UDC 621.181

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RESTORATION OF MECHANICAL PROPERTIES OF HEAT-RESISTANT STEEL BY HEAT TREATMENT AFTER ITS LONG-TERM OPERATION ON A TPP STEAM PIPELINE

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Abstract.
The operation of heat power equipment elements under the conditions of complex impact of high temperature and steam pressure in combination with static, dynamic and cyclic loads, corrosion and hydrogenation factors leads to significant degradation of heat-resistant steels, in particular, those used in steam pipelines. In the paper, a mode of restorative heat treatment (RHT) of 12Kh1MF steel after 286,000 hours of operation in the extended bend zone of the main steam pipeline is proposed and substantiated. RHT includes two-stage normalization at 1100°C and 960°C, followed by tempering at 740°C. The proposed treatment effectively refined the grain structure, reduced the amount of large carbides at grain boundaries, increased hardness, strength and ductility characteristics, and impact toughness. These improvements demonstrated the effectiveness of the proposed RHT mode for restoring the properties of degraded steel and showed the potential for ensuring safe operation and extending the service life of steam pipelines of thermal power plants.

Key words: heat-resistant steel 12Kh1MF, degradation, restorative heat treatment, service life extension, steam pipelines, grain size, mechanical properties.

Thermal power equipment is usually operated under difficult conditions of the combined impact of many process factors, in particular, high-temperature steam under high pressure, cyclic and static loads, as well as corrosion and hydrogenation effects of process environments. These factors cause significant degradation of heat-resistant steels, especially in such critical sections of steam pipelines as the stretching of their bend zones. The processes of steel degradation are largely determined by creep and are manifested in changes in the microstructure of steel, in particular, in the coarsening of both carbides and grains, which reduces the mechanical properties of steel [1, 2].

The objective of this study is to substantiate the restorative heat treatment (RHT) regime to improve the microstructure and mechanical properties of 12Kh1MF steel, thereby demonstrating the potential for extending the service life of steam pipeline components. The steel was used after 286,000 hours of operation in the tensile zone of a thermal power plant steam pipeline bend at a temperature of 540 °C and a pressure of 14 MPa. The RHT process included a two-stage normalization (1100 °C/150 min and 960°C/30 min) followed by high-temperature tempering at 740 °C/180 min [3]. Metallographic and fractographic studies were performed using scanning electron microscopy. Mechanical properties, including hardness, tensile and yield strength, ductility and impact toughness, were used to certify the steel before and after operation using standard testing methods.

Metallographic studies have shown that after RHT, the grains in the steel structure are significantly refined (over the entire thickness of the pipe wall). As a result, after treatment, the proportion of small grains increased to 55%, and large grains to 10%, which was considered a factor in reducing the resistance of steel to creep. The treatment also reduced the number of large carbides at the grain boundaries, moving them inside the grains, thereby increasing the cohesion strength of adjacent grains.

After applying the proposed RHT mode, the mechanical properties of long-term operated 12Kh1MF steel increase over the entire thickness of the pipe wall in the stretched bending zone. Mechanical tests

confirmed an increase in hardness (up to 170 HB), as well as strength, ductility and impact toughness of the restored steel. As a result, the hardness HB increased by almost 40%, the tensile strength by 19%, and RA by 60%. At the same time, the impact toughness of the restored steel increased more than twofold. But the main thing is that all the obtained characteristics exceeded the values regulated for this steel in the original state. This is a convincing argument for justifying the legitimacy of using the proposed RHT regime to extend the service life of 12Kh1MF steel in critical elements of TPP steam pipelines.

Thus, it was shown that the proposed RHT mode ensured effective restoration of both the microstructure and mechanical properties of 12Kh1MF steel after its degradation under operating conditions. This substantiated the possibility of using heat treatment under the proposed RHT mode as an effective method for extending the service life of critically degraded elements of TPP steam pipeline bends.

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ВІДНОВЛЕННЯ ТЕРМІЧНИМ ОБРОБЛЕННЯМ МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ ТЕПЛОТРИВКОЇ СТАЛІ ПІСЛЯ ЇЇ ТРИВАЛОЇ ЕКСПЛУАТАЦІЇ НА ПАРОГОНІ ТЕС

Анотація.

Експлуатація елементів теплоенергетичного обладнання в умовах комплексного впливу високої температури та тиску пари у поєднанні зі статичними, динамічними та циклічними навантаженнями, корозійними та наводнювальними чинниками призводить до суттєвої деградації теплотривких сталей, зокрема, що використовуються на парогонах. У роботі запропоновано та обґрунтовано режим відновлювального термічного оброблення (ВТО), що включає двоступеневу нормалізацію при 1100 та 960°С з наступним відпуском при 740°С. Така обробка ефективно подрібнює зеренну структуру, знижує кількість великих карбідів вздовж меж зерен, підвищує твердість характеристики міцності і пластичності та ударну в'язкість. Ці покращення продемонстрували ефективність запропонованого режиму ВТО для відновлення властивостей деградованої сталі та показали потенційну можливість забезпечення безпечної експлуатації та продовження терміну служби парогонів теплових електростанцій.

Ключові слова: теплотривка сталь 12Х1МФ, деградація, відновлювальна термічна обробка, продовження терміну експлуатації, парогони, розмір зерна, механічні властивості.

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