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REMAINING LIFE ASSESSMENT OF DRUM IN THERMAL POWER PLANT

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Abstract:

This paper presents the estimation of the remaining life time of the thermal power plant drum. Remaining life time assessment was done using finite element method as well as standards. The analysis was performed using thermo-elastic-plastic material model while creep deformation were neglected. The method of the stress determining in accordance with the standards do not take into account many possible conditions that can occur during plant operation. This applies particularly to the sudden temperature changes that occur in conditions of cold start, turns and correction of operation parameters of the drum. During drum operation, it is necessary to locally introduce a cooling medium in the form of water mist for rapid local cooling due to evaporation of water. This is characteristic of the elements that are close to temperature controller, such as preheating chamber. The frequency change of thermal loads and temperature changes size in such cases several hundred times greater than the frequency of start-up and shutdown unit.

Key words: life time, boiler drum, finite element method

1. Introduction

The requirements of the market have been changed toward increasing the flexibility of power plants. Power plants work more cyclical than in the past. It seems that the systems for fatigue monitoring become important because of the need to immediately know the impact of start or shut to the remaining life of the boiler and components. The basis for the estimation of RUL-remaining useful life are European standards EN 12952-3 / 4 [1,2], which contains simplified rules for the calculation of creep and low cycle fatigue. These simplified rules are conservative, but they have the advantage of being easy to use.

This paper presents the evaluation of remaining life of the steam drum of power plant which is performed by finite element method as well as usage of EN 12952-3 / 4 and TRD301 [3]. Analysis was performed using thermo-elastic-plastic material model, while creeping neglected. Calculation of the construction was done by PAK program [4], which is used for general linear and nonlinear structural analysis, heat transfer, fluid mechanics, coupled problems, fracture mechanics and fatigue. Remaining life assessment was done by the application of standard EN 12952-3 and norm TRD301.

2. Remining life assessment of drum by finite elements method

By analyzing the geometry can be concluded that the structure has two planes of symmetry so quarter of the drum was modeled. The quarter with screen tubes, i.e. quarter with the largest number of openings was selected. For modeling 3D parabolic finite elements were used [5,6]. Supports were modeled using contact GAP elements. The constant wall thickness equal to the smallest measured 83.4 mm was adopted.

The structure was exposed to static loads: its self-weight, the weight of water and variable internal pressure, as well as variable thermal load. Since the temperature regime range up to 340°C, the structure was analyzed using the thermo-elastic-plastic material model and creep deformation were ignored. The values of yield strength at the reference and operating temperature were taken from the literature [7, 8]. The analysis used the following elastic constants: the elastic modulus at a reference temperature T_{ref}=20°C E=2.03·105MPa; the modulus of elasticity at a temperature of 340°C E=1.88105MPa; Poisson number ν = 0.3; coefficient of linear expansion α = 12.5 10^{-6} 1/°C.

Analyses for the following modes were performed: 1) nominal operating mode: pressure p=14,6 MPa and temperature T=340°C; 2) water test: pressures p=18.25 MPa and 12,48; temperature T=60°C; 3) cold start: temperature field was determined on the basis of the measurements in certain points by the diagrams obtained from the user. The calculation was done for the moment that has been found that the temperature difference in the measuring points was maximal. The pressure was not measured and it was adopted p=7 MPa; 4) an emergency situation with a sudden pressure drop: analyzed the state of stress on the drum in the first 15 minutes after the occurrence of accidents. Pressure change is given according to the diagram provided by users. The rate of change of temperature of the wall of the drum V_{max} = 20 °C/min was assumed.

To estimate the drum lifetime, the characteristics of the material for stress-deformation curve were used [8]: coefficient σ_f fatigue strength ε_f'=845.9 MPa; the fatigue strength exponent b=-0.0727; fatigue ductility coefficient ε_f=0.3458; fatigue ductility exponent c=-0.5904; cyclic amplification exponent n'=0.066; cyclic amplification coefficient H'=666 MPa.

<u>Nominal mode.</u> In nominal mode occur plastic deformation, and for assessment of lifetime of the structure used curve corresponding amplitudes of the plastic deformation [8].

