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New Burner Technology for Low Grade Biofuels

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Abstract

In the frame of the EU project Bio-Pro Gaswärme-Institut e. V. Essen (GWI) and TPS Termiska Processer AB Nyköping collaborated in developing an improved combustion system for low calorific fuels generated by biomass gasification processes. The main objective of the project was to reduce NO_X emission by 50 % compared to the combustion of the fuel in available combustion systems; the upper limit for CO emission was set to 30 mg/m³. The innovative combustion technique of continuous staged air (COSTAIR) served as a basis for the development. In this contribution the performed activities of GWI in transferring of the COSTAIR concept to the TPS BioSwirl burner configurations will be shown and explained. Additionally, experimental results achieved at GWI on a small scale burner using different low calorific gas mixtures and at TPS on a large scale burner using two types of biomass gasification fuels will be presented and discussed.

1. Introduction

The main features of low calorific gases as those from biomass gasification processes are well known. They can be expressed as low calorific values, high water content, corrosive actions and composition changes. Due to these characteristics it is difficult to find combustion systems that are capable to utilise such gases efficiently. The ordinary combustion concepts frequently do not guarantee sufficient flame stability. The high emissions of harmful substances as CO and NO_x are another problem. Because of mentioned difficulties it is necessary and also a challenge to develop an efficient and flexible combustion system which can handle these problems. That was the main goal of the already finished EU project Bio-Pro [1], where nine European partners were involved to develop new burner technologies for low grade biofuels to supply clean energy for processes in biorefineries. Innovative burning techniques like the flameless oxidation (FLOX®) and the

® registered trade mark of WS Wärmeprozesstechnik Renningen, Germany continuous air staging (COSTAIR) served as a basis for the aimed development. The project partners Gaswärme-Institut e. V. Essen (GWI) and TPS Termiska Processer AB Nyköping dealt with the development based on the COSTAIR technology. In the following, the activities of both partners regarding the transfer of COSTAIR concept to TPS BioSwirl burner as well as the up-scaling of this burner from small scale to large scale is explained. Additionally, the results achieved by numerical investigations and experimental tests using different types of low calorific fuels are presented and discussed.

2. Development Methodology

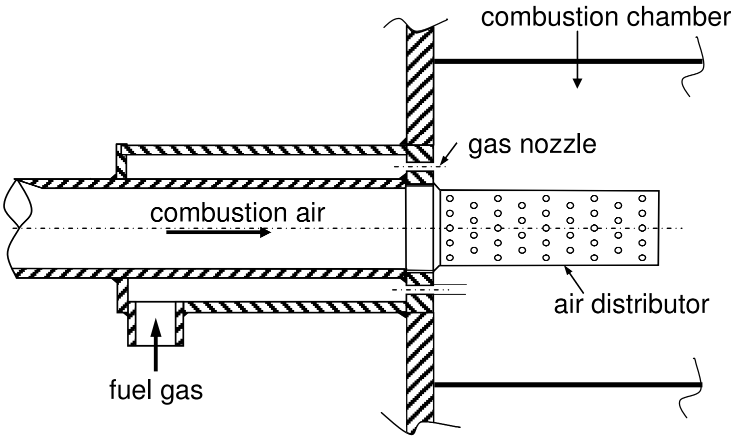
In close collaboration between GWI and TPS the following development methodology was successfully applied>

a) Numerical and experimental investigations to set up the optimal COSTAIR configurations for a burner load of 30 kW_{th}.
b) Transfer of COSTAIR concept to TPS BioSwirl at 30 kW_{th} by scale-up criteria and numerical simulations.
c) Modification and optimisation of BioSwirl burner at 30 kW_{th} by experimental investigation.
d) Scale-up of BioSwirl burner from 30 kW_{th} to 2 MW_{th} and modification by numerical simulations.
e) Validation of the up-scaled BioSwirl burner by experimental tests at 2 MW_{th}.

2. Optimal COSTAIR configuration

To find the optimal configuration of the COSTAIR burner for efficient use of low calorific fuels GWI carried out extensive numerical and experimental investigations in different research works [2 to 4]. Figure 1 shows the basis design for the optimised COSTAIR combustion concept at 30 kW_{th}.

Figure 1:
Optimised design of the COSTAIR combustion concept



3. Transfer COSTAIR to BioSwirl at 30 kW_{th}

As shown in figure 2 the TPS BioSwirl burner is a reversed variant of the COSTAIR concept. Therefore the first step of the development was to transfer the air distributor (AD) of the COSTAIR burner to a suitable shape for the BioSwirl burner and to arrange the air openings on it in a corresponding way. For this work scale-up criteria and numerical simulation were used. Figure 3a shows different shapes of the new TPS BioSwirl burner construction based on the optimised COSTAIR burner variant for 30 kW_{th}. Best simulation results were achieved by the conical air distributor shape.

In closed collaboration with partner TPS the new design of the BioSwirl burner with the conical air distributor was set up and the gas and air supply systems were changed. GWI did an extensive program of numerical simulations to find the optimal construction for the conical air distributor. As an example from the huge numerical results Figure 3b shows the typical temperature and NO field distributions for the conical air distributor at the operating conditions: burner load = 28,9 kW, air ratio λ =1.2, T_{gas} = 540 °C, T_{air} = 20 °C. The gas mixture used consists of the following components in vol.-%: CO = 21, CO_2 = 10, H_2 = 14, N_2 = 55.

