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STUDY OF EXTERNAL COOLING OF STEAM GENERATOR PGV-1000M COLLECTORS POCKET WELD № 111 FOR SUPPRESSING OF STRESS CORROSION CRACKING

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Abstract: *The subject of this report is to assess different rates of cooling the bottom of the collector region, specifically the outer surface of the weld JS1200 (also known as weld 111) and the surrounding area. Based on the experience from Russia (OKB Gidropress) it is possible by external cooling of the outer surface of the weld area to reduce tensile stresses in the weld and in the outer radius of collectors pockets, or even change them into compressive stresses. The presence of tensile stresses in the outer radius of collectors pocket in combination with a corrosive environment in the collectors pocket support the possibility of crack initiation and propagation mechanism of stress corrosion cracking (SCC).*

Keywords: **Fluid structure interaction, Steam generator, CFD thermal analysis, Stress corrosion cracking.**

1. Introduction

One of the most important components of a nuclear power plant is steam generator (SG) which produce steam to turbogenerator for electricity production. Nuclear power plants in Czech Republic operate with pressurized water reactors and horizontal steam generators, same like in Russian federation or Ukraine. SG is constructed as horizontal cylindrical vessel and horizontal tube bundles which are built into the vertical collectors (Figs. 1, 2).

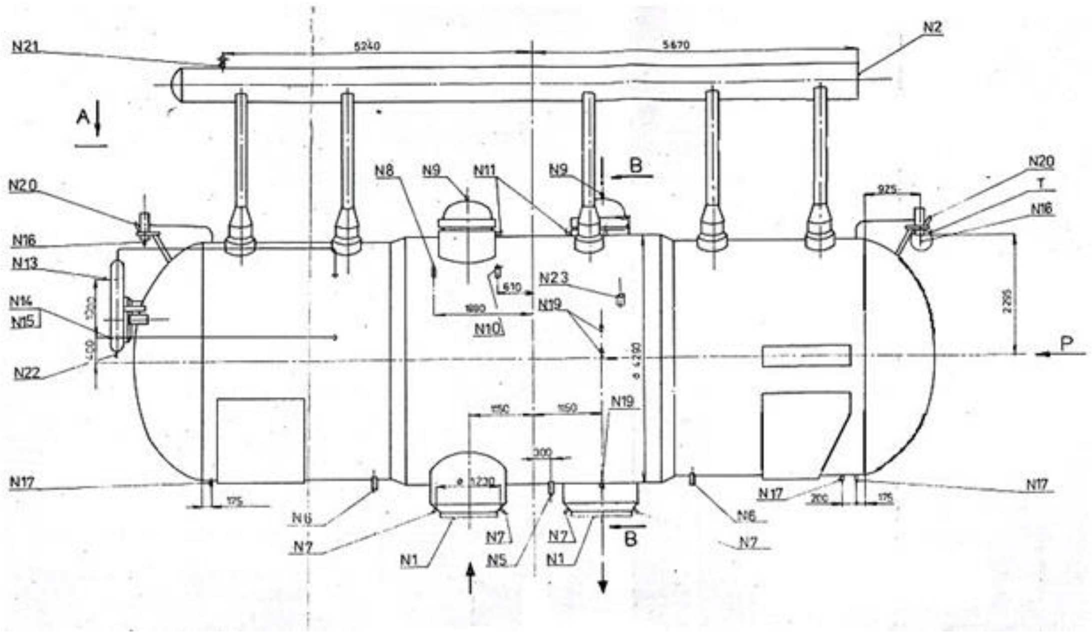

Fig. 1: Steam generator (SG) PGV-1000M.

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Horizontal steam generator, contrary to vertical SG used in PWR nuclear power plants, often works with worse water quality. This could be one of the reasons of pilling up deposits in collector pockets and the creation of corrosive environment.

As a result of stress corrosion cracking and growth of cracks in steam generator collector pockets (Fig. 2), it was necessary to replace or repair steam generators in several VVER nuclear power plants abroad.

