20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

ANALYSIS OF DAMAGED CONNECTION PIPING

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Abstract: *The following paper analyses a cracking of a superheater connection piping which occurred after a general repair. Pipes repeatedly detached in the area of welding to the collector nozzles. Connection piping was subjected to a thorough FEM analysis and flow simulation using CFD software.*

Keywords: Piping, Nozzles, Boiler, Crack, FEM, CFD.

1. Introduction

Boiler superheaters and their connection piping are the soft spots of boilers and often get damaged, which is caused by high operating temperature and pressure inside the system where every slight change in operation significantly decreases system life. Fig. 1 shows a damaged piping. Design of the vertical connection piping is given in the figures throughout the paper.

Fig. 1: Detachment of DN 100 connection piping in the area of welding to the chamber nozzle.

In order to detect the cause of pipe cracking, structural calculation of the design was examined at first. The design flaws, which make up approximately 30 to 40 per cent of all equipment damage in the industry, may be eliminated. Major design flaws are revealed soon (several days or months), minor flaws show after several years. Examination of structural calculation of the design proved that the calculation complies with all requirements of boiler design standards (EN 12952, 2012).

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2. Stress State Analysis of Connection Piping for Operating Conditions

Analysis of operating conditions revealed that there are two basic regimes for operating conditions, i.e. summer and winter regimes. With respect to the loading, operating conditions in winter regime proved to be more significant (steam capacity reaches 20 to 30 t/h).

Following operating conditions were selected for analysis of the connection piping: 32.1 t/h capacity, 3.5 MPa working external pressure in steam superheater piping, 302.8 °C temperature at the outlet from first convective superheater, and 240 °C temperature at the inlet to second convective superheater. Temperature distribution was designed using standard methods of linear distribution along connection piping height. Fixing of chambers (collectors and vertical chamber) was modelled using sleeves, according to design of these parts.

Provided operating conditions helped to model stress distribution in the piping (given in Fig. 2).

