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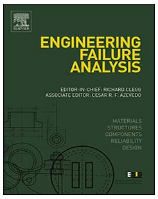

Failure analysis of casing of draft tube of turbine used in hydropower plant

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ABSTRACT

Corrosion of massive components used in hydropower plants causes considerable technical problems and economic losses. Due to the corrosive environment and strong dynamic loading, such components must meet high demands. Quality of the components is essentially influenced by quality of material—chemical composition, correct metallurgical processes and also good practice of subsequent forming and welding technology.

Aim of the analysis was to determine the failure cause of the massive casing of draft tube from turbine used in hydropower plant. The main part of this study was focused on detailed analysis of chemical composition and microstructural analysis of the failed component. Light microscopy and scanning electron microscopy techniques together with energy dispersive spectroscopy were used for assessment and detailed evaluation of present phases.

Detailed analysis determined corrosion attack to be intergranular corrosion. Furthermore influence of deviations in chemical composition and presence of a typical titanium nitrides on corrosion resistance of material were identified.

1. Introduction

Stainless steels, used for construction of components in hydro power plants are complex alloys containing not just Cr and Ni as main alloying element, but also other elements such as Mo, Mn, C, N, Ti among others. Based on their solubility, these elements can precipitate in form of secondary particles, for example carbides, nitrides, sulfides etc. Presence of such secondary particles in microstructure can severely influence mechanical properties and corrosion resistance of final component [1–3].

This paper describes failure analysis of draft tube, component from hydroelectric power station, equipped with 48 MW Kaplan turbines, submitted to our laboratory by customer. In such turbine type, flow is entered through a spiral casing, passes through runner and finally leaves through the draft tube, which transforms dynamic pressure, to static pressure. The draft tube, steel weldment embedded in reinforced concrete, has been inspected by customer every year. Last in situ visual inspection revealed cracks and their existence was confirmed by non-destructive testing method. Every high temperature operation (welding, grinding) during the draft tube repair caused propagation of cracks. Basic metallographic analysis performed by customer's laboratory revealed presence of intermediate phase, which reduced plasticity of the material. Even when the phase was eliminated by heat treatment, precipitated again during welding operation.

Draft tube was replaced and failed material send to our laboratory for further analysis in order to confirm cause of the failure and analyze degradation mechanism. Comprehensive analysis of chemical composition and microstructure of material used for the draft tube was revealed, that component failed due to intercrytalline corrosion resulting from unsuitable chemical composition and

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Fig. 1. (a) replacement of draft tube, (b) individual sheets after removing from the draft tube.

microstructure.

2. Material and methods

Failed draft tube from hydropower plant turbine was replaced (see Fig. 1) and part with visible cracks and degraded area was submitted to as by a customer for further analysis. It was specified by the detail drawing documentation that submitted part is a weldment—two welded sheets with the thickness of 20 mm. Both sheets were supposed to be made of the same material, 17 246 stainless steel (ČSN 41 7246 Standard), equivalent to X6CrNiTi18-10 stainless steel.

Submitted part is shown in Fig. 2. At first a detailed visual inspection was performed in order to determine degraded areas and other areas of interest. As can be seen from Fig. 2, sheet A contained distinctive crack. Another defect was observed along the weld on the side of sheet B. Samples for further observation were taken from both mentioned areas i.e. one sample from the degraded area of the sheet A and one sample for cross-section macro-observation of the weld.

Sectioning of component was carried out on cut-off machine Struerse Discotom 100 using intensive cooling. Two samples, one from each sheet were used for analysis of chemical composition via CCD based Optical emission spectrometer Tasman Q4. Samples from the close vicinity of the weld, but out of the heat affected zone from both sheets were taken for metallographic analysis.

Samples for metallographic assessment were prepared in the usual way using automatic grinding/polishing machine Struers Tegramin. Samples were wet ground with silicon carbide papers, polished with diamond suspensions and finally polished using colloidal silica suspension. After determination of content of non-metallic inclusions, samples were etched using mixture of picric acid and hydrochloric acid in ethanol. Microstructure was observed and documented by high-resolution digital microscope Olympus DSX510. For detailed observation and local analysis of chemical composition, scanning electron microscopes Tescan Lyra and Philips XL30 with EDX analyzer were used. At least 3 to 5 EDX measurements for each type of phase were performed to determine its chemical composition.

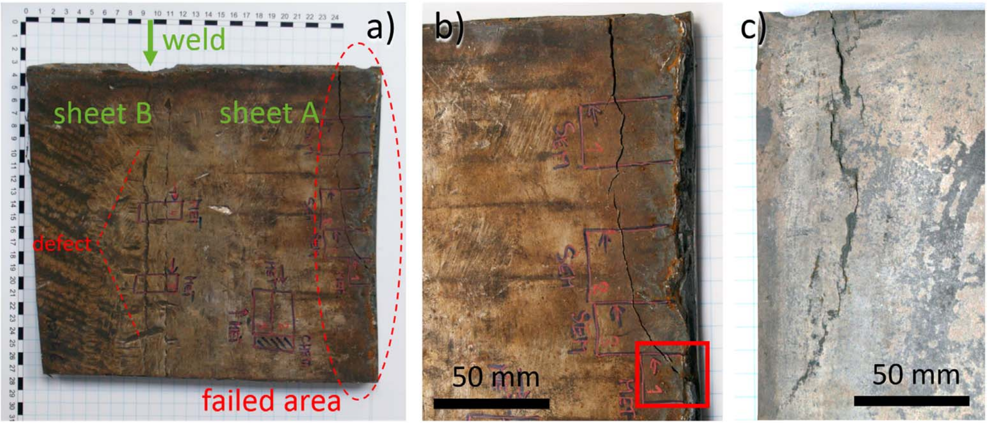

Fig. 2. Part of the draft tube submitted for analyses: (a) overall image, (b) detailed image of the crack—inner side with designated sample for analysis, (c) detailed image of the crack—outer side.