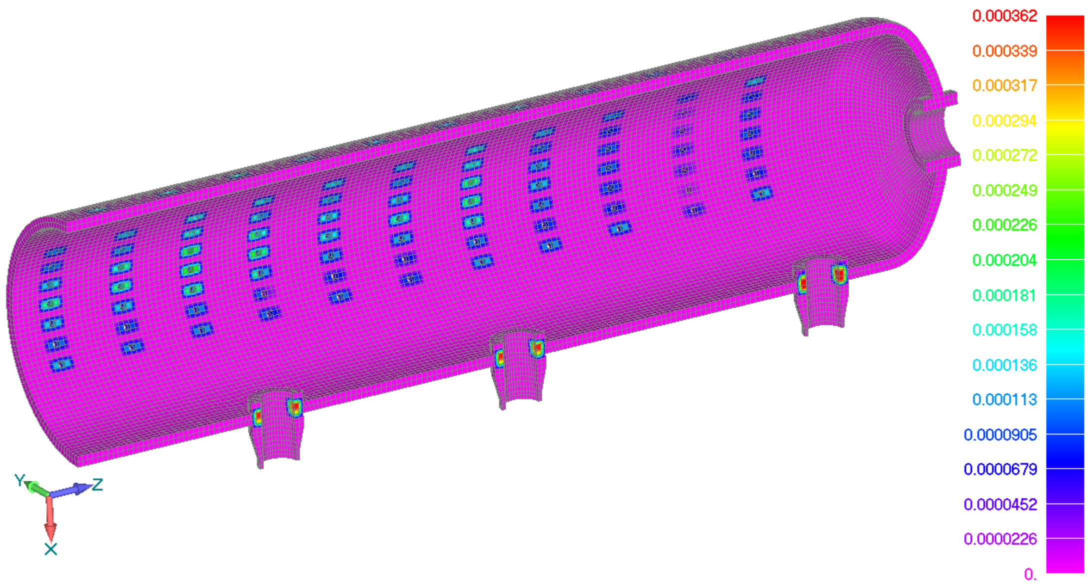

Figure 2.1 Effective plastic deformation filed

Maximal value of the plastic deformation is $\varepsilon_p = 3.62 \cdot 10^{-4}$, Figure 2.1. Life time N (remaining number of cycles till failure) is calculated from the following expression: $\varepsilon_p = \varepsilon_f^{'} (2N)^c$. Solving the previous expression is obtained that the expected number of cycles to failure due to fatigue $N = 111500$ cycles.

Water test. Results of the analysis showed that the material enters the zone of plastic deformation for pressure 18.25 MPa. The maximum value of plastic deformation is $\varepsilon_p = 3.04 \cdot 10^{-4}$, Figure 2.2. The expected number of cycles to failure due to fatigue is $N = 150000$ cycles.

