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Doctoral dissertation:

“Trwałość eksploatacyjna złączy spawanych ze stali Super 304H”

ABSTRACT

This doctoral dissertation analyses the operational durability of welded joints made of the new generation of austenitic steel Super 304H (X10CrNiCuNb18-9-3), used in ultra-supercritical and super-ultra-supercritical boilers, including pressure components, coils, and steam superheaters operating at temperatures up to 640°C. Integrated research methods were employed to assess operational durability, including creep tests under laboratory conditions, microstructural analyses using scanning microscopy, mechanical property testing, chemical composition and hardness assessments, and predictive calculations based on time-temperature relationships to forecast changes in material properties.

The theoretical part of the thesis outlines the primary directions of development for the Polish energy sector, its current status, and the formal and legal conditions that define the objectives of Poland's energy transformation. The main groups of materials used in modern energy production are discussed, including heat-resistant austenitic steels, with a particular focus on the tested Super 304H steel. Microstructure degradation mechanisms that negatively impact the mechanical properties and corrosion resistance of steel are described in detail, including the precipitation of secondary phases, changes in their morphology, and the processes of spheroidization and coagulation. Methodologies for assessing the service life of materials used in pressure components are presented, with particular emphasis on diagnostic procedures for determining the degree of structural degradation of components operating at temperature limits.

The research section presents the test results obtained for welded joints in their initial state and after long-term annealing at 700 and 750 °C for 1000, 5000, and 10,000 hours. Material characteristics are presented, including the microstructure state, mechanical properties, and creep resistance for each of the tested material states. Based on knowledge of the material's morphological characteristics in its initial state and EDS analysis, precipitates were identified. Based on the results of creep tests with elongation measurements, the loss of service life of the tested joints was determined depending on the annealing time and temperature.

Developing material characteristics of steam superheater coil joints operating under both stationary and variable operating conditions enables the estimation of service life loss under actual operating conditions, without requiring knowledge of the operating history or information on actual operating parameters at the facility. The obtained test results provide the basis for developing quality and technological procedures, the implementation of which in industrial practice will enable the standardization of actions in emergencies and other disruptions to the power plant's energy production process.