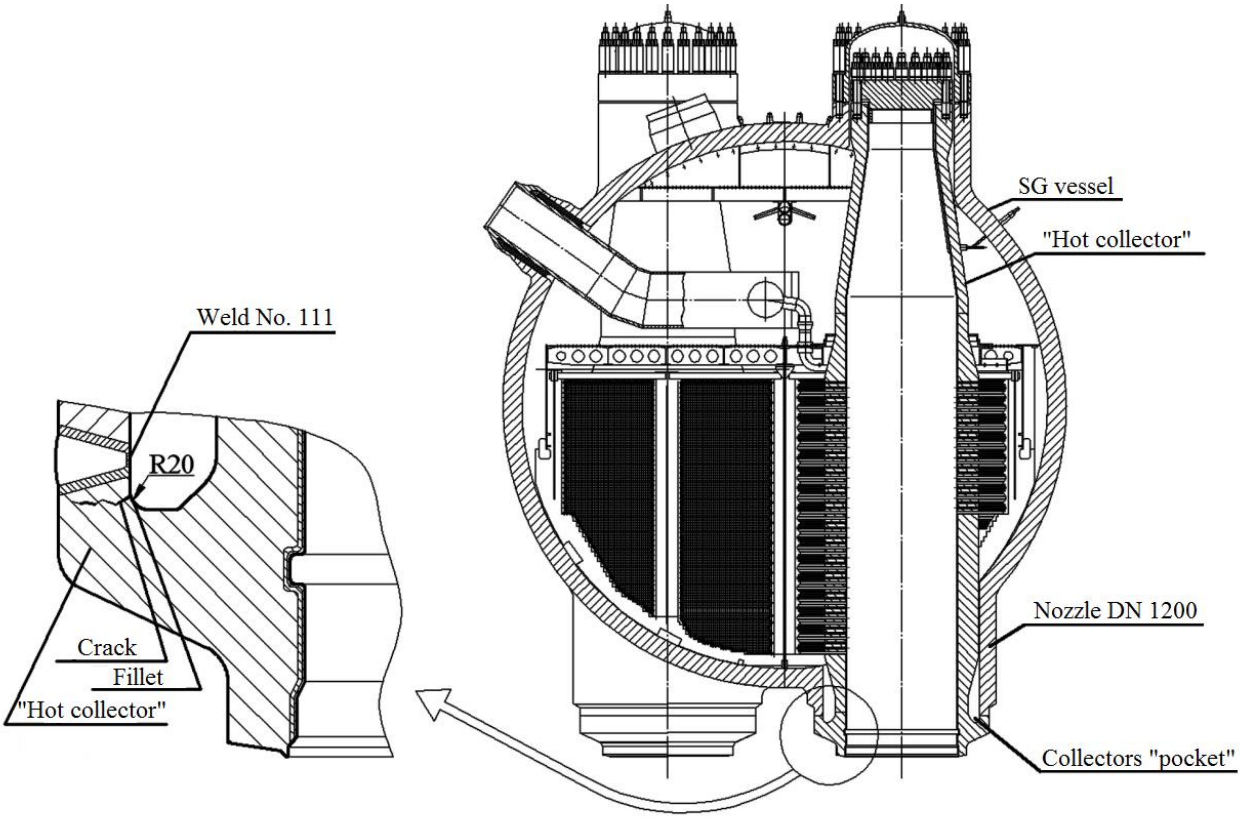


Fig. 2: Steam generator cross section view with detail of collectors pocket (Lyakishev et al., 2009).

This work is based on studies carried out in Russia (OKB Gidropress) where they deal with the possibility of reducing tensile stress in the pocket of the steam generator collectors which should lead to prevent occurrence and growth of these defects.

Decreasing tensile stresses or even converting them into compressive stresses can be achieved by local cooling of the external surface area of the collector.

For the collector cooling was used a similar model as the cooling sleeve referenced in publications of OKB Gidropress (Fig. 3) (Lyakishev et al., 2009) (Kutdusov. et al, 2013).

Subsequently it was developed a CFD numerical model. For the numerical structural analysis exported temperature fields from CFD analysis were used.

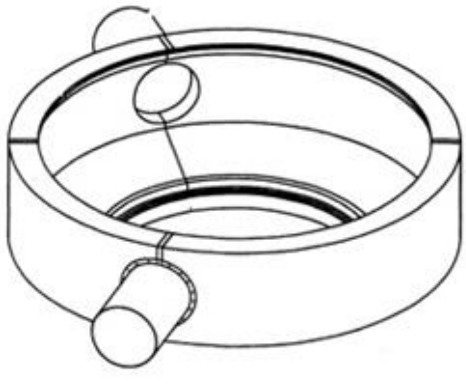


Fig. 3: Cooling sleeve (Kutdusov et al., 2013).

