732. Numerical and experimental identification of vibration convection chamber of fluid power boiler

Michał Paduchowicz[1], Artur Górski[2], Jerzy Czmochowski[3], Eugeniusz Rusiński[4]
Wroclaw University of Technology, Institute of Machine Design and Operation
50-371 Wroclaw, Str. I. Lukasiewicza 7/9, Poland
E-mail: [1]*michal.paduchowicz@pwr.wroc.pl*, [2]*artur.gorski@pwr.wroc.pl*,
[3]*jerzy.czmochowski@pwr.wroc.pl*, [4]*eugeniusz.rusinski@pwr.wroc.pl*

(Received 11 September 2011; accepted 14 February 2012)

Abstract. On the housing of convection chamber vibrations were measured, using acceleration sensors in 16 measurement points, connected to a multichannel recorder. The measurement data were recorded for different states of boiler load, in a wide range of time - 4 hours of measurement. The measurement results indicated that the most important vibrations frequencies of side walls were in the band 30- 30.5 Hz, appeared in block during increase of the power and operation under full load. High amplitudes were also recorded in the band 7-9Hz with a load of 260 MW unit after 2 hours of steady work. Convection chamber was at resonance for these frequencies [1]. In order to identify the vibration of the actual object it was necessary to identify the form of natural frequency of the convection chamber. As first, was discrete model of convection chamber created, and then modal analysis was made, using the Lanczos algorithm. Results of the modal analysis pointed out that due to the complexity of the convection chambers geometry there was a big number of local and global modal shapes. We could see big amplitudes of convection chamber shell displacements in the ranges of structural mode bands: 7-9 Hz, 16-18 Hz, 30-30.5 Hz. If the excitations frequencies in the example from flowing gas are in the same range as natural shapes, the resonance may occur. We cannot determine actual displacements and stress using numerical modal analysis. We have to identify the source of variable strength, to obtain values of time-varying stresses. If we compare the results of modal analysis and measurement at the real object, we can select the areas of construction, in which there is a high probability of resonance. The cause of the convection chambers resonance was probably force created by turbulent boundary layer of gas. The gas flows along the inside of the convection chamber walls [6]. Resonance can be prevented by increasing the stiffness of the chamber walls in areas where there are large vibration amplitude. In this way, we can increase local natural frequency of the chamber. A good method to increase stiffness of the chamber walls is the distribution of bracing beams between the existing stiffeners [2].

Keywords: power boilers, convection chamber, vibration measurements, FEM.

Introduction

A reliable model, experimental studies and exploitation history from start-up construction are the basis for developing of current stress state and the degree of degradation. This is important in process of mechanical degradation for each of technical objects that are working under changing thermal and mechanical loads. So is it difficult to answer the questions about the possibility of further and safety exploitation. If we treat the loads as stochastic process or use the operating documentation, we can solve the problem. Hence it is good solutions to use the numerical and experimental methods that are describing stress state and durability of power plants elements for example convections chambers of fluid power boiler [1, 2].There were excessive vibration of convection chamber walls during operation of power plant in different states of the load. The vibrations of these structural elements are dangerous because of the possibility of cracks on their surface, what can lead to stop of entire power blocks. [2, 3].We can use both of experimental and numerical methods in order to identify the causes of vibration, as well as their localization. The experimental part of work consist of measurements vibration of convection chambers walls. Then modal analysis was made using FEM method [4, 5]. The calculation identified places of large vibration displacement. It was base to purpose of changes in walls construction. The measurements and the numerical calculation were made for convection chambers of fluid power boiler No. 4, 6, operating in Turów Power Plant.

Experimental studies

The measurements were made to determine vibrations influence on behavior of convection chamber walls. The vibrations were measured using sensors in 16 measurement points, on the housing of convection chambers. The Figure 1 presents the localization of sensors on convection chambers power units No. 4, 6. The sensors were installed between 41,5 m and 50 m of convection chamber high level in accessible places for people.

