements of standard documentation. 3. Service, caused by service conditions: difference of real condition of steam pipelines from the design one; increase in number of starts–stops of power units; increased rate of heating up during the process starting; conditions of manoeuvrable operation mode of power units.
Corrosion-fatigue cracks		
Zones of contact of pipe elements of different thicknesses, areas of fusion, overheating and partial recrystallization of HAZ metal, WM and BM (rarely). The cracks are developing from the inner surface of welded joints. Shape of cracks — thread-like, with branches, in the form of blunt crack filled with corrosion products, and sharp cracks with side branches.	Cracks formation occurs along the boundaries and in body of grains, with domination of one or another type, which depends on service conditions.	Initiation and growth of cracks cause mutual effect of cyclic thermal stresses and corrosion environment on metal and are also activated by degradation of structure.

The presence of structural, chemical and mechanical heterogeneities results in higher level of degradation of metal of welded joints than of base metal. To improve the reliability of operation of welded joints of steam pipelines and to increase their service life it is rational to delay the physical and chemical processes, which occur in their metal at the long operation under the conditions of creep and low-cyclic fatigue, that can be possible by applying steels of new generation.

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