POLITECHNIKA ŚLĄSKA
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DIAGNOSTYKA STOPNIA WYPRACOWANIA ŁOPATEK CZĘŚCI WYSOKOPRĘŻNEJ WIRNIKA TURBINY 13K225 METODĄ MAGNETO-INDUKCYJNĄ

Rozprawa doktorska

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SUMMARY

The subject of this dissertation is the use of a magneto-induction method to diagnose the condition from the blades of the 13K225 steam turbine, which is innovative in the energy sector. The investigation addresses an important issue, which is the condition and life of machines and equipment. Important issues, especially for the energy industry, for industrial power plants, are ensuring business continuity and the ability to supply electricity to the grid. That is why the trouble-free operation of turbo units, without downtime or with the shortest possible downtime is the result not only of the proper design of among others turbines but also the result of proper operation with the necessary diagnostics. Preventive diagnostics avoid unforeseen breakdowns or even failures by determining the condition of the material and identifying areas of concern about structure changes that will lead to material degradation in the future. NDT diagnostic methods, such as ultrasonic testing, eddy current testing, dye – penetrant testing or magnetic particle suspension testing have been widely used in the energy industry to detect already existing material degradation, such as cracking. These methods do not ensure the early detection of a process of changes in structure continuity, that is preceded by material degradation.

The aim of the work is to develop a new diagnostic method, that allows early determination of the condition of the steam turbine blade material in an effective and efficient manner. The work presents the results of magneto-induction studies developed using Förster Plot methodology, which allows the analysis of changes in magnetic and electrical properties of the material. Changes in electrical and magnetic parameters in the test material were analysed in the frequency range from 3 to 7 times the limit frequency for the X22CrMoV12-1+QT2 steel tested, which ranges from 150 Hz to 700 Hz. Structural studies using transmission microscopy, X-ray structural analysis, as well as micro hardness measurements and basic mechanical parameter testing confirmed consistency with changes in electrical and magnetic parameters.

The results of the Förster Plot have been compared with the results of structural, microhardness and half-width tests of the X-ray diffraction line Δ^2. X-rays supported the analysis of chromium carbide precipitations in martensitic steel. In the case of turbine rotor blades, there is a complex stress state of varying intensity of its components between the blades, due to their length and centrifugal forces, and therefore variable and complex creep processes.

For small degradation recorded during inter-exploitation studies, linear relationships may be assumed between the degradation of the structure from high temperature creep and the measured hardness, since these distortions are many times lower [%] than the degradation for the range of elasticity and plasticity of the test steel [from the standard].

However, for low-energy steel, structure positioning error cannot be expected to be linearly dependent on material degradation [J/cm^{2}], even with single-axis tensile (2), [3], [4]. Examples include similarities and associations between deformation, hardness, network parameters and test results. This is confirmed by domestic and foreign literature for iron αFe [2], [5], [6].

An important determinant was the crystallographic lattice parameter for chromium carbides, which is an order of magnitude more sensitive than changes in the parameter for iron. The parameter of chromium carbide very sensitively reflects the state of the degradation process (however, the test process requires methods that destroy the samples and is expensive). Based on the microstructure studies conducted on the blades of the turbine made of X22CrMoV12-1+QT2 steel, it is possible to formulate a link between the electrical and magnetic parameters of the martensitic steel microstructure under high temperature creep conditions. In order to better demonstrate these links, the Poisson similarity parameter was set and all key figures were included in the table.

A comparison of the results of the test methods used revealed a link between structural changes resulting from material degradation and the progression of standardized impedance components analyzed by the Förster method.

Analysis of electrical and magnetic parameters in relation to changes in structural parameters has shown:

- high degree of similarity between the normalised real re component and the imaginary Im impedance Z with the designated network parameters for chromium carbide $Cr_{23}C_6$,
- significant hardness relationship $HV_{0,1}$ with imaginary component Im impedance Z,
- strong correlation between the number of reflexes counts - Height [cts] with the square of the width of the diffraction line $\Delta 2$ and with the Fe-Cr [A] lattice parameter for the tested blade steel (commonly ignored in X-ray diffraction methods as irrelevant).

Research on magneto-induction methods should be undoubtedly continued, as their application in industrial conditions will be a major advance, not only in material research, but also in the diagnosis of machinery and equipment working in the energy sector and other key industries such as oil and gas or renewable energy.