20th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2016, Mediterranean Sea Cruising, 24th September - 1st October, 2016

THE REASONS OF THE SUSPENSION FRACTURE IN A WATER SEPARATOR OF THE BP-1150 BOILER

Donat Renowicz, Marek Plaza, Bogusław Plaza, Dariusz Kowala, Ewa Renowicz,
BTHU Thermex s.c.
Graniczna 29/211A, 40-017 Katowice
Poland

Jerzy Okrajni,
Silesian University of Technology
Krasińskiego 8, 40-019 Katowice
Poland

ABSTRACT
Power plant boilers, operating in a one-pass configuration, are equipped with separators applied to separate steam from the water flowing from waterwalls. Turbulent flow of a wet steam inside the separator causes vibrations. The fatigue processes observed in the material microstructure of these components are caused by these vibrations. Fatigue leads to fracture of the separator suspension rods. Such phenomena were observed under real operating conditions. The paper provides an analysis of vibrations occurring in mechanical system of separators. A new developed suspension solution has been presented in the paper. The vibration amplitude was decreased as a result of the new suspension design. Significant reduction of the maximum local stress leading to increase the durability of suspension rods was obtained. The calculation results as well as conclusions from vibration studies have confirmed the beneficial effects of the suspension system modification.
Keywords: boiler structure, vibration, material fracture

1. INTRODUCTION

A separator is one of basic elements of boilers installed in modern power units. Wet steam flowing from the boiler waterwalls is supplied to the device, and its purpose is to separate steam, subsequently transported by pipelines in the upper section to steam superheaters and water which flows down to a mixer connected with the separator in its lower section. In the mixer, water flowing from the separator combines with the water preheated in the economiser while flowing to the circulating pump which delivers water to the collector and lower chambers of the boiler proper. In pipelines connected with the separator head, turbulent steam flow causes the occurrence of dynamic reactions of random nature inside the separator. Theirs results are separator's vibration as well as the connected pipelines and mounting parts. Due to the vibrations, processes of the microstructural material fatigue take place in some parts of the separator. The basic separator rods belongs to these parts, where the cracks were observed under the operating conditions of the boiler (Fig. 1,2) [1-3]
In the study an attempt to reduce vibrations occurring in the suspension rods by introducing structural modifications of the water separator mounting was made.

2. CHARACTERISTICS OF A NEW MOUNTING SYSTEM

Basic new parts of the mounting system form a system of rods rigidly connected with the boiler load-bearing structure (Fig. 3). In new solution the beam traverses with four rods were preserved. Such a system enables using the upper mounting rods to partially transfer the load from the separator as well as allows for adjustment of this load through pre-tensioning of rods. Consequently, it provides an

option for altering the boundary conditions of vibrations in the mounting system by changing the forces occurring in suspension rods.

