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Triple-finned tubes – Increasing efficiency, decreasing CO_2 pollution of a steam boiler

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ABSTRACT

This paper presents the results of techno-economical analysis of a proposal of the utilization of TFT (triple-finned tubes) in a boiler's tube banks. The following three tube bank arrangements were compared: (A) the base – staggered plain tube bank; (B) the combination of triple-finned and plain tubes – two rows of triple-finned tubes every 10 rows; (C) the alternating tube bank, where half of the plain tubes were replaced by triple-finned tubes in an in-line arrangement.

The results of CFD calculations of heat load q let to obtain relative values of the Nu number on the tube bank in (B) and (C) arrangements and the base arrangement (A) were carried out in a 2D model using the CFD (computational fluid dynamics) code Fluent.

Heat transfer values of an ECO (economizer) with triple-finned tubes were obtained for the calculation of outlet flue gas temperature and outlet loss. Calculations of the Nu number of the tube were performed for all arrangements. Next, boiler efficiency and fuel consumption were calculated by 0D modelling. Received results were used to make economical analysis. In the case of modernization in the (C) arrangement, efficiency would be 90.67%, which is an increase of 1.1%. This is related to the reduction of flue gas temperature to 138 °C from 158.8 °C.

Economically, the most advantageous solutions, are the variants of modernization (B) and (C) for the newly formed boiler. In both cases, SPBT (simple payback time) capital payback period is very short - close to half of a year.

It is worth noting that the proposed modernizations of the arrangement (B) and (C), will respectively reduce CO_2 emissions by 550 t/a and 826 t/a.

The results show that triple-finned tubes can be used to increase the performance of cross-flow tube banks.

1. Introduction

Enhancement of tube bank's performance is one of the methods for increasing coal boiler's efficiency and decreasing CO_2 pollution.

The results of implementation of an additional high pressure economizer at Unit B1 of the 620 MWe lignite-fired Power Plant "Nikola Tesla B" were presented in [1]. It is shown that more than 30 MWth of the flue gas waste heat is recovered. The Unit gross efficiency is increased by 0.53 percentage points. Other way of increasing efficiency and decreasing CO_2 pollution is implementation of finned tubes.

Studies of heat transfer and flow resistance, performed so far for the following types finned tube bundles:

a) inline and staggered tube banks with longitudinal fins:
   - membrane - [2–5],
   - finned - [4],
   - finned diagonal - [6],
   - profiled fins [7,8].
b) inline and staggered transverse tube banks [9,10]:
   - bundles of tubes with spiral fins.
   - bundles of tubes with disc fins.
c) tube banks of both longitudinal and transverse fins [11].

The erosion risk for solid-fuel boilers that use finned tubes is unknown. Particular arrangements of tubes and fins tubulise the flow of flue gas, stepping up the heat penetration, and these tube

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arrangements may be relatively vulnerable to heat damage [12]. Studies of erosion in the convective section of steam boilers conducted in earlier years ([13–15]) focused on solving the erosion problem of boilers with plain-tube exchangers. Examination of erosion in a modern complex of finned tubes, including TFT (triple-finned tubes), is presented in [16]. Techno-economic feasibility analysis of using a new form of tubes, TFT, in convective heat-exchangers suggests that TFT use is necessary.

2. Methodology

2.1. Tube bank arrangements

To analyse the economic feasibility of using a new form of tubes, TFT, an ECO (economizer) of the Polish boiler OP-140 (pulverized fuel boiler, max. continuous rating 140 t/h of steam) was selected. The ECO in this boiler is constructed as a heat exchanger with 76 coils from ϕ 32 × 4 (steel K18 type) tubes. These coils are installed in duct sizes of 3615–6055 mm, transverse scale $s_1 = 150$ mm, and longitudinal scale $s_2 = 50$ mm. This staggered heater is divided into three sections with 16 rows of tubes (Fig. 1).

To improve boiler efficiency by reducing outlet loss, two modernizations with TFT were proposed. The following arrangements were compared:

- (A) the base – staggered PT (plain tube) bank (Fig. 1)
- (B) a combination of TFT and PT: for every 10 rows in each coil of the ECO, replace 2 rows of PT with TFT (Fig. 2).
- (C) an alternating tube bank, where half of the PT are replaced by TFT in an in-line arrangement (Fig. 3).

