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The effect of mechanical characteristics of steels on the residual stress level after pressing in of heat exchanging tubes in steam generator collectors

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ABSTRACT: The effect of pressing in of heat exchanging tube on residual stress level in steam generator collector based on computer simulation results are described. Computer program based on the finite elements method was used to calculate residual stress-strain fields. The program makes it possible to investigate influence of deformation process, separate for tubes and collectors in the presence of a clearance and their contact interaction, taking into account material non-linear rheologic properties, damage and crack appearance.

The influence of the yield stresses of the tube and collector materials, the ratio of the material yield stress to hydrostatic pressure used for pressing in on residual stress level are shown. The numerical results reveal that residual stresses depend on the used schemes of loading and parameters of pressing in.

1 INTRODUCTION

There are known many cases of limited life assessment, lower then calculated, almost for all steam generators of Atomic Power Stations used in the world (Working Material 1993). That is connected with initiation of cracks in heat exchange tubes and collectors. Cracks in tubes or collectors cause unpermitable flow out of radioactive water. That is why detailed investigations of collector and tubes stress-strain state kinetics during manufacturing and in the course of service are necessary. Materials of steam generator construction elements are working under complex thermomechanical loading and influence of corrosion. Damage of various nature of the materials causes great expenses for repair and all manufacturers could not avoid such difficulties. Collector of the first contour with heat exchanging tubes is one of the most responsible units of steam generator. Residual stresses induced by manufacture have significant influence on the maximum stress level in elements and the time of their service (Titov 1993), (Mavko et al.1993), (Karzov et al. 1993). Using more conventional materials, geometry and parameters of pressing in residual stresses can be minimised and life time of elements enlarged.

Computer simulation is the main method to get necessary results. Three dimentional stress-strain state of collector is nonstationary in the process of pressing in and its residual stress-strain state depends of many parameters (connected with construction and technology). Known calculations are limited for some variations of parameters, that does not permit to have necessary information about their overall influence on maximum stress level. Further calculation of such type are necessary to analyse strength and life time of construction elements.

2 USED CALCULATION METHODS

The task is formulated as a three-dimentional problem, but main calculations are fulfilled in simplified two-dimentional (axisymmetrical and plain) statements.. That has allowed to expand considerably the number of considered variants and to understand the tendency of residual stress intensity changes with change of materials characteristics and other parameters of pressing in. In formulation of nonstationary two-dimentional task known equations of deformable medium and equations of finite elements method were used (Kharchenko 1984). Taking into account high stress intensity and nonstationary loading used in calculation equations of state for materials (perlitic and austenitic steels) was taken in the form, that corresponds to elastic-viscoplastic medium (Stepanov 1991). Physical and mechanical characteristics of used materials can be varied significantly. For example, change of yield and ultimate stress for perlitic steel 10GN2MFA can be in the regions Y = 400...560 MPa, U = 556...670 MPa, for austenitic stainless steel 08H18N10T - Y = 200...285 MPa (Titov 1993),(Degtyarev 1994). Dependence of stress-strain intensities was described by power function. The constructive parameters of tube and collector for steam generator PGV-1000U was taken in calculation. Numerical simulation was conducted for the collector material yield stress 200...285 MPa, the ratio of the yield stress of the tube material to the yield stress of the collector material 0.7 ... 1.2 (pressure for pressing in p= 200...350 MPa).

Used programs for calculation, described earlier (Kharchenko 1984), were modified to solve dynamic and quasistatic problems with the same methods, that make it possible to get correct results and to analyse deformation kinetics. Modified program also permits solving the problems of solids interaction on contact surface, that was used for solving the task of pressing in with initial clearance between tubes and collector. There is possibility to investigate problem with few contact surfaces, that was used for the task of pressing in of few tubes.

Influence of various parameters on local residual stresses in collector induced by pressing in of tubes were analysed in (Stepanov et al, 1994). In this report the main point of investigation - influence of mechanical characteristics of used materials on residual stresses.