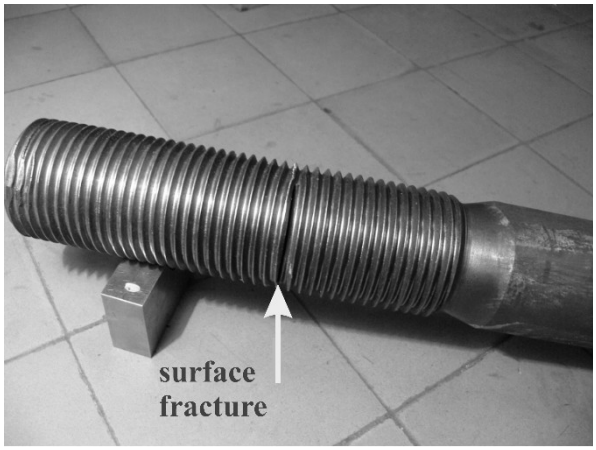

Fig. 1. Fractured end of a separator suspension rod

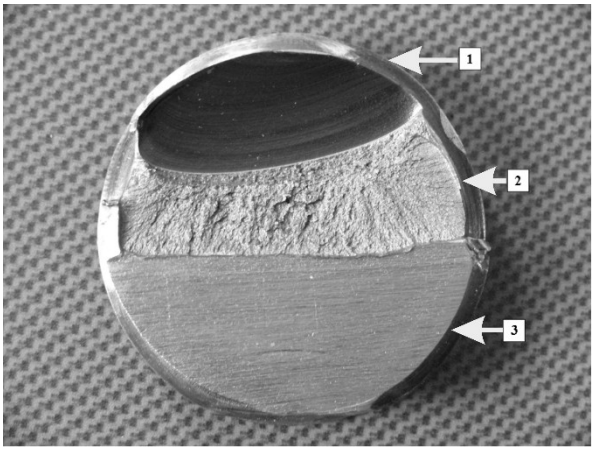

Fig. 2. Fracture of the suspension rod: 1 – fatigue zone, 2 – transition zone formed in the bending test, 3 – area formed after undercutting with a band saw

The implementation of the new water separator suspension solution was preceded by an analysis of its behaviour patterns under projected operating conditions (Fig. 4, 5). For this purpose, a computer simulation of vibrations of the mechanical system was carried out. The movement of the separator anchorages (point M in Fig 3) in the horizontal plane in the function of time has been described by formula (1):

$$s = a \sin(2\pi f t) \tag{1}$$

where: a=0.5 mm - is the amplitude value of the separator displacement, f=4.91 Hz - is the frequency of beam traverses and t - is the time argument.

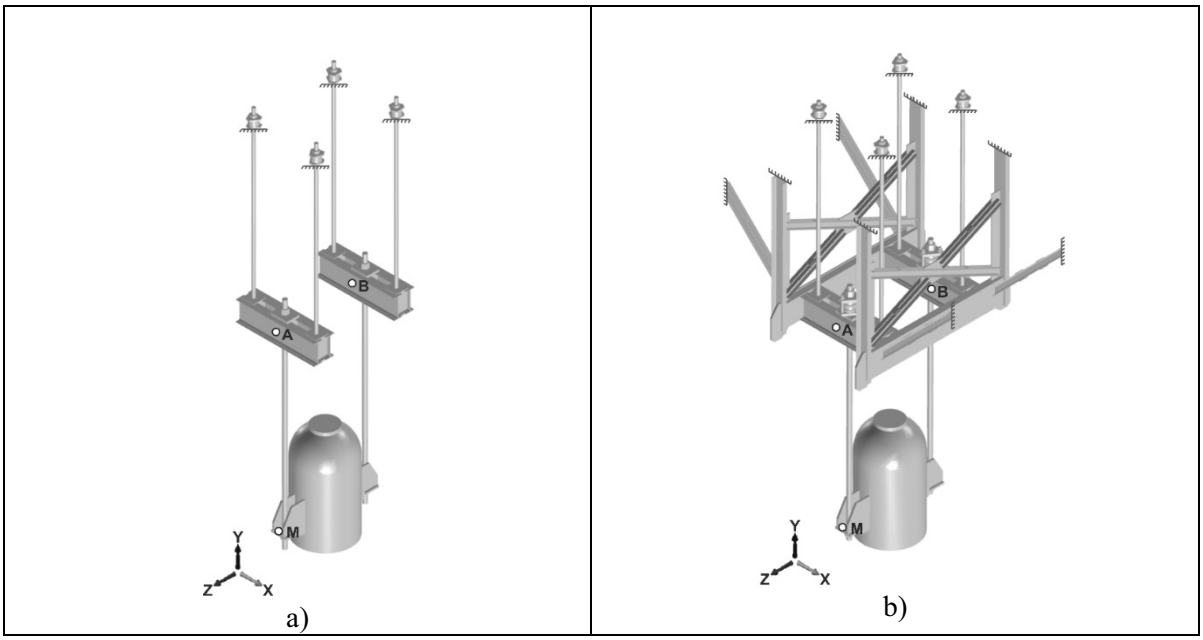

Fig. 3. Separator suspension system: a) before modernization, b) after introducing an additional mounting system. A, B, M – vibration measurement points.