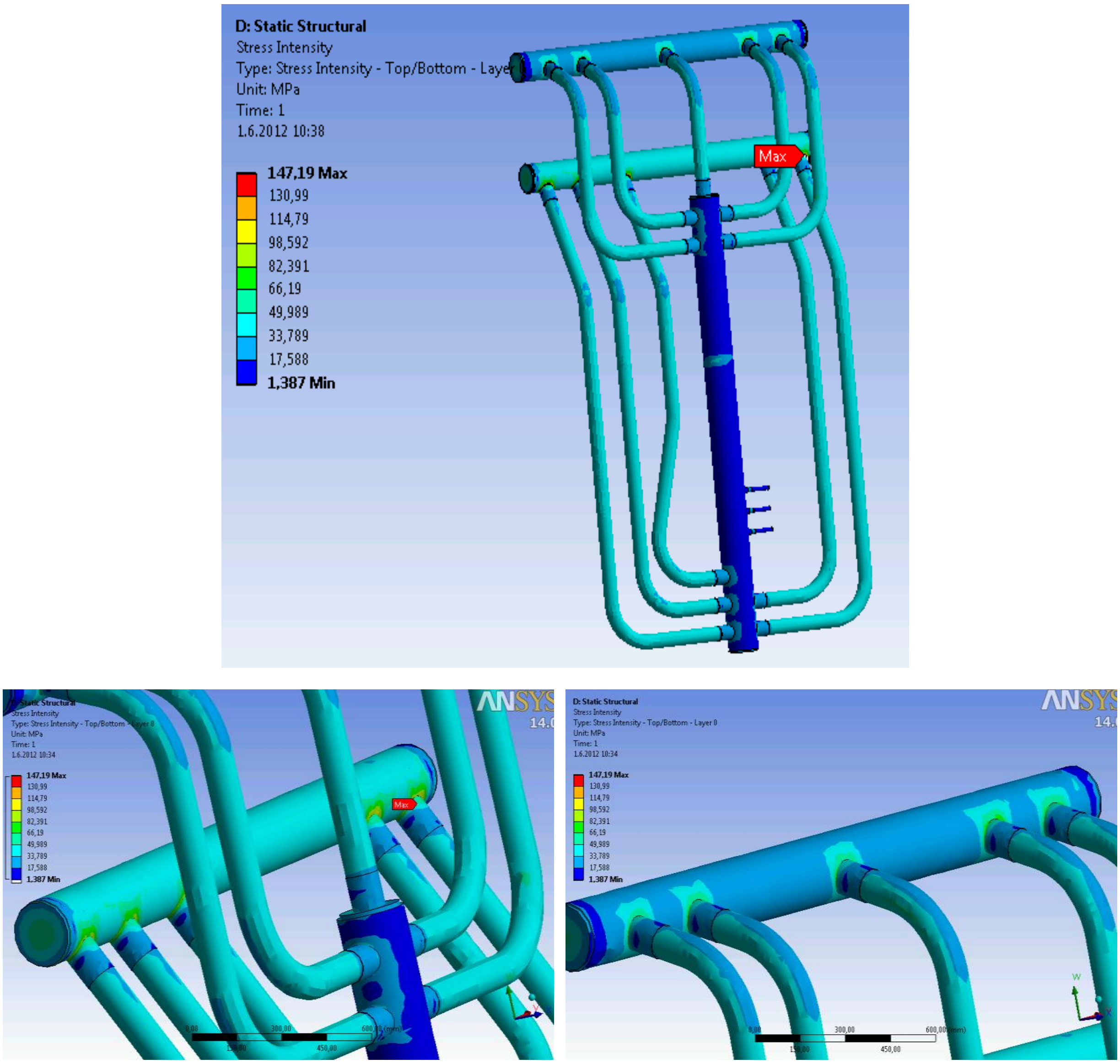

Fig. 2: Stress distribution in chambers and connection piping.

Stress values peak at 147.2 MPa, which is significantly lower than 165 MPa (Annaraton, 2007), the permissible values for membrane and bending stress (piping is made of steel 12022). Therefore, we may conclude that these normal operating conditions could not cause the damage of critical areas.

3. Analysis of Various Distributions of Heat Flux

With respect to the fact that the equipment is operated at a lower capacity than the capacity designed, it is assumed that velocity flows in individual branches of connection piping are not identical. This has further impact on different heat fluxes in individual branches, and creation of additional stress. CFD simulation was performed so that temperature distribution upon injection of water into main pipe of connection piping may be identified. Analysis revealed the nature of velocity distribution which has direct impact on heat transfer coefficient in individual areas, and on temperature distribution itself (Moinereau et al., 2001).

Analysis used identical conditions that were used in the previous chapter, i.e. 32.1 t/h capacity. Following parameters of the saturated steam were applied in the analysis: 14.16 kg/m^3 density, 2.10^{-5} Pa.s viscosity. Injection was calculated to equal 1.6 t/h and temperature of condensate cooler (998.2 kg/m^3 density, 1.003.10^{-3} Pa.s viscosity) was ca. 190 °C. Even steam distribution at the chamber inlet was the only simplification in the analysis.

Following figure presents velocity distribution in individual parts of the connection piping. Velocity profiles indicate uneven mixing and distribution of media flows (for both saturated steam and injected condensate). These facts had a major impact on temperature distribution in the pipes.

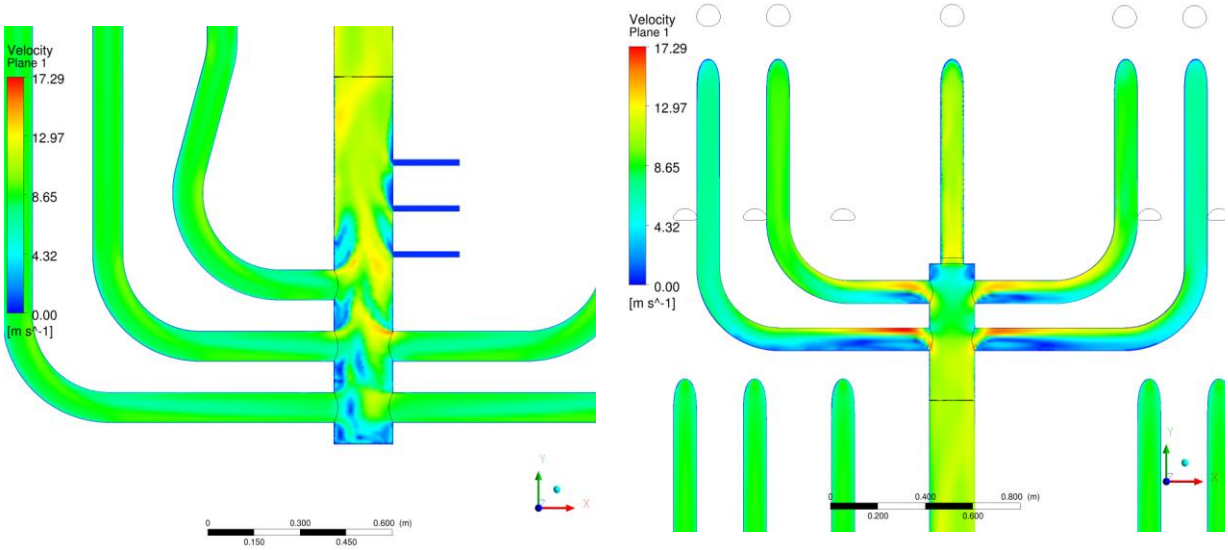

Fig. 3: Velocity distribution during mixing of steam flows and injection of condensate (left), and steam distribution in individual branches (right).