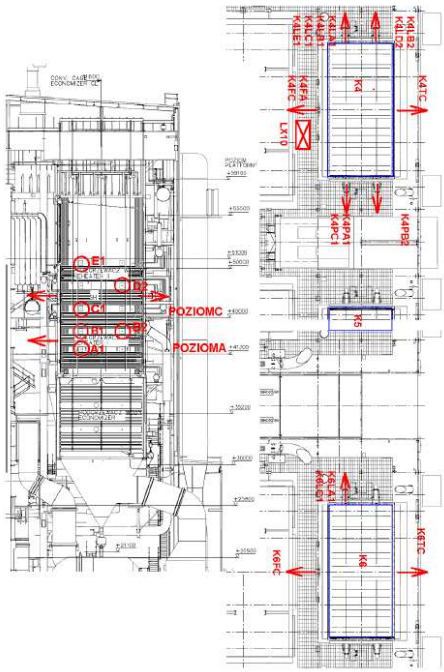


Fig. 1. Localization of sensors on convection chambers power units No. 4, 6

The following type of sensors were used during the measurements:

- tri-axial vibrations sensors, ICP type of general purpose,
- ICP type sensors of high resolution,
- ICP type seismic sensors of vibrations,
- capacitive sensors of vibrations.

The sensors were connected to the multichannel recorder, model LX-10, made by TEAC company (Fig. 2).

The measurement data were recorded for different states of operational load. The loads appeared in a wide range of measurements time. The power was changing during the measurements (Fig. 3 - 2.4).

Convection chamber of power block No. 4 has started to vibrate after 3 hours of measurements. Convection chamber of power block No. 6 has vibrated since the beginning of measurements. Walls of convection chambers have vibrated around manholes between soot blowers (a *Z* axis of sensors). Vibration direction of the bumpers was different (a *X* axis of sensor). The results of the measurements were registered as spectrums of the amplitude acceleration (Fig.5). The spectrums were filtered using Fourier analysis in order to identify the main frequencies of vibration.

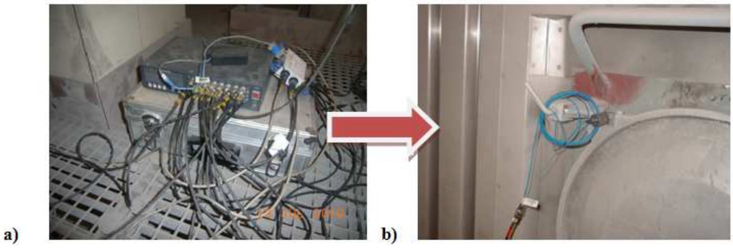


Fig. 2. Measuring system of convection chamber walls a) LX-10 multichannel recorder, b) view of seismic sensor on the convection chamber wall

