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Decreasing thermal stresses in steam generator collector weld's area using external cooling

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Abstract

Numerous WWER-440 steam generators showed a very serious problem of cracking in weld joints which are connecting primary collectors to the steam generator's vessel. As a cause of this cracking was determined stress corrosion cracking mechanism. The weld is connecting austenitic steel collector to the carbon steel vessel, so it is a dissimilar metal weld. There are two approaches how to lower the possibility of stress corrosion cracking in the weld. First one is to improve the secondary water chemistry in the weld's surrounding to stop the corrosion and second one is to decrease presented stresses in weld's area. It is better to combine both approaches. This paper deals with the second approach of possibilities to decrease presented stresses. Inspired by Russian study of external cooling on WWER-1000 steam generators, it was an attempt to adapt the external cooling idea on the WWER-440 steam generators and their problem of weld cracking. It was shown that by using the external cooling it is possible not just lower the presented tensile stresses but to change the tensile stresses into compressive stresses. This will of course result in significant reduction of stress corrosion cracking possibility in the steam generator primary collector weld's area.

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Keywords: steam generator; thermal stresses; external cooling; stress corrosion cracking; dissimilar metal weld

1. Introduction

On various WWER-440 nuclear power plants (NPPs) steam generators (SG) occurred quite serious problem of cracking in weld joints connecting primary collectors to the SG vessel's nozzle (Fig. 1). The cause of this cracking is stress corrosion cracking (SCC) mechanism. The crack rises and grows on the interface between different kinds of material, austenitic steel 08CH18N10T on one side and carbon steel 22K on the other (Fig. 2).

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On the SG secondary side, there is a space between the SG nozzle and the primary collector, which is also called “pocket”. In this pocket, due to poor possibilities of effective blowdown, exist the secondary media of higher corrosive potential. The existence of corrosive media together with existing stresses can cause intergranular corrosion and cracking in this area. Existing stresses are combination of thermal stresses from different thermal expansion properties of austenitic and carbon steels, and external stresses on the SG nozzle from the primary circuit. Thermal stresses are in this case higher and thus more important.

Dissimilar metal welds are of Vitkovice Machinery and Russian design. It can be seen that the crack is propagating between the two different materials, austenitic and carbon steels (Fig. 2).

The mechanism of crack initiation and propagation was studied in detail on different institutes. Results show that the initiation process is electrochemical corrosion on the inner surface of the collector pocket. The pocket is difficult to clean of deposits (Fe_3O_4, Fe_2O_3, graphite, etc.) and the water there contains higher concentration of chlorine and other ions. This makes the pocket ideal environment for such electrochemical corrosion mechanism.

In the next phase, the crack can grow due to stress corrosion cracking mechanism, because of existing thermal and external stresses. The growth of the crack is still caused by corrosion and assisted by stresses in the material.

Fracture toughness of Russian and Vitkovice Machinery weld design were measured. Fracture toughness was measured on specimens in initial state (290 °C) and real conditions simulated after 30 years (290 °C). Fracture toughness at 0.2 mm elongation $J_{0.2}$ was taken 147 N/mm.

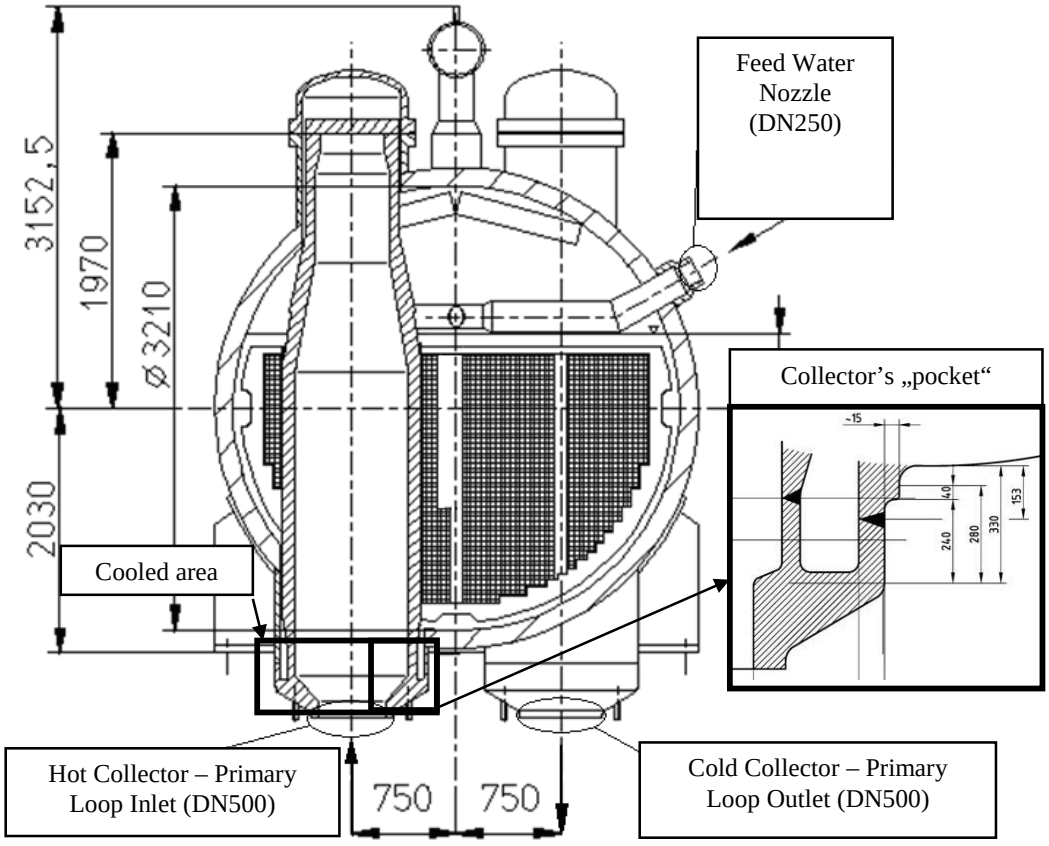

Fig. 1. Steam Generator PGV-440 cross section (through the Hot Collector).