3 RESULTS AND THEIR ANALYSIS

In this report local residual stresses near outer surface of collector induced by pressing in were investigated. The main results were obtained for two-dimentional axisymmetrical scheme of interaction of tube and adjacent part of collector of some outer radius. The second scheme - two-dimentional flat loading of collector part with few holes, loaded one after another.

Influence of mechanical characteristics of tubes and collector on residual stresses induced by hydrostatic pressing in are shown on fig.1 - 2.

Mechanical characteristics of materials depend on the choice of steels and plastic deformation in pressing in connected with the clearance. Strain strengthening (increases with clearance) increases local residual tangential stresses in tubes and decreases in collector (up to 50% in compare with ideally plastic material).

Hydrostatic pressure (p =350 MPa) for pressing in causes large plastic deformation in stainless steel tubes and small area of plastic deformation in collector of perlitic steel 10GN2MFA . Maximum residual tangential tensile stresses (80 MPa), shear and axial deformation (up to 0,2%) in collector of this steel are near surface. Under the surface (on the depth 8 mm and more) residual stress-strain state is homogeneous along axis of symmetry. In the radial direction residual stress intensity decreases with the radius. Stresses in tube are about 0,8 Y (state of three dimentional compression), on the inner surface of tubes near the collector surface there are tensile stresses about 70 MPa. The same pressure of pressing in (p = 350 MPa) causes

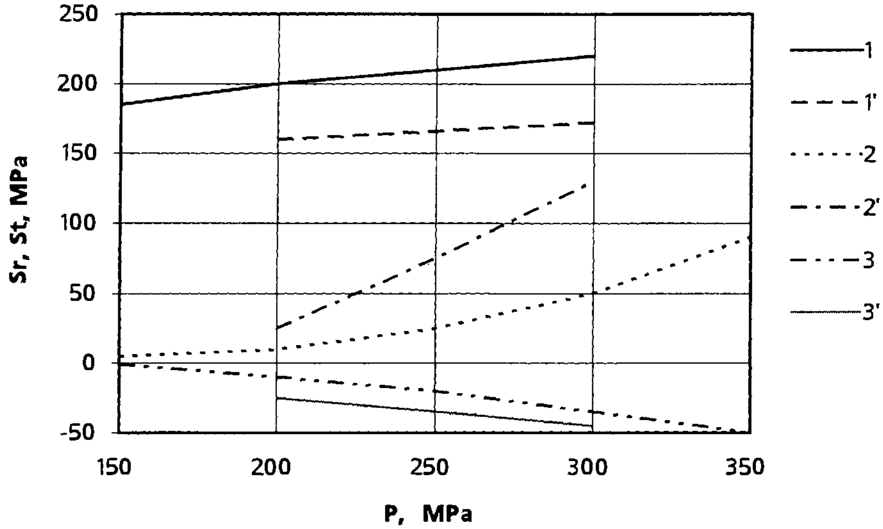

Figure 1. Dependence of maximum residual tangential stress in tube (1,1') and collector (2,2'); residual radial stress on contact surface (3,3') on pressure of pressing in (1, 2, 3 for steel 08H18N10T with Y=285 Mpa; 1', 2', 3' -for steel 08H18N10T with Y=200 Mpa)