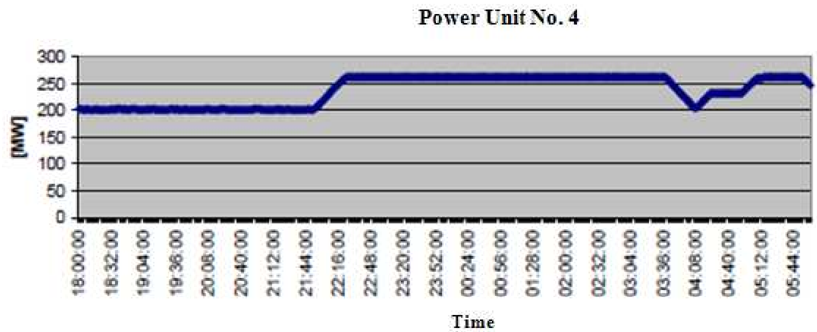


Fig. 3. The changes of Power Unit No. 4 power during the measurements

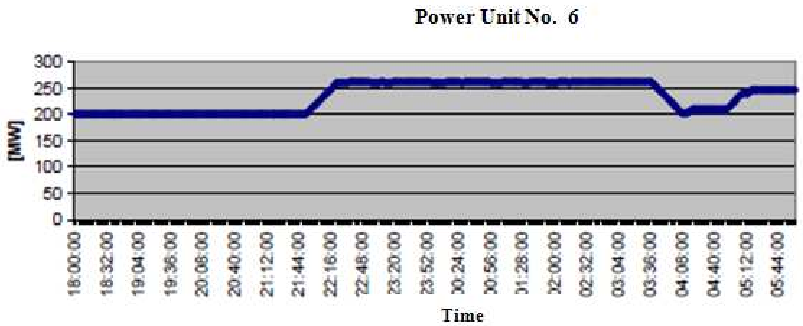


Fig. 4. The changes of Power Unit No.6 power during the measurements

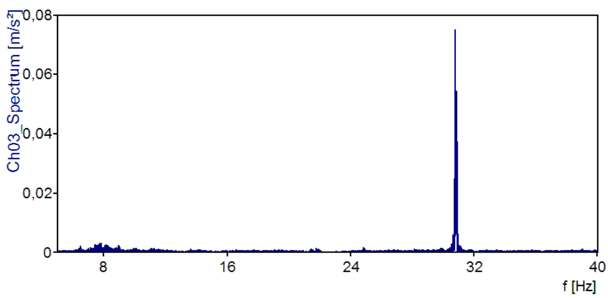


Fig. 5. The exemplary amplitude spectrum of acceleration in the band 4-40 Hz in 03 measurement point

Results of measurements indicated that there were no connection between vibrations and state of boiler power. The speeding of the power changes had no influence on value of vibration too. The measurement results indicated that the most important vibration frequencies of side walls were +30.5 Hz. The frequency was the same for convection chamber of power unit No. 4 and 6. The large vibrations amplitude appeared in blocks during increase of the power (power unit No. 6) and operation under full load (power unit No. 4). The frequencies of chambers vibrations were different for different areas of chamber walls and the different time of measurements. All of vibration frequencies were included on narrow range from 1.5 Hz to 30.5 Hz. Vibration frequencies of the convection chambers for power unit No. 4 and 6 were in the band of 30÷31.5 Hz. One of the vibrations frequencies about 30 Hz was reinforcement, during the intensification of the convection chamber vibration. The acceleration's amplitude of these vibrations was increased over 100 times. The amplitude was dominated over the other vibrations frequencies. Verification of convection chambers vibration measurements was made using 2 – channel vibrometer. It was made simultaneously with sensors measurement.

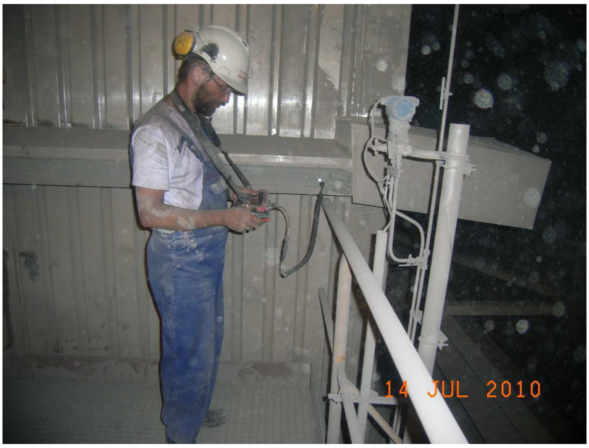


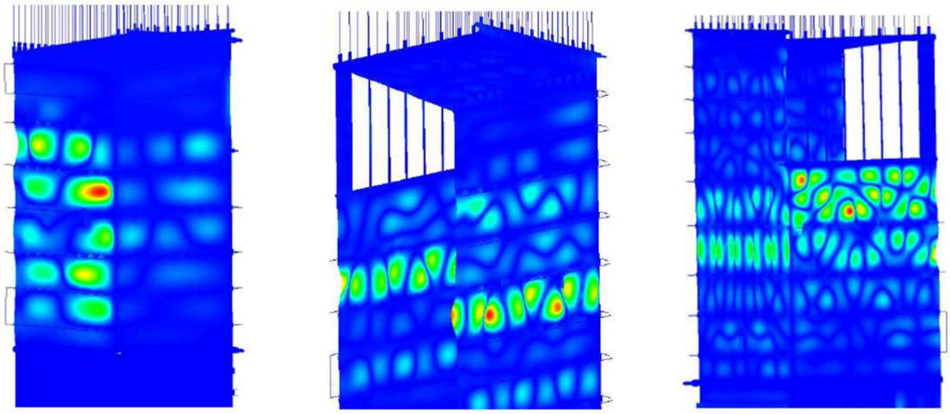
Fig. 6. The measurements of convection chambers vibrations using 2-channnel vibrometer