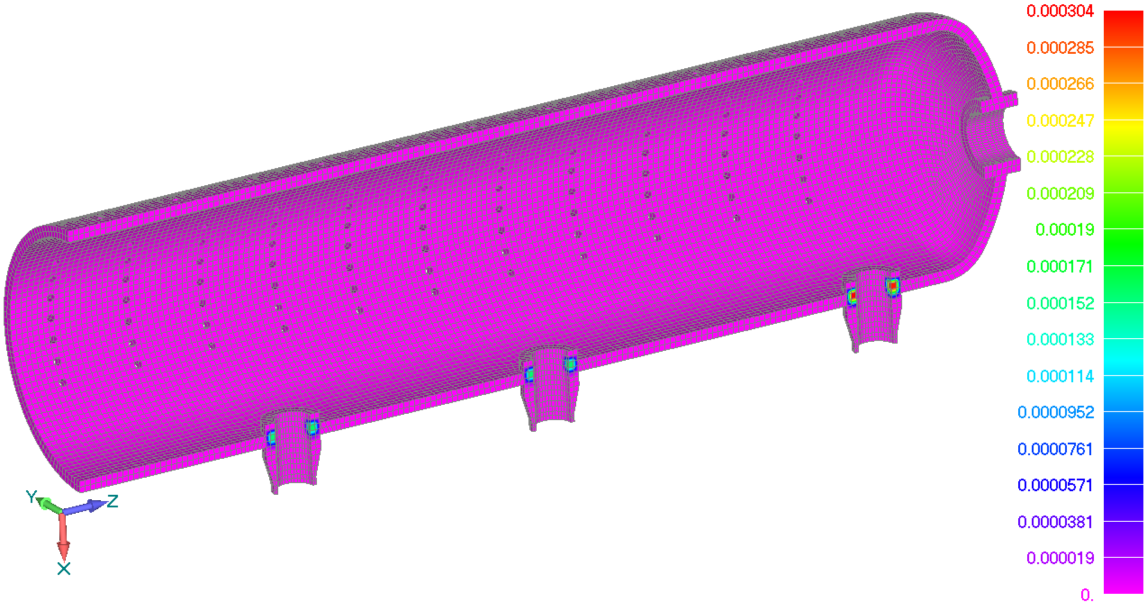

Figure 2.2 Effective plastic deformation field

Maximum temperature gradient during cold start. Results of the analysis showed that for this load case material remains in the elastic deformation zone. The maximum value of elastic deformation is $\varepsilon_{t\max} = \sigma_{\max} / E = 0.001096$, where is $\sigma_{\max} = 206.1\,\text{MPa}$ maximum value of stress obtained by calculation, figure 2.3. The expected number of cycles to failure due to fatigue is $N = 2.85 \cdot 10^8$ cycles.

An emergency situation with a sudden pressure drop. Results of thermo-elastic-plastic analysis showed that the material enters the zone of plastic deformation after failure. The maximum value of plastic deformation is after the second minutes of the failure $\varepsilon_p = 4.69 \cdot 10^{-4}$, where is $\sigma_{\max} = 300.2\,\text{MPa}$ maximum value of stress obtained by calculation, figure 2.4. The expected number of cycles to failure due to fatigue is $N = 72000$ cycles.

To verify used numerical methods, a great number of calculation were done with different mesh size, with different types of finite elements (3D, shells), different numerical integration (Gauss, Newton-Cotes). Different software based on finite elements method were used (NASTRAN, ADINA, ABAQUS, ANSYS and PAK). In all analysis in the case of nominal modes small plastic deformation were obtained which leads to the conclusion that previous damage to the drum was caused by another condition thermomechanical loading.

