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Application of Taguchi method and grey relational analysis on a turbulated heat exchanger

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ABSTRACT

In this study, turbulators constructed by corrugated tapes, referred as flue breaker in the industry are used in a concentric pipe heat exchanger system. Thickness (*t*), width (*w*) and pitch (*p*) of these tapes and Reynolds number are addressed as the design parameters of the experimental studies.

Formerly, the number of experiments namely the orthogonal array is determined via Taguchi method. Base on that array the experiments are performed and then the effects of design parameters on heat transfer and pressure loss are investigated by Analysis of Variance (ANOVA). Finally, the relationship between heat transfer and friction factor is examined by grey relational analysis.

As a result, it is shown that most strength parameter on average Nusselt number is the Reynolds number. Then the width, pitch and thickness of the corrugated tapes can be ordered according to their effects' levels. However, the thickness is the most effective factor of the friction factor. Then the width and Reynolds number comes in order. The pitch has found to have negligible effect on friction factor.

1. Introduction

As is known, flue breaking turbulators are applied to smoke pipes in boilers to enhance the turbulence intensity of the flue gases and improve the heat transfer by increasing the contact of gases with the surface. Using any type of turbulator in a heat exchanger is an important method to increase the heat and was addressed in tens, maybe even hundreds of studies to this day. Many researchers studied the turbulator geometry in particular in an attempt to achieve high heat transfer with minimum pressure loss. Some of these studies produced good results in theory, yet were not viable for application, whereas some studies could not be implemented due to poor economic analysis and optimization. Therefore, the aim of this study is to increase efficiency by applying a design and optimization analysis to an actual industrial problem.

In the last century, numerous kinds of turbulators such as twisted tape, wire coil or spring, baffle, rib, fin, etc. are proposed to promote turbulence and convective heat transfer in the heat exchangers. To determine the performance of the heat exchangers equipped with turbulators, the heat transfer and flow friction characteristics must be simultaneously considered [1,2]. Furthermore, effects of each design parameter such as the width/length/height/thickness of the turbulators or velocity/flowrate of the fluid should be well investigated. For this aim some new optimization methods have been proposed. Taguchi method is one of the well-known optimization and design of experiment (DoE) method, newly used in the turbulated heat exchanger applications. The authors of this study find it beneficial to introduce DoE methods in general, before focusing Tagıuchi as an exclusive topic.

A detailed description of the design of experiments theory can be found in some earlier works [3,4], where the use of several designs for multidisciplinary design optimization are reviewed and discussed. Until now, different methodologies are used as DoE method such as; full factorial design, central composite design (CCD), D-optimal design, the randomized complete block design, latin square design, Box-Behnken design, Plackett-Burman design and Taguchi design methods [5]. All of these strategies were originally developed for the model fitting of physical experiments, but can also be applied to numerical experiments. The objective of DoE is the selection of the points where the response should be evaluated [6].

In the heat enhancement applications the CCD and Taguchi methods are the mostly used methods. Hatami and his co-workers have preferred to use CCD as the DoE method in several heat transfer enhancement works. For example, they applied the CCD method on a finned type heat exchanger to recover waste heat from the exhaust of a diesel engine