The measurements were carried out in places where it was found very clear and strong audible rumble convection chamber. The measurements indicated there were vibrations with big amplitudes in the bands of: 7-9 Hz besides the vibration frequency 30 Hz measured by a stationary recorder. The vibrations were registered at 260 MW of boiler power for 2 hours of steady work. Convection chamber was in resonance for these frequencies [2, 3].

Numerical analysis

In order to identify the vibration of the actual object it was necessary to identify the form of natural frequency of the convection chamber. At first a discrete model of convection chamber was created, then modal analysis was made using the Lanczos algorithm [5]. Results of the modal analysis pointed out that due to the complexity of the convection chambers geometry there was a big number of local and global modal shapes. We could see big amplitudes of convection chamber shell displacements in the ranges of structural mode bands: 7-9 Hz, 16-18 Hz, 30-30.5 Hz (Fig. 7a, b, c). If the frequencies of excitations from flowing gas are in the same range as natural shapes, the resonance may occur on convection chambers walls [6].

We cannot determine actual displacements and stresses using numerical modal analysis. We have to identify the source of changing loads, to obtain values of time-changing stresses. If we compare the results of modal analysis and measurement at the real object, we can select the areas of construction, in which is a high probability of resonance.



a) b) c)

Fig. 7. Modal shape of convection chambers left and back walls for natural ferquencies: a) f = 8.277 Hz, b) f = 16.93 Hz, c) f = 30.047 Hz

Conclusions

The cause of the convection chamber resonance was probably created by turbulent boundary layer of combustion gas. The gas flows along the inside of the convection chamber [3]. Resonance can be prevented by increasing the stiffness of the chamber walls in areas where are large vibration amplitude. In this way, we can move local natural frequency of the chamber walls from the resonance frequencies bands. A good method to increase stiffness of the chamber walls is the distribution of bracing beams between the existing stiffeners [2]. Propositions of convections chambers walls stiffening are presented in figures 10, 11. We proposed I-sections size 160 and 200 as a stiffening element.

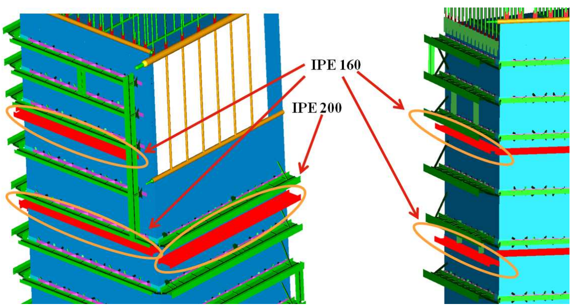


Fig. 8. Added stiffening on convection chambers walls in areas where the resonance appeared

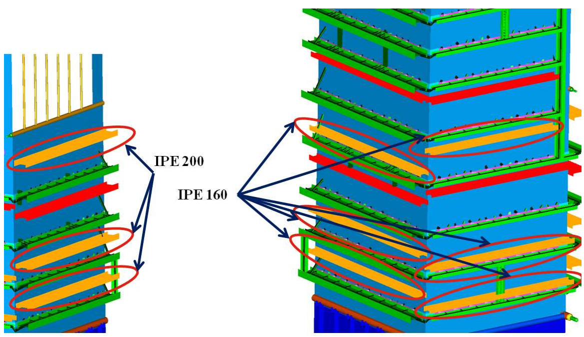


Fig. 9. Added stiffening on convection chambers walls in areas where the resonance appeared