2. Methods

2.1. Fluid-structure interaction

Fluid-structure interaction (FSI) problems describe the coupled dynamics of fluid mechanics (CFD) and structure mechanics (FEM). There exist two approaches to coupling of CFD and FEM, one-way and two-way FSI, in this case was used one-way fluid-structure interaction to transfer temperature fields from CFD analyses to FEM structural analyses.

One-way FSI is typically created by the pure mapping of physical properties resulting from the CFD analysis to FEM. CFD and FEM models typically do not rely on matching meshes (e.g. mapping temperature field onto a structural Finite Element model). However in our case of one-way FSI the mapping of the physical properties does not include the modification of any of the meshes.

2.2. Computational model

The first step was to create a 3D model of the steam generator wit cooling sleeve, which was placed around the area of collector and SG vessel connection (around surrounding the connection weld No. 111). The model covered the lower half of the SG vessel (Fig. 1).

CFD computational model considered three medium regions. Inside the collector is water from the primary circuit, the secondary side of SG vessel considered saturated water-steam and the cooling sleeve contained the cooling air medium of ambient temperature and pressure.

In the second step CFD calculated temperature fields were mapped as a boundary condition for finite element analysis model. Numerical model for stress-strain analysis was created using quadratic (mid-side node) elements. The areas of FE mesh, which were used for evaluation of stresses, were appropriately refined.

3. Results

3.1. CFD results

In Fig. 4 two of the modeled temperature fields, which give some idea of the change of temperature fields due to external cooling, are shown. We are interested of course mainly in the area around the connection of the collector with SG vessel. This temperature field was mapped onto a structural Finite Element model.

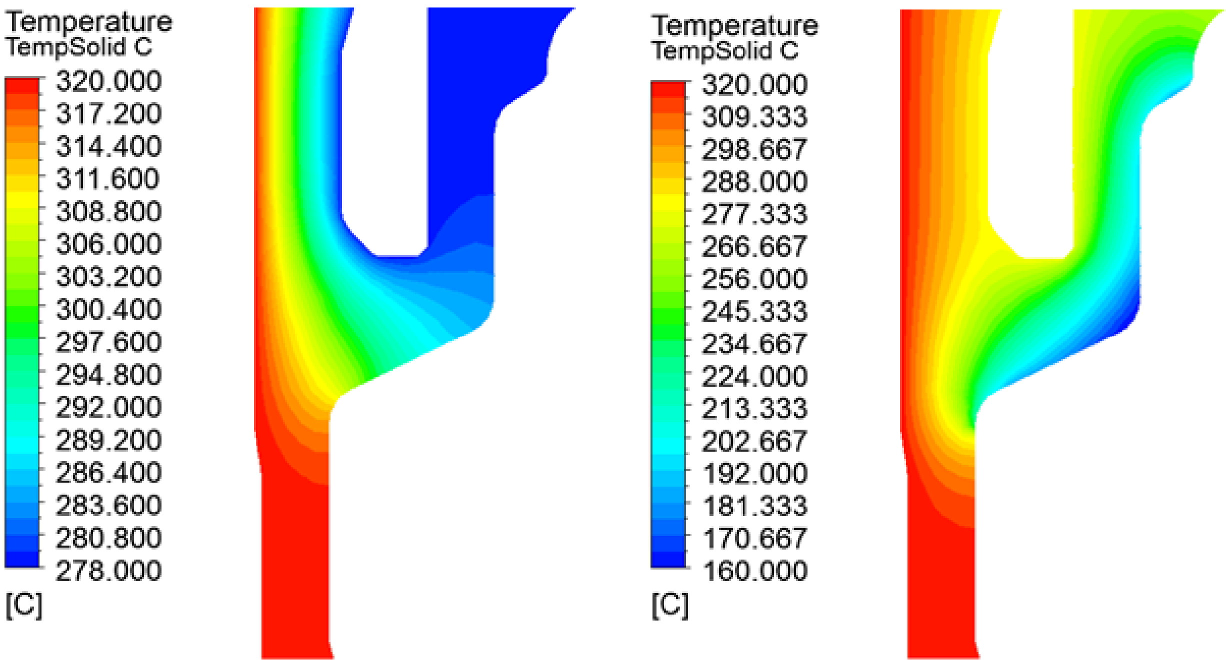
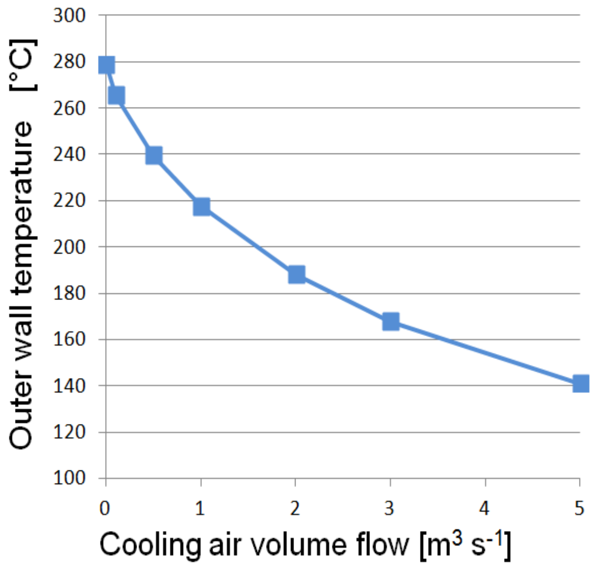


