CORPUS PUBLISHERS

Journal of Mineral and Material Science (JMMS)

ISSN: 2833-3616

Volume 6 Issue 2, 2025

Article Information

Received date : February 10, 2025

Published date: February 26, 2025

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DOI: 10.54026/JMMS/1111

Opinion

Structure and Damageability of Welded Joints Made of Heat-Resistant Steels

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Opinion

Increasing the reliability of operation of Thermal Power Plants (TPP) facilities made of heat-resistant steels largely depends on their original structure. And first of all, on the structure of welded joints of such facilities. The metal of welded joints is characterized by the presence of structural and phase heterogeneity, which is impossible to get rid of, but it is possible to reduce the level of heterogeneity to a certain extent. Reducing heterogeneity will increase the reliability of the corresponding welded joints, which seems to be very important. The purpose of the work is to determine typical defective structures that are formed during the manufacture of welded joints from heat-resistant steels and reduce their reliability when operating under creep and fatigue conditions. At TPPs in Ukraine, some of the equipment of their power units, including some steam pipelines, operate at a temperature of 545-565 ℃ and a steam pressure of 20.0-25.5 MPa. Such equipment and steam pipelines are made of 12X1MΦ and 15X1M1Φ steels [1]. Let us consider typical defective structures of welded joints, due to the presence of which their damage occurs by creep and fatigue mechanisms [1-4]. Note that damage is noticeably accelerated at permissible overheating in the temperature range of 580-610 ℃, as well as at the operating time of welded joints over 280 thousand hours. The areas of the Heat-Affected Zone (HAZ) of welded joints, the structure of which was formed under the influence of welding heating, are damaged to the greatest extent, Figure 1.

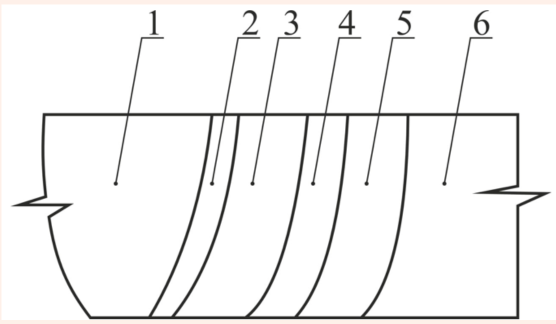

Figure 1: Schematic diagram of a welded joint made of heat-resistant steels: 1 - weld metal. HAZ sections: 2 - fusion; 3 - overheating; 4 - normalization; 5 - incomplete recrystallization; 6 - base metal.

Defective structures are mostly formed in the HAZ areas of those welded joints whose thickness is greater than 30 mm. The fusion area, Figure 1, width 0.11-0.21 mm, is subjected to welding heating in the temperature range limited by T_L-T_S. The metal of this area is in a solid-liquid state. Here, depending on the duration of its heating and cooling rate, large austenite grains, as well as pearlite and ferrite structures, can form. These structures should be considered defective. They are formed primarily in the central area of thick-walled welded joints, especially when welding at increased mode parameters. Optimization of the welding mode parameters allows obtaining sorbite or troostite structures in the fusion area, which significantly increases their resistance to damage. The structure of the HAZ overheating area is formed under the influence of welding heating in the temperature range T_S – 1150 ℃ (approximately) and may have large austenite grains of the 3rd and 4th points (DSTU 8972:2019). Their presence contributes to the acceleration of damage due to creep and fatigue mechanisms. The width of the overheating area is approximately 1.1-1.9 mm. Optimization of the welding mode parameters makes it possible to reduce the size of the austenite grains and the width of the overheating area. The HAZ normalization area, 0.9-1.2 mm wide, is subjected to welding heating in the temperature range of about 1150 ℃ - Ac_3. Structures close to the structures of the base metal are formed here. Therefore, the damage to this area is significantly lower than other areas of the HAZ. The area of incomplete recrystallization of the HAZ, 2.0-2.2 mm wide, is subjected to welding heating in the temperature range limited by the critical points Ac_1-Ac_3. Here, along the boundaries of the former austenite grains, austenite is formed again, which is transformed mainly into pearlite upon cooling. Its formation is determined by the heating temperature and the duration of holding in the induced temperature range. The presence of pearlite significantly reduces the stability of the structural-phase state of this area and contributes to the acceleration of its damage, which occurs conjugately by the mechanisms of creep and fatigue [4]. It is advisable to obtain sorbite or troostite in this area instead of pearlite, which is possible when welding at optimized mode parameters.

Increasing the operating parameters of power unit objects to a temperature of 650 ℃ and a pressure of 35 MPa will allow significant energy savings. And therefore, when developing new steels, it is advisable to take into account the features of the formation of defective structures in the HAZ areas of their welded joints. Such accounting will help prevent their damage, which is necessary to increase the reliability of the welded joint metal.

Conclusion

a. We have established the features of the formation of defective structures in areas of the heat-affected zone, the formation of which is caused by welding heating.

b. We have substantiated that the formation of defective structures can be prevented by optimizing welding heating, which should be taken into account when developing new, more heat-resistant steels.

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