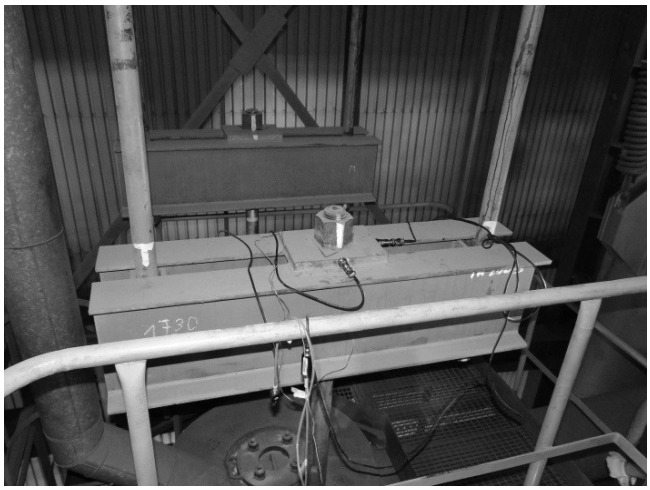

Fig. 4. Original separator mounting system.

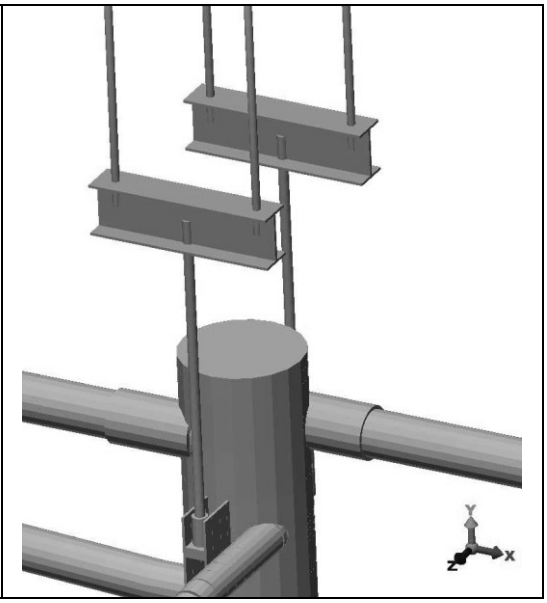

Fig. 5. Model of original separator mounting system.

Analysis of behaviour of the hanger's system was performed using finite element method. Two models of the separator's mounting system were prepared, one corresponding to the status before modernization, and the other one including the additional system improving the rigidity of the upper section of suspension rods (Fig. 3b). The existing geometric properties of the separator components, its suspension rods and the pipelines connecting the separator with the waterwalls were took into account. The elastic characteristics of the pipeline suspensions, elastic assembly parts in the form of disk springs were applied in the models. Mass of these components was also taken into consideration.
For models developed in that way, a dynamic analysis [4-6] was performed, comprising modal analysis and determination of displacement values for selected points of the examined system.

3. CALCULATION RESULTS AND CONCLUSIONS

In the course of the study, dynamic characteristics were compared by developing a dependence between the displacements and the vibration frequency of the suspension systems, both the original and the new one. The results of calculations have shown a change in dynamic characteristics of the system owing to the application of a new mounting system. It should be noted that the new solution which has been applied, led to decreasing the amplitude of displacements of the upper mounting rod end compared with the amplitude displacement of the separator lug established for the original solution. Change in the relative values of displacement of ends of suspension rods exerts a significant impact on the value of bending stresses which are variable in time. In both cases of the design solutions, for the same driving force applied in point M, vibrations were reduced decreasing displacements of that point. The stresses variable in time generated in this area were the reason of material fatigue fracture of the suspension rods.
The analysis of calculations have shown that by changing the structure solution, one could successfully affect the free vibration frequency values and cause the reduction in the value of displacement of the beam traverses. In the original solution they were the structure components which had intensified vibrations whose amplitude reached extreme values at the critical cross section of the separator suspension rods leading to failure. The displacements of the beam traverse points, established in the modal analysis of the new system, were significantly lower than those established for the original state.
It was also confirmed by vibration measurements conducted after the modernization. The range of vibrations was reduced a lot of times in comparison to the original separator mounting system (Fig. 6, 7).

