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Burner design for an industrial furnace for thermal post-combustion

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Abstract

The industrial furnace considered in this work is designed to remove organic flue gas components by thermal post-combustion. In the existing device air contaminated with organic components is mixed with auxiliary fuel (methane) in a conical diffuser. Optimization of the post-combustion with respect to heat recovery and, thereby, inlet temperatures led to non-proper stabilization of the flame followed by a thermal damage of the conical burner in the existing design. In order to protect the burner from thermal damage, a new robust swirl-induced lifted flame design has been considered. This design includes possibilities of varying the angle of the cone and the swirl number of the incoming mixture. It allows adjusting the lifted flame position as well as improving the oxidation of the organic component while simultaneously lowering the risk of thermal damage of the burner.
The methodology for burner design is based on the numerical simulation of the turbulent reacting flow in the furnace. Results for velocity and temperature fields in the furnace for the old and the new design of the burner are compared. The final, optimized burner design enables the combustion of a wide range of gas mixtures with different calorific values at different thermal loads.

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Keywords: Burner design; furnaces; thermal post-combustiion, numerical simulation

1. Introduction

The industrial furnace considered in this work is designed to remediate organic gaseous compounds evolving with the drying air from drying processes by thermal post-combustion. The contaminated drying air is mixed with auxiliary fuel in a conical burner, which is the main target for optimization in the existing design. Auxiliary fuel is methane.

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A scheme of the furnace and its main components is given in Fig. 1. The conical burner is responsible for mixing of the air/waste gas mixture with the auxiliary fuel and for stabilization of the flame.

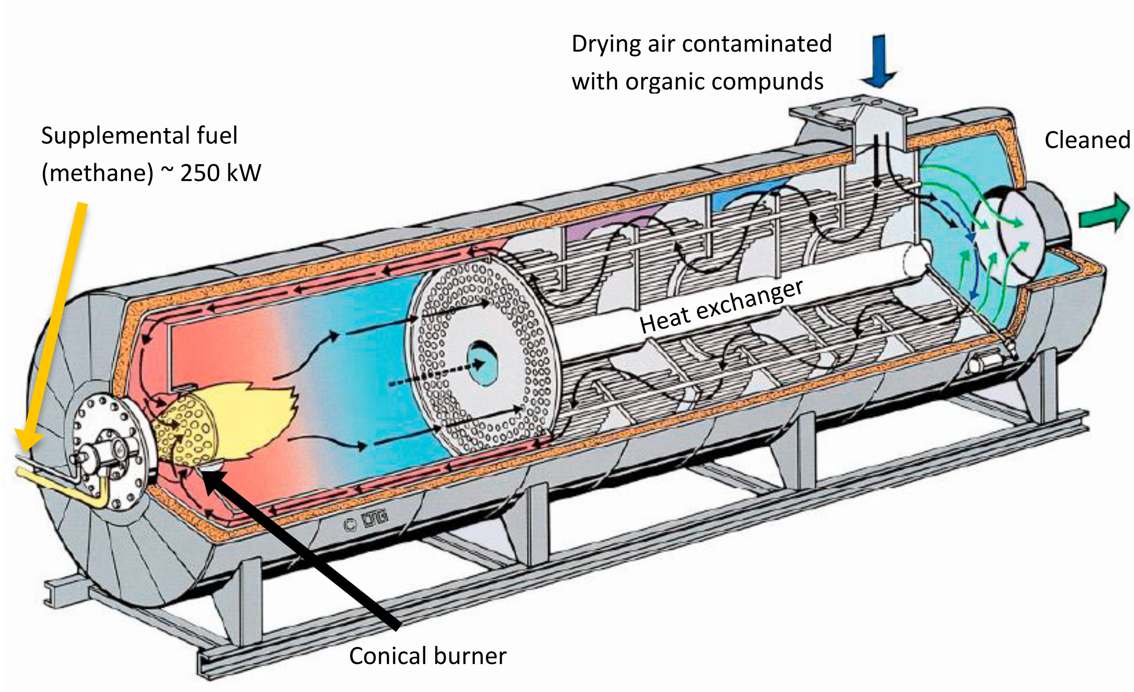

Fig. 1. Scheme of the investigated combustion chamber of the furnace.

The driving force for the work presented in this paper was the thermal damage appearing on the conical burner (thickness 2.5 to 4mm). Initially, the furnace has been operated stable with NO_x emissions below the limits prescribed in Europe, see e.g. [1]. To improve the thermal efficiency of the drying process, a shell-and-tube heat exchanger has been included as a part of the original equipment. It allowed fuel savings up to 50% on an annual basis. After modification the temperature of the contaminated drying air increased from approx. 410 [^oC] to approx. 550 [^oC] when leaving the heat exchanger and entering the ring gap of the furnace, see Fig. 1. This led to a strong permanent deformation causing a thermal damage of the conical burner. Consequently, the flame stabilisation mechanism was deteriorated and the NO_x emissions were rising above the limits of the legal constraints.

The objective of this work was the design of a completely new conical burner that overcomes the problem of thermal damage. This design includes possibilities of varying the angle of the cone and the swirl strength of the air/waste gas mixture. It allows adjusting the lifted flame position and decreasing the temperature of the burner.

The methodology of the work is based on the use of numerical simulation of the turbulent reacting flow in the furnace. For this purpose, the operating parameters of the furnace were analyzed first. The analysis included the identification of the waste gas contents and composition and its influence on the combustion in the furnace. Second, a chemical reaction scheme was developed including combustion of the waste gas components. After implementation of this reaction scheme into a commercially available Computational Fluid Dynamics (CFD) tool, the furnace has been simulated for different operating conditions. Finally, the CFD tool was used to develop and optimize the geometric parameters of the newly designed burner.

2. Analysis of the combustion parameters of the furnace

During the drying process of varnished metal parts, the drying air absorbs the volatile components of the solvents used for the dyes in the preceding varnishing operations. An analysis of these solvents showed benzene and partly naphthalene being predominant components of the solvents. Therefore, the influence of benzene and naphthalene on