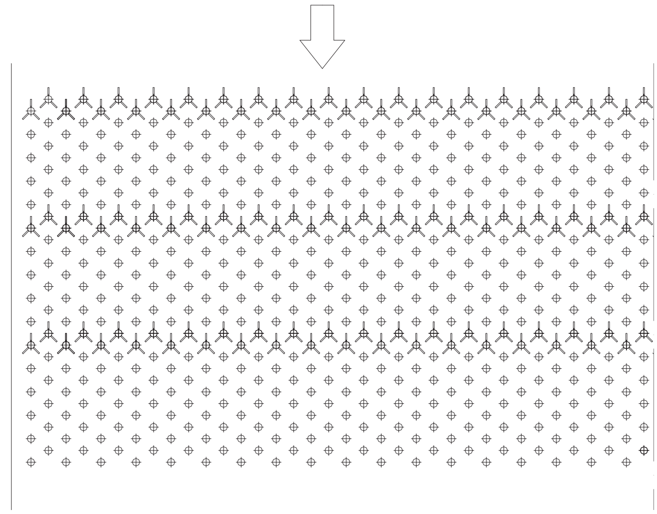

Fig. 2. A single section of the OP-140 economizer for the proposed modernization arrangement (B).

- (D) in-line PT bank, for comparison with (C) to obtain heat transfer coefficient k for 0D modelling of in-line bank (C).

For the OP-140 ECO tube bank (tubes $D = \phi32$, $s_1 = 150$ mm and $s_2 = 50$ mm), fins of dimensions heigh $h = 35$ mm and thickness $g = 5$ mm were approved (three fins with the same geometry with 45° between two symmetric fins and a vertical line of symmetry).

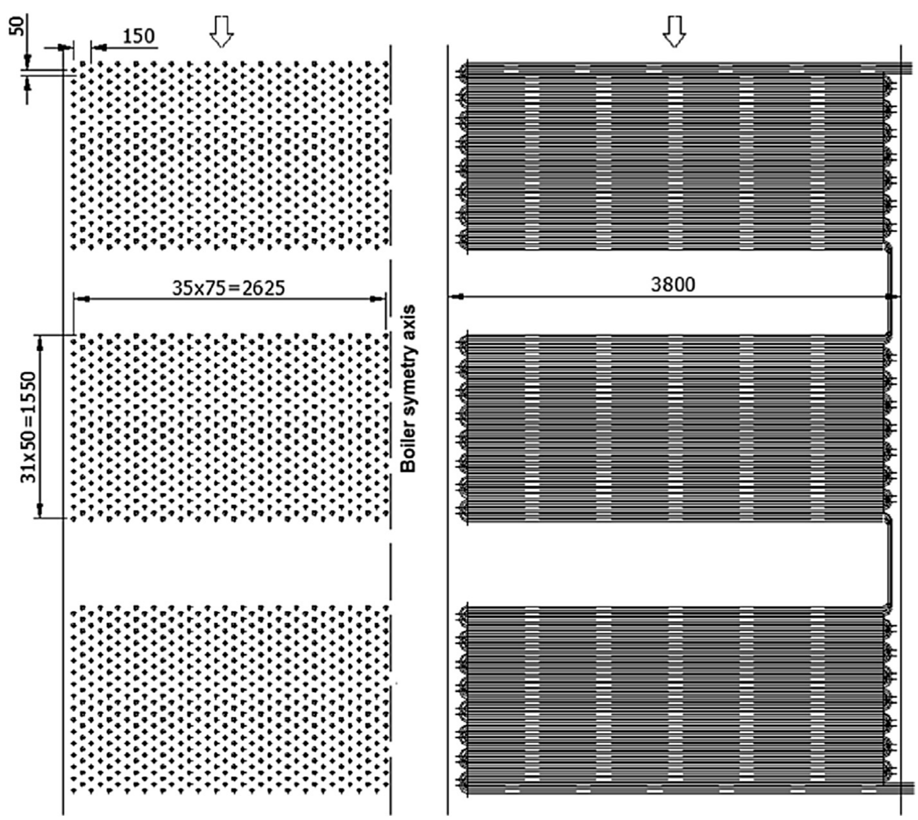

Fig. 1. Tri-sectional water heater of OP-140 boiler, built in the staggered plain tubes arrangement (A).