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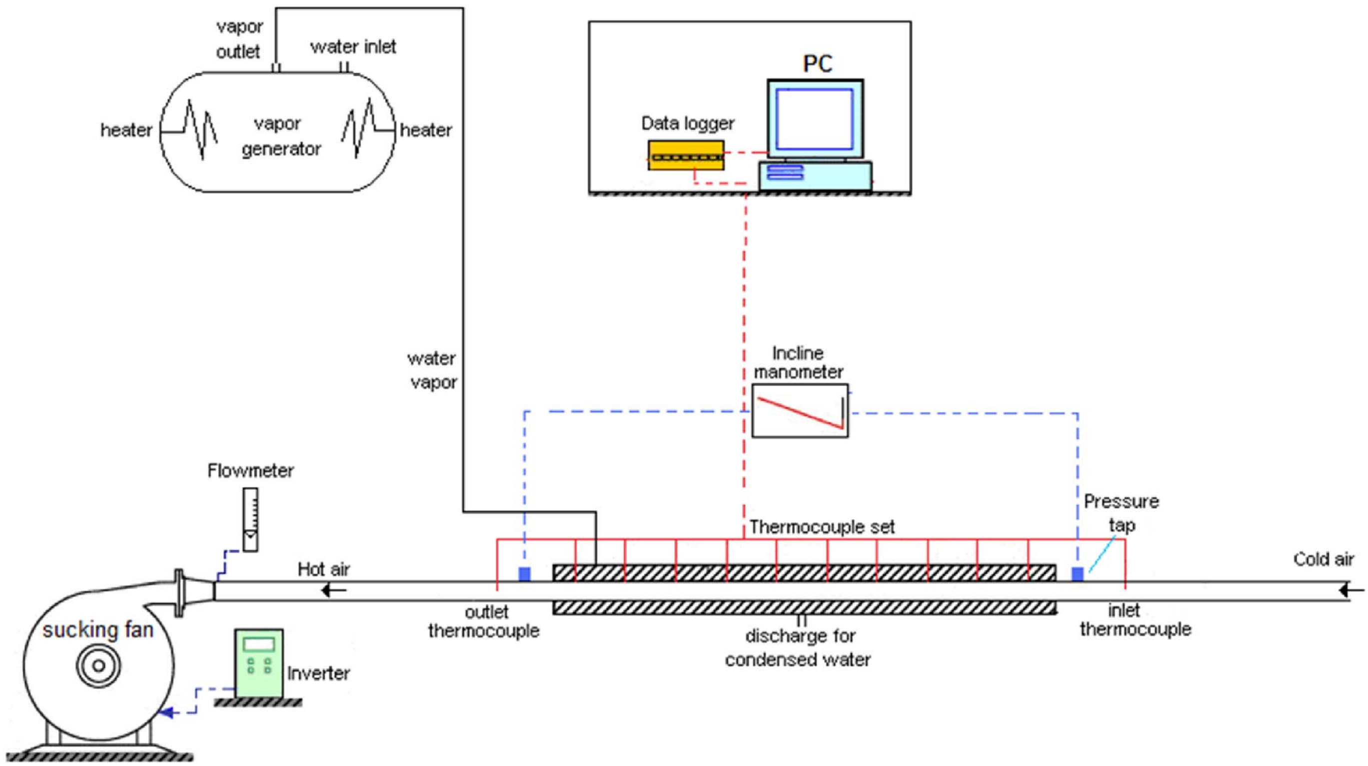
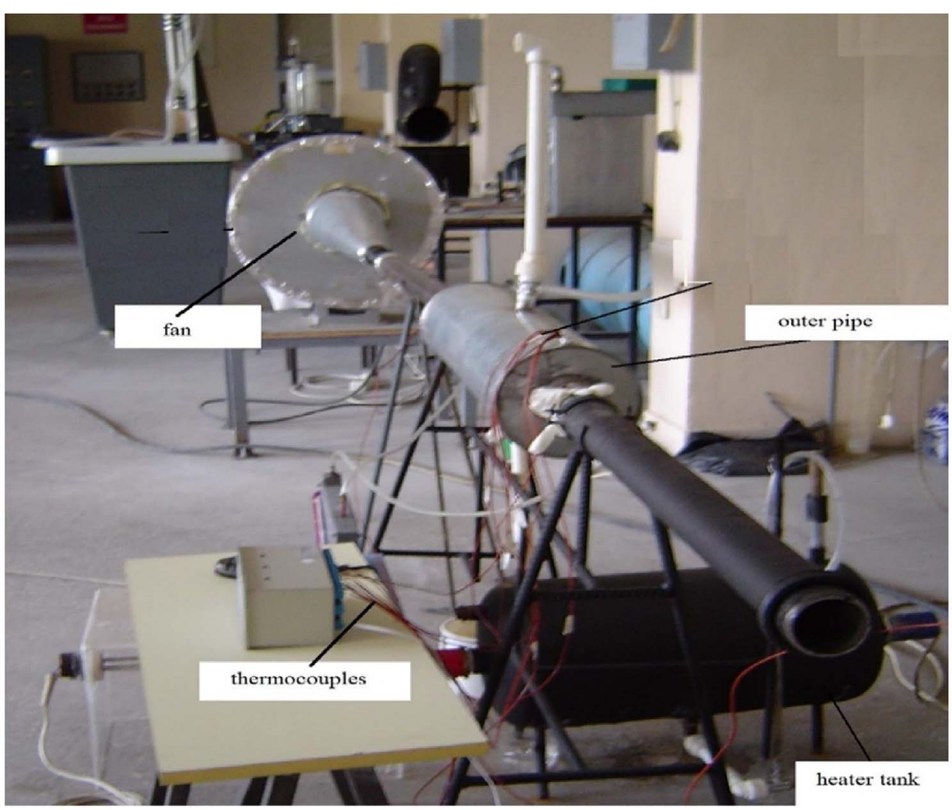


a)



b)

Fig. 1. a) Schematic view, **b)** photo of experimental setup.