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A newly designed economizer to improve waste heat recovery: A case study in a pasteurized milk plant

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HIGHLIGHTS

- We propose the newly designed economizer to improve the heat transfer.
- The exhaust gas is designed flowing over bank of tubes with triple pass mode.
- The performance is evaluated by heat transfer model including fluid dynamics.
- The economizer gives the heat recovery of 38% and the cost saving of 13%.

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ABSTRACT

An economizer is normally employed to perform heat recovery from hot exhaust gases to cold fluid. In this work, a newly designed economizer is devised to achieve high heat recovery in a pasteurized milk plant. In the economizer, the hot exhaust gas is divided into two channels flowing up on the left and right sides. After that, it is moving down passing over aligned banks of tubes, which water is flowing inside, in a triple passes fashion. Moreover, three dimensional (3D) models with heat transfer including fluid dynamic have been developed, validated by actual plant data and used to evaluate the performance of the economizer. Simulation results indicate that the newly designed economizer can recover the heat loss of 38% and can achieve the cost saving of 13%.

1. Introduction

Heating system such as furnace and boiler are frequently carried out to generate thermal energy for many applications. In a pasteurized milk plant, heat is mainly required to kill virus and bacteria in raw milk. This means that the hot water supplied to this process should be over 72 °C [1]. Furthermore, the heat is also utilized to sterilize piping systems and equipments before and after production [2]. Hence, a boiler is mostly employed to supply thermal energy in terms of steam or hot water for these processes. Generally, it has an inefficient consumption in energy owing to heat loss as waste heat in term of an exhaust gas. The waste heat in the exhaust gas is able to be recovered by many techniques: preheating the boiler's feed water by the economizer, preheating the combustion air with the recuperator and preheating the bunker oil [3–5].

In literature, relevant studies on the economizer found have been addressed that an economizer is employed in between the flue gas and the chimney of heating systems such as boiler, furnace etc. for removing an excessive heat from the combustion gas to improve the efficiency of the heating system. An economizer is frequently designed as the shell and tubes type that comprises a cylindrical or rectangular shell mounting a bank of tubes and an inlet chamber connected to the chimney and an outlet chamber at its end. The flow of exhaust gas is arranged in the countercurrent or cross pattern with water flow direction [6–9].

The existing design indicates that the economizers have the exhaust gas flowing with single or double pass fashion. Moreover, the performance improvement for an economizer has been often carried out by redesigning the coil shape or changing the coil material at the water side. As a result, the flow pattern for the exhaust gas of the newly designed economizer is changed to improve its performance. This paper presents the newly designed economizer

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in order to perform heat transfer on the both fluid sides. The performance of this new design is examined using mathematical modeling and numerical analysis.

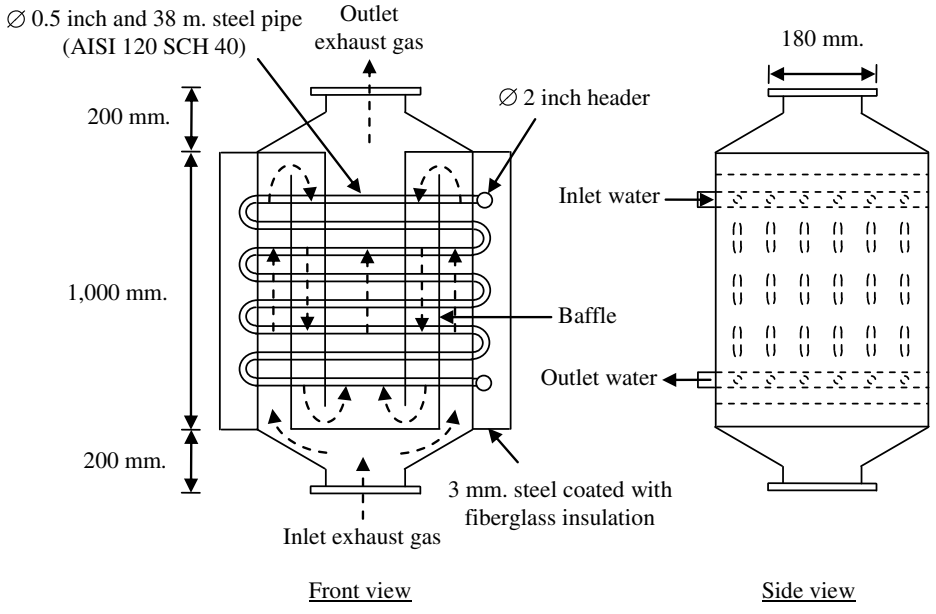
2. Overview of newly designed economizer

Economizers are normally designed and operated with single pass or double pass of the exhaust gas. The improvement of an economizer focuses on modifying the pattern or the material of piping coil. It causes to improve the overall heat transfer coefficient. This work has introduced a new gas flow pattern flowing over the tube bank with double pathway and triple pass fashion and the sizing has been carried out to achieve the maximum heat transfer of the exhausted gas with respect to the retention time of the exhaust gas inside shell side.

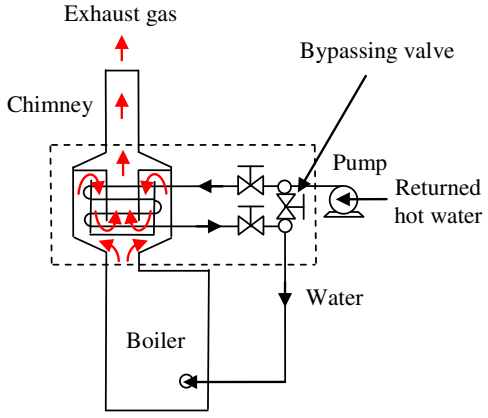
The detailed design of the economizer is illustrated in Fig. 1A [10]. It consists of the single rectangular shell and eight rows of tubes in the gas flow direction and six tubes per row connected to header. The baffles are installed to halve the amount of the exhaust gas and to control the flow pattern of the exhaust gas with unmixed and triple pass mode. The returned hot water is fed into the top of header. After that, the outlet water which has a high temperature is delivered from the bottom of header before feeding to the boiler. For real implementation, the newly designed economizer is placed into the chimney of the existing boiler as shown in Fig. 1B [10].

3. Model description

On account of the structure of the newly designed economizer shown in Fig. 1, computational domain is composed of representative economizer parts illustrated in Fig. 2. A mathematical model is based on three dimensional heat transfer including the fluid dynamic on both fluid sides. The governing equations consist of general heat transfer equation [11], Reynolds Averaged Navier–Stoke (RANS) model [12] and Wilcox revised (k–ω) turbulence model [13].



A) Drawing of newly designed economizer



B) Schematic diagram of economizer placed into an existing boiler system

Fig. 1. Newly designed economizer.