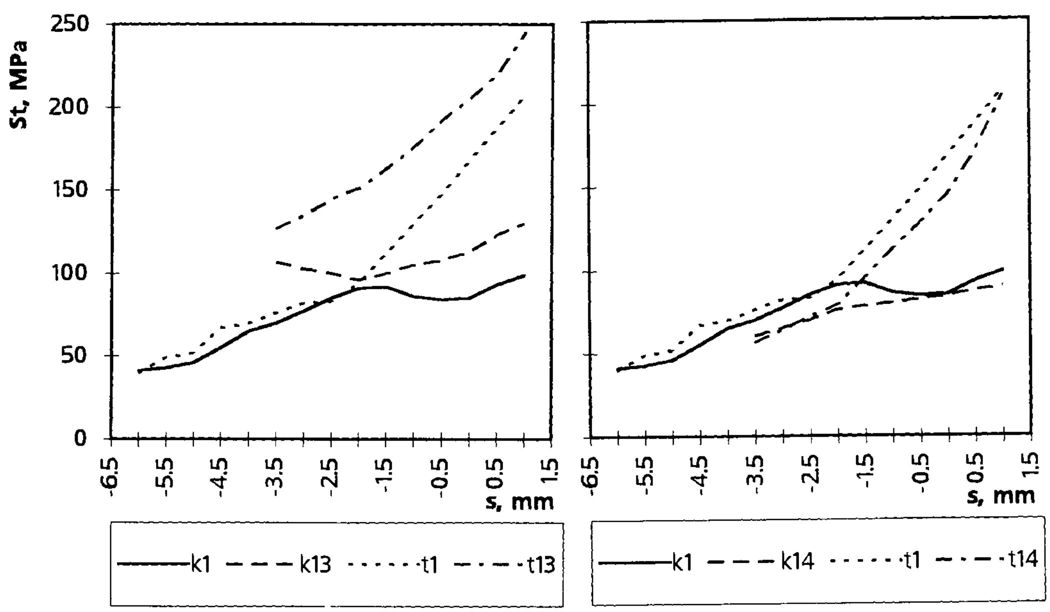

Figure 2. Dependence of maximum residual tangential stress in tube and collector after pressing in on the yield stress of materials (yield stress of tube - Y; yield stress of collector - Y') and the distance from collector outer surface to the boundary of pressure loading (k1,k13,k14 - stresses in collector; t1,t13,t14 - stresses in tube; 1 - Y=Y'=285 MPa; 13 - Y= 285 MPa; Y'=200 MPa; 14 - Y=285 MPa; Y'=350 MPa)

significant plastic deformations (up to 0,3%) in collector of austenitic stainless steel 08H18N10T'. Maximum tangential tensile stressing collector near the surface reaches 100 MPa. In tube plastic deformation can reach 7-15% (for clearance =0,335...0,6125 mm) and tangential tensile stress up to 300 MPa.

All variants of calculations shows existence of clearance after pressing in. Decrease of hydrostatic pressure increases clearance insignificantly, but decreases maximum residual stress in collector. For the same pressure of pressing in decrease of the yield stress (for equal yield stress of the tube and collector materials) increases residual stresses both in tube and collector, more significantly in collector (fig. 2). Increase of the yield stress of the tube material in compare with the yield stress of the collector also increases residual stresses in tube and collector.

Redistribution of residual stresses, induced by pressing in one tube, after pressing in the next tube in the adjacent hole was calculated, solving two-dimensional plane task, for the initial clearance 0,1 mm on one side and pressure of pressing in 350 MPa. In collector of perlitic steel plastic deformation after pressing in are significant only in the area near hole, but stress near the next hole reach 200 MPa. Stresses are nongomogenious in plane and reach maximum value in the narrow part of the material between two adjacent holes. In collector of stainless steel plastic deformation of significant value appear after the first pressing, after the next pressing in plastic deformation develop in all material between two holes. Calculations showed that pressing in of one tube after another causes significant changes in stress-strain state induced by previous pressing in. Change of stresses can reach 50% for pressure p>1,5 Y' (Y' - yield stress for collector material). For pressure p~ Y' calculated change of stresses was insignificant.

CONCLUSIONS

The analysis of results of numerical simulation of hydrostatic pressing in of heat exchanging tubes into collector has shown, that:

- mechanical characteristics for the material of tubes and collector, used pressure value significantly influence residual stress-strain state in tubes and collector after pressing in;
- level of residual deformations in tube can reach 0,5 ...7,5 % and depend on initial clearance, in collector deformations do not exceed 0,5 %;

- maximum residual tensile stresses and stress intensity, induced by pressure 350 MPa for pressing in, can reach in collector 100 MPa, in tube 300 MPa;
- redistribution of residual stresses after pressing in of next tube in the adjacent hole depend on ratio of used pressure to yield stress of the collector material.

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