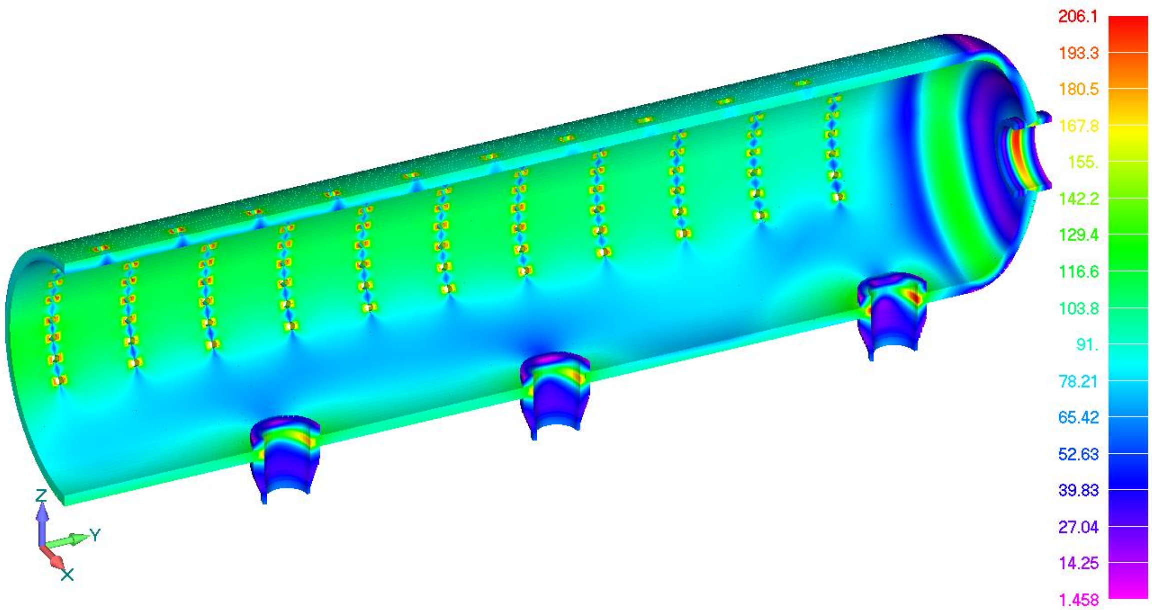

Figure 2.3 Stress filed

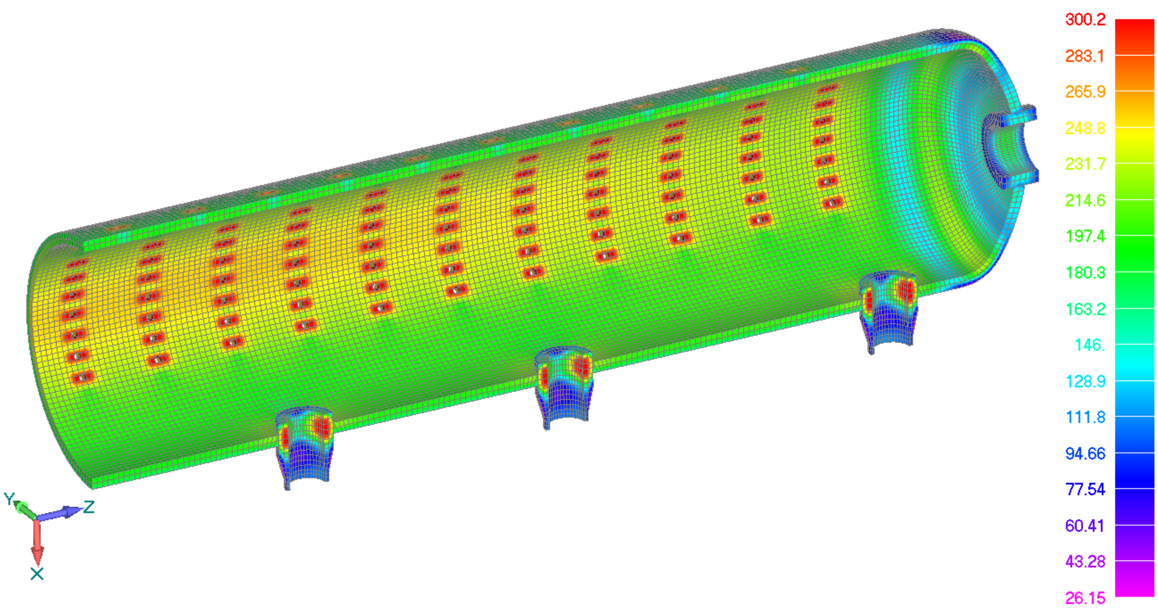

Figure 2.4 Stress field 2 minutes after failure

3. Remining life assessment of drum according to the EN 12952-3

Thermal stresses in the components of power plant installations are determined in accordance with standard EN 12952 [1, 2], just for temperature gradient in the unsteady state during heating and cooling. According to this standard characteristics of the material generated during one-axial fatigue tests at a constant temperature are used. Therefore, the standards and procedures are based on the fatigue specifications provided at a constant temperature. Methods of calculation of stress and strain in terms of thermo-mechanical fatigue are based on many simplifications. Therefore, this is an approximate method which does not take into account the simultaneous effect of temperature changes and strain on the characteristics of the material.