Fig. 4: Temperature field in the area of collectors pocket without cooling (left) a and with external cooling 5m^3/s (right).

3.2. FEM results

Fig. 5 shows that by appropriate external cooling it is possible to lower tensile stresses in the collectors pocket area and even change the tensile stresses into compressible (coolant flow of 5 m^3/s). Unfortunately, it is connected with growth of temperature gradients in this area, which is increasing stress intensity in collector pocket.



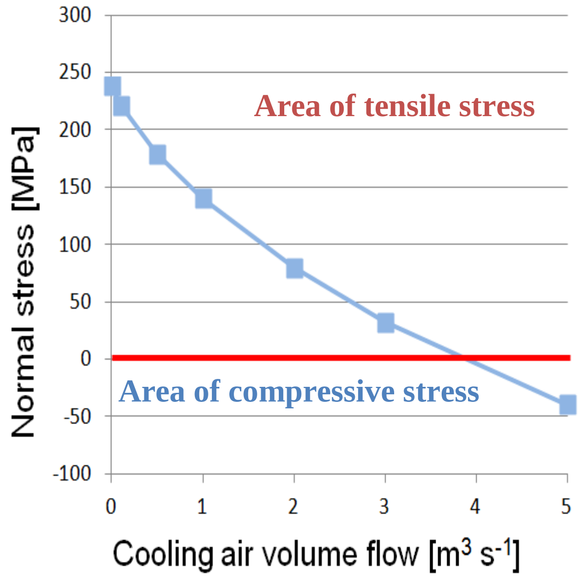


Fig. 5: Calculated outer wall temperature in the area of collectors pocket (left) and calculated normal stresses in the collectors pocket area (right).

4. Conclusions

This paper deals with the influence of external cooling of the area of steam generator collector pocket on normal stresses in this area. The greater the tensile stresses are, the bigger is the danger of stress corrosion cracking occurrence. By appropriate external cooling of this area, it is possible to influence not just the stresses level, but also the character.

External cooling of the outer surface of the area of interest was made by placing “cooling sleeve” around this area. The cooling sleeve has an inlet and outlet nozzle and as the cooling medium is used air of ambient temperature and pressure (air from the NPP containment around 30°C).

This study used the one-way fluid structure interaction (FSI) approach. First the CFD analysis was done and then temperature fields were transferred onto FEM model to calculate stresses. Then calculated stresses were evaluated in the area of steam generator pocket. Four different rates of cooling were analyzed (coolant flow 0 m^3/s (no cooling), 1 m^3/s, 3 m^3/s and 5 m^3/s).

The article concludes that by appropriate external cooling it is possible to lower normal tensile stresses in the SG collector pocket area and even change them into compressible one. This will positively affect the possibility of stress corrosion cracking in this critical area.

Acknowledgement

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