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USING OF METHODS OF EXPERIMENTAL STRESS ANALYSIS FOR DETERMINATION OF RESIDUAL LIFESPAN OF STEAM BOILERS

VYUŽITIE METÓD EXPERIMENTÁLNEJ ANALÝZY NAPÄTOSTI PRE URČENIE ZVYŠKOVEJ ŽIVOTNOSTI NOSNÝCH KONŠTRUKCIÍ PARNÝCH KOTLOV

Abstract

Supporting structures of steam boilers are loaded by various combinations of loading and thermal influences that can result to the failure of supporting elements. The stresses in the individual parts of structure are significantly influenced by boundary conditions. Supporting structures of steam boilers is suitable to assess by the methods of experimental stress analysis.

Abstrakt

Nosné konštrukcie parných kotlov sú počas prevádzky často vystavené kombinácii silových a teplotných účinkov, ktoré spôsobujú až porušenie nosných prvkov. Na napäťové pomery v jednotlivých častiach konštrukcie pritom podstatne vplývajú aj okrajové podmienky. Nosné konštrukcie parných kotlov je pritom vhodné posudzovať využitím experimentálnej analýzy napätosti.

1 INTRODUCTION

Steam boilers of heating plants and energy producing systems are often in operation several decades. During this time are realized general repairs or reconstructions in order to improve and modernize technological equipment. This results to the change in loadings of steam boiler supporting structures that are in many cases rearranged during reconstruction. For the structure assessment it is necessary to know possible damages in individual parts of supporting structure due to corrosion and thermal influences (mainly in case, if the thermal insulation is disrupted) that invoke additional loadings. In Fig. 1 are given typical examples of corrosion damages of the flange and the web of U-profile that is a part of supporting structure of steam boiler. Thermal influence together with static indeterminacy of supporting structure results often to overstepping of critical states and in local areas can lead to lost of stability (Fig. 2), or to plastic deformation which leads to failure.

Fig. 1 Typical examples of corrosion damages in supporting structure of steam boiler

Fig. 2 Lost of stability connected with plastic deformation

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In Fig. 3 is shown typical shape of steam boiler supporting structure together with its basic dimensions. Because the supporting structures of steam boilers are influenced by mechanical and thermal loading during their operation, it is necessary to assess their residual lifespan and so it must be taken into account the load history. For the determination of stress states is suitable (because of very complex boundary conditions) to use the methods of experimental stress analysis [2,3].

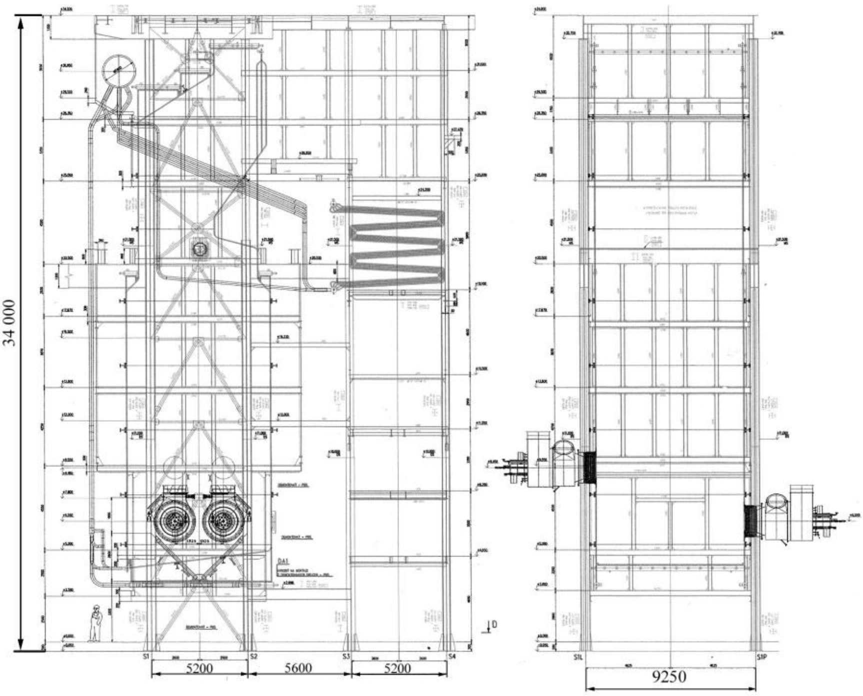


Fig. 3 Steam boiler with basic dimensions of supporting structure

2 EXPERIMENTAL STRESS ANALYSIS IN SUPPORTING STRUCTURE – INFORMATION SOURCE FOR ASSESSMENT OF ITS LIFESPAN

Determination of stresses due to self-weight of structure can be provided only by procedures that are used for the measurement of residual stresses – by strain gage measurements. The authors use hole-drilling equipment RS-200 or SINT MTS-3000 [1]. For the registration of released deformations are applied special strain gage rosettes (RY-21, CEA 062UL, or similar). Residual stresses are mostly determined in columns of supporting structure closely to ground terrain in order to be able to catch the most danger stress states. Example of application of strain gages for the measurement of residual stresses is given in a Fig. 4 and in Fig. 5 is shown hole drilling by equipment RS-200. Magnitudes of compression residual stresses in columns of steam boiler supporting structure that represent stresses due to static self-weight loading reach in standard cases 100-150 MPa. The tests according to ASTM 837E-01 have confirmed that stresses along the hole depth are constant. This fact shows that the magnitudes of normal stresses determined by drilling are represent the stresses invoked by self-weight of the structure. This static component is important for assessment of strength and stability of supporting elements, but its influence to lifespan of supporting structure is relatively small. Fatigue is influenced mainly by stress amplitudes during compression tests and by various operational regimes (charging and discharging of water, start or end of boiler operation and so on). Because the boiler is covered by isolation the measurements are realized mostly in locations of possible extreme loadings during operation. In order to reach thermal compensation it is suitable to use strain gage rosettes. Example of stress increments that were measured during boiler operation is given in Fig. 6.