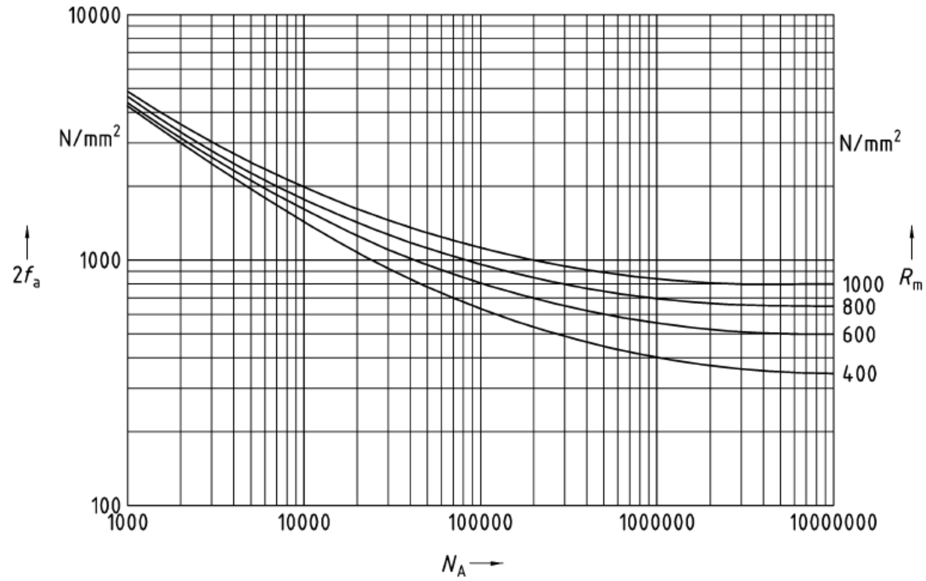

Figure 2.5 Number of cycles N_A on the appearance of cracks in terms of the stress amplitude

The allowable number of cycles to the clause 13 and annex B was calculated. The number of cycles is determined based on the diagram shown in Figure 2.5 (Figure B.9 in Annex B). The application of this standard is obtained that the utilization factor of the life-time of the drum 22.5%.

4. Remining life assessment of drum according to the norm TRD301

According to the norm TRD301 [3] the allowable number of cycles for a given rate of change of the temperature of the wall of the drum during cold start and turns were calculated. The permitted number of cycles is calculated for three different rates of change temperature of the wall of the drum: 2°C/min, 3°C/min, 4°C/min. In an emergency situation the rate of change of temperature of the wall of the drum 20°C/min was used. The total time of exploitation is 194115 hours. The allowable number of cycles is shown in Table 3.1. Utilization factor for different temperature change rate, is shown in Table 3.2. By using this method a utilization factor 27,48% was obtained for the rate of change of the temperature of the wall of the drum 3°C/min.

		Permitted number of cycles	Real number of cycles	Utilization factor [%]
Water test	18,25 MPa	679	25	3.68
	12.48 MPa	1722	12	0.70
Start and standing	2 °C/min	7367	639	8.67
	3 °C/min	5080		12.58
	4 °C/min	4273		14.95
Emergency state	20 °C/min	2130	224	10.52

Table 3.1 Permitted number of cycles

Rate	2 °C/min	3 °C/min	4 °C/min
Collective utilization factor	23.57	27.48	29.85

Table 3.2 Utilization factor

5. Conclusions

The paper presents three methods for the evaluation of the remaining lifetime of the drum: 1) assessment using finite elements method and diagrams deformation-number of cycles until failure; 2) using standard EN-12952-3; and 3) using norm TRD301. By applying standard EN-12952-3 is obtained that the utilization factor of working life time of around 22,5%, using norm TRD301 utilization factor of working life time is 27,48%, while the application of finite elements method generated small plastic deformation at the stress concentration in the analyzed load cases. In the case of nominal operation mode and a cold start, based on available data, finite element analysis shows that it can achieve tens of thousands of cycles.

It is necessary to bear in mind that the method of determining the stress in accordance with the standards do not take into account the many possible conditions that may occur during operation. This applies especially to sudden temperature changes that occur in conditions of cold start and turns and when the correction operation parameters of the drum. During operation of the drum, it is necessary to locally introduce a cooling medium in the form of water spray suddenly, local cooling due to evaporation of water. This is inherent to the elements of which are located near to the so-called temperature controller, such as preheating chambers. The cyclical nature of the work the temperature controller is the reason a high temperature gradient that occurs on the surface of these elements [7]. The frequency of changes of thermal load as well as the size of temperature changes in these cases are several hundred times higher than the frequency of start-up and shutdown of unit. This effect is caused by the action of water coming from the system for the water dispersion. Because of the above mentioned we consider that it is necessary to know the data about opening in the drum for inserting media, moment as well as temperature to perform a cold start to the nominal mode and how to stop the drum in the normal and emergency states. Based on these data, it would be possible to determine using finite elements method local stresses which occur due to local thermal shocks.

Acknowledgement

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