Analysis of uneven heating/cooling of connection piping was performed using acquired results. Temperatures in outer pipes differ from inner pipes and thus the outer pipes may have higher/lower temperatures. Temperature distribution was used for stress state analysis (Fluid Structure Interaction method) along with provided boundary conditions. Stress state distribution in connection piping is given in Fig. 4. Stress state peaks in the area of welding of the pipe and nozzle which are critical. Stress state reached 165.9 MPa in the critical spot, which is a permissible value. Consequently, even more specific operating conditions did not help in identification of a damage cause.

Therefore, it is recommended that the samples are taken for material analysis, and technology compliance of the equipment repair is examined.

4. Conclusion

Based on the check analysis, no cause for the pipe cracking was identified and the design of the connection piping was verified as correct. Individual samples were afterwards taken for material analysis which also did not show any major irregularities in operation of the equipment. Failure to comply with repair technology was identified as the only possible cause of the damage. Due to inconsistencies in the drawings, two different structures may have been manufactured (in terms of dimensions) and shift of nozzles and tubes prior to welding may have reached up to 25 mm. These inconsistencies are usually disposed of by proper fitting of the pieces during the installment process. In this case, the welding then caused serious stress in the welding area, which was manifested in the cracking of the equipment.

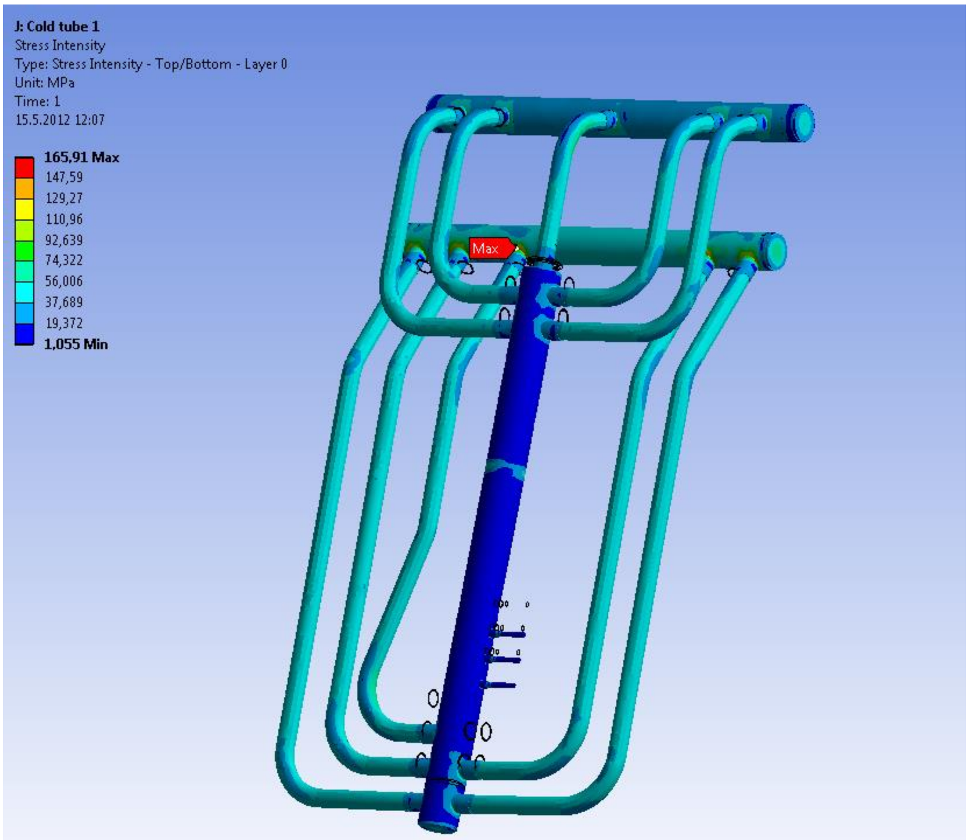

Fig. 4: Stress state distribution in connection piping.

Acknowledgement

The results of this project NETME CENTRE PLUS (LO1202) were co-funded by the Ministry of Education, Youth and Sports within the support programme „National Sustainability Programme I".

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