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Combustor concept for industrial gas turbines with single digit NOx and CO emission values

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Abstract

Natural gas, when compared to other solid, liquid or gaseous fuels, offers a cleaner and more environmentally friendly combustion. Nevertheless, it also produces unwanted pollutant species such as nitrogen oxides (NO_x) and carbon monoxide (CO) when fired in combustors of industrial gas turbines under high temperature and pressure. These emissions of NO_x and CO are harmful for human and nature and need to be kept below the regulatory limits.

This problem has been the subject of numerous research and development activities for decades. The current state of the art provides well-developed firing systems for industrial gas turbines, which ensure NO_x and CO emission levels well below the legal limits [1 - 5]. A comprehensive overview of the characteristics currently available gas turbines on the German market is offered by the revised version of the ASUE brochure from 2015 in [6], where beyond the reference list about industrial and municipal gas turbines, NO_x reduction methods and achieved NO_x emission values are recorded.

Nevertheless, there still is the need for additional research in order to contribute to both the simplification of the still complicated design of the overall combustor concepts and the further reduction of harmful emissions.

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Keywords: gas burner, gas turbine, combustion, low NO_x and CO emissions.

1. Introduction

In this paper, the activities undertaken by Gas- und Wärme-Institut Essen e.V. (GWI) in the course of several research projects and in cooperation with industrial partners are presented, showing the development of a simplified combustor concept for industrial gas turbines. The basic design of the combustion concept is the product of previous research projects [7 - 9] for use in applications of industrial and micro gas turbines. Results achieved there confirmed

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a stable combustion and low pollutant emission at different thermal loads. Thus, a first compact combustor configuration was available for further optimization and modification. To prove the concept of the combustor economically and ecologically, an existing industrial gas turbine with an output of 25 MW_{el} was chosen as a testbed for the new combustor. The ring combustion chamber of this gas turbine consists of 12 single combustors. Combustor optimization and validation are presented in this article.

2. Combustor Concept

In previous research projects [7 - 9] a new burner concept for industrial and micro gas turbines was developed and tested experimentally. Based on the achieved results, a basic combustor design was available for carrying out further investigations to optimize and validate its combustion and emission behavior at similar operational conditions of industrial gas turbines. The base design of the new combustor consists mainly of the so-called COSTAIR burner (continuous air staging with internal recirculation), a compact combustion chamber with a perforated wall and an outside casing. Figure 1 illustrates the design of the gas turbine combustor.

The primary air is introduced through the holes of the air distributor into the combustion chamber in stages, contributing significantly to NO_x reduction. By mixing of the auxiliary air into the natural gas before entering the combustion chamber, a high momentum is generated at the gas nozzles improving both the mixing process inside the combustion chamber and the combustion stability. Both flows (main air and secondary air with fuel) cause a large recirculation zone leading to a full burnout. In combination with an optimized air distributor and cooling air holes, single digit NO_x and CO emission values are expected. For this, extensive CFD simulations were carried out at GWI. Results achieved are presented and discussed in the following.

3. CFD Optimization

The optimization and modification of the new combustor concept were carried out by numerical simulations followed by experimental investigations. The burner load was set to 225 kW at atmospheric pressure; the other operating parameters were chosen to represent typical gas turbine conditions follows:

- Gas type: natural gas
- Gas temperature: 25 °C
- Gas and air pressure: 1 bar
- Gas flow rate: 24.3 m_N^3/h
- Air temperature: 555 °C
- Total air ratio: 1.2 - 1.5

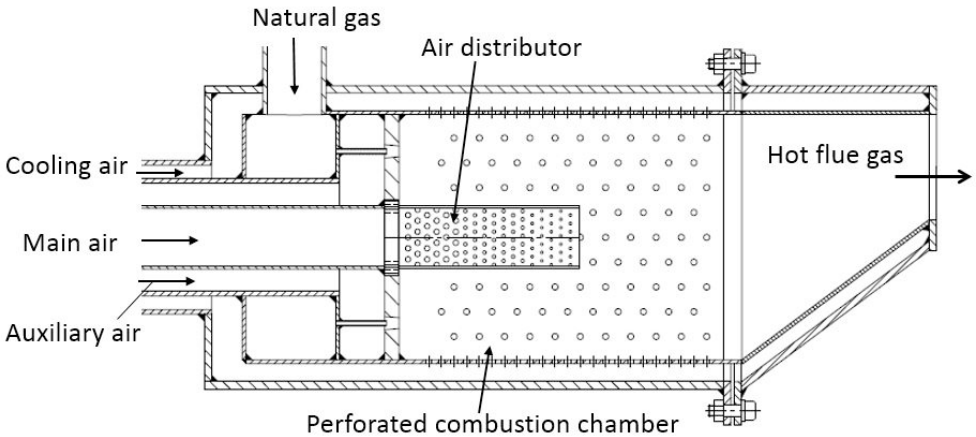

Fig. 1. Schematic design of the new gas turbine combustor.