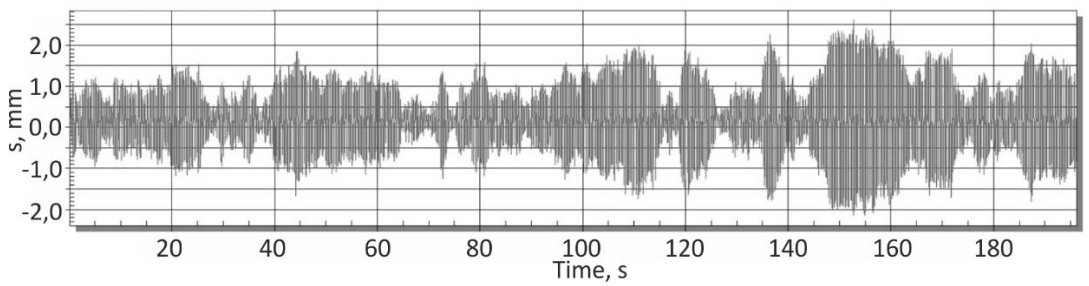

Fig. 6. Displacement changes of point A and B (Fig. 3a) as the time function, – measurement conducted before modernization.

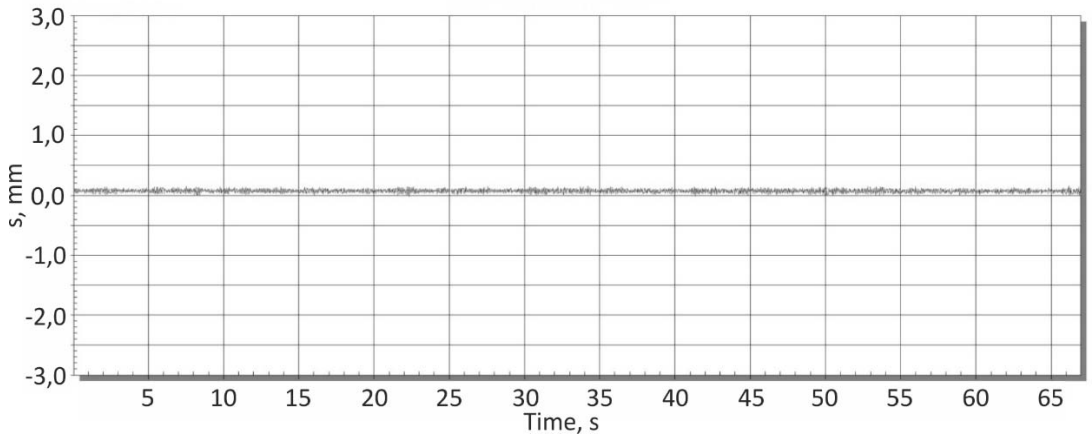

Fig. 7. Displacement changes of points A and B (Fig. 3b) as the time function, – measurement conducted after modernization.

Reducing the amplitude of bending vibrations of the suspensions in the AM section (Fig. 3) exerts a significant effect on reduction of the amplitude value of the stress intensity factor in the rod's thread of suspension. This factor determines the conditions of crack initiation and directly affects crack growth rate. By reducing this value, one was able to successfully increase durability of the separator's main suspensions.

4. REFERENCES

[1] Okrajni J., Plaza M., Renowicz D., Pietrzyk M.: The effect of modification method of suspension of the water separator on the dynamic characteristics of the system, Energetyka 11/2014 (725), Poland., 2014.,
[2] Plaza M., Okrajni J., Pietrzyk M.: Model dynamiczny i analiza modalna na przykładzie wybranego układu rurowego w bloku energetycznym, Energetyka nr 11/2012 (701), Of. Wyd. Energia COSiW SEP< Katowice, Poland, 2012.,
[3] Renowicz D., Plaza M.: Trwałość zawieszeń wodooddzielacza pracującego w bloku energetycznym BP 1150 Energetyka nr 9 (711), Of. Wyd. Energia COSiW SEP<, Katowice, Poland, 2013.,
[4] Renowicz D., Plaza M., Essler W.: Ocena trwałości resztkowej cięgien w zawieszeniach głównych wodooddzielacza, Materiały Konferencji PIRE 2004, Szklarska Poręba, Poland, 2004.,
[5] Warmiński J.: Nieliniowe postacie drgań (Nonlinear mode vibration), Wyd. Naukowe PWN, Warszawa, Poland 2011.,
[6] Kucharski T.: System pomiaru drgań mechanicznych (Measurement of mechanical vibrations), WNT, Warszawa, Poland 2002.,
[7] Giergiel J.: Tłumienie drgań mechanicznych (Dumping of mechanical vibrations), PWN, Warszawa, Poland, 1990.