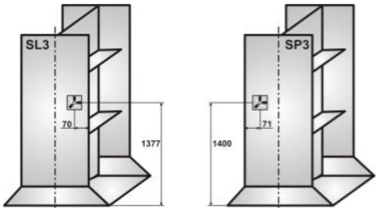


Fig. 4 Locations for application of strain gages for residual stress measurement

Fig. 5 Drilling in strain gage rosette by RS-200

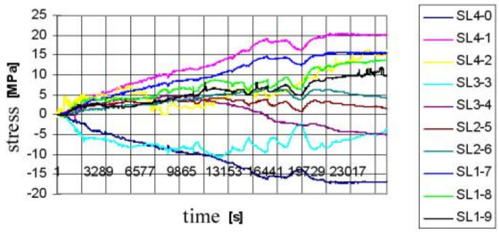


Fig. 6 Charts of time dependent stress increments in columns of supporting structure during boiler operation

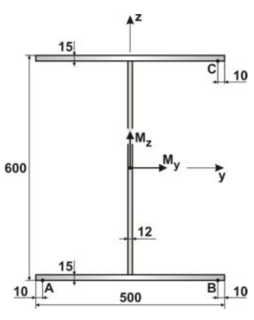
Application of three strain gages in one cross-section of column allows determining influence of axial force and bending moments separately. If we consider cross-section of supporting structure column according to Fig. 7a, placement of strain gages in locations A,B,C allows us to determine the magnitude of axial force N and bending moments M_y, M_z from relations

$$N = A\left[0{,}5\sigma_A - \frac{3z_A - z_B + 2z_C}{2(z_A + z_B - 2z_C)}\sigma_B + \frac{2z_A}{z_A + z_B - 2z_C}\sigma_C\right],$$

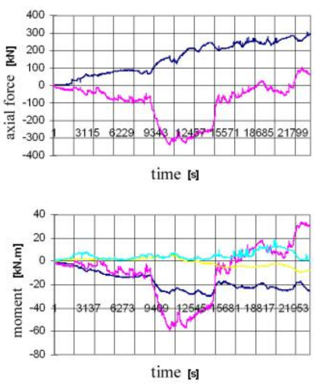
$$M_y = \frac{2J_y}{z_A + z_B - 2z_C}(\sigma_B - \sigma_C) \qquad M_z = \frac{J_z}{2y_B}(\sigma_A - \sigma_B),$$

where y_B, z_A, z_B, z_C are coordinates of strain gages A, B, C; A, J_y, J_z - area, inertial moments of column cross-section, respectively; $\sigma_A, \sigma_B, \sigma_C$ - stresses in locations of strain gages A,B,C.

In Fig. 7b are given examples of time dependent charts of axial forces and bending moments in columns cross-sections during boiler operation.



a)



b)

Fig. 7 Time dependent charts of axial forces and bending moment increments in columns cross-sections during boiler operation

The measured time dependent force and stress quantities allow assessing lifespan of supporting structure. For this process is possible to use assessment for limit state of fatigue according to STN 73 1401 [4] or it can be applied general schema of fatigue lifespan assessment according to Fig. 8 [5].

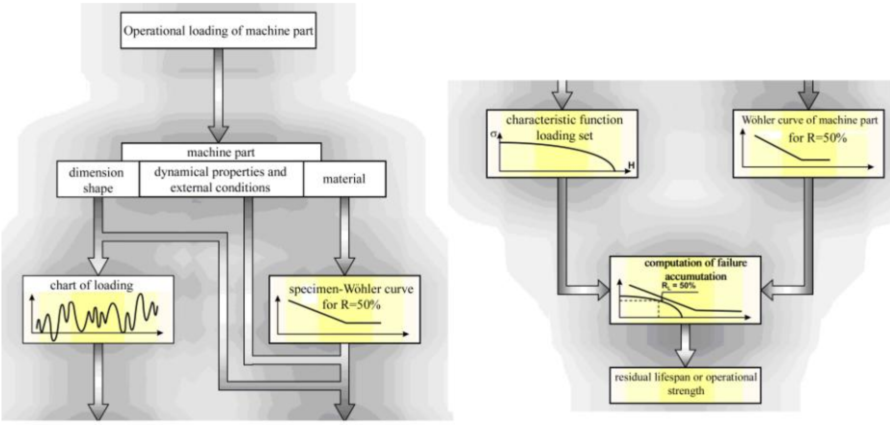


Fig. 8 Assessment of lifespan or residual lifespan

3 CONCLUSION

Assessment of supporting structure lifespan of machines and equipments that are in the long run operation is becoming more and more important. It is very important for supporting structures that undergo variable mechanical and thermal loading, especially in case of their reconstruction or regime changes in which technological equipments work. For determination of real stress states in supporting structures is suitable, because of complex boundary conditions, to use the methods of experimental stress analysis. For identification of static components due to self-weight of structure, technological equipment and water is possible to use the hole drilling method. Time dependent stress increments in supporting structure during boiler operation were measured by electrical resistance strain gages. Lifespan assessment can be realized by according to the theory of fatigue damage accumulation for the known previous history of operation.

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