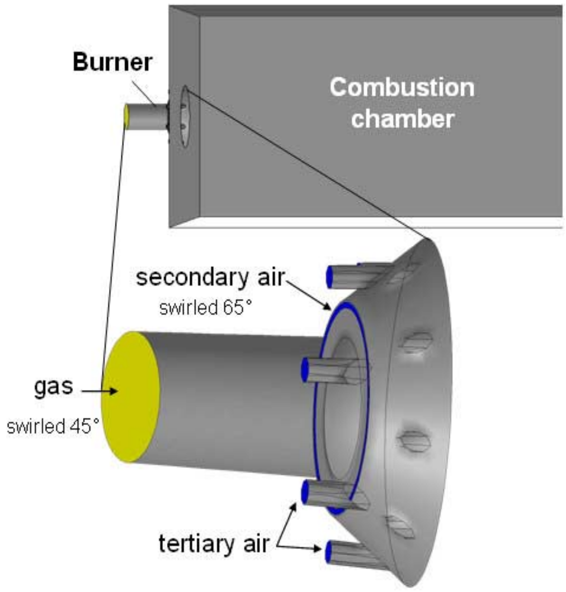


Figure 2: Original TPS Bioswirl Burner

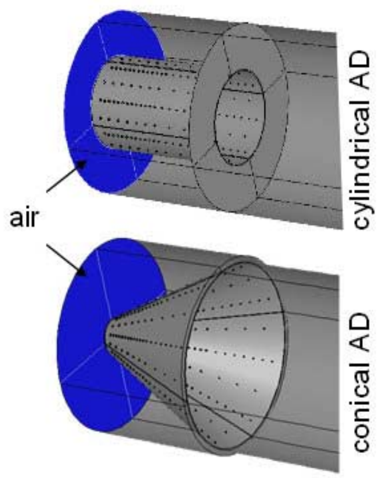


Figure 3a: New TPS BioSwirl burner

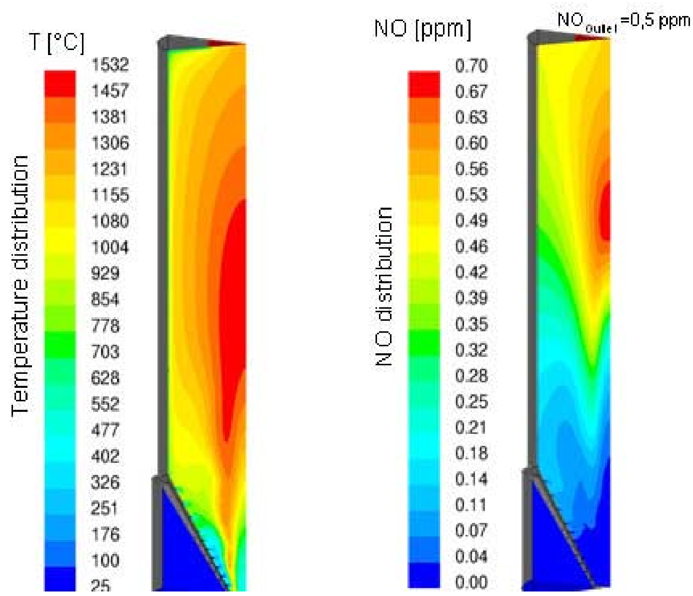


Figure **3b:** Numerical results for the conical AD

4. Modification and optimisation of BioSwirl burner at 30 kW

GWI built the new BioSwirl burner for 30 kW_{th} and tested it experimentally. The Gas mixture used contains the same components as for the numerical simulations mentioned above. NH_3 was added to the gas mixture to simulate real compositions as from biomass gasification process. N_2 was also mixed to the combustion air to find the potential of NO_x and CO emission reduction by admixing of recirculated flue gas to the combustion air. Figure 4 schematically shows the new BioSwirl burner design for 30 kW_{th} and the position of N_2 admixing to the combustion air.

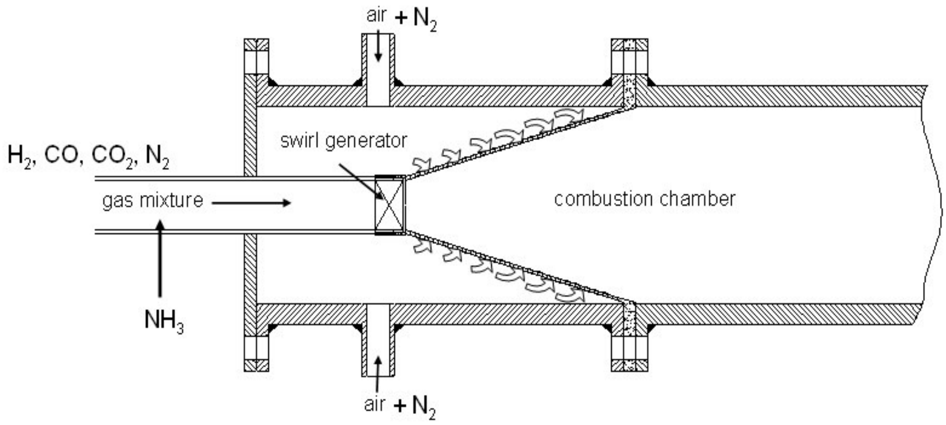


Figure 4: New design of BioSwirl burner for 30 kW_{th} with conical air distributor

Figure 5 shows the measured NO_x emission values over a wide range of air ratio for the gas mixture without and with ammonia and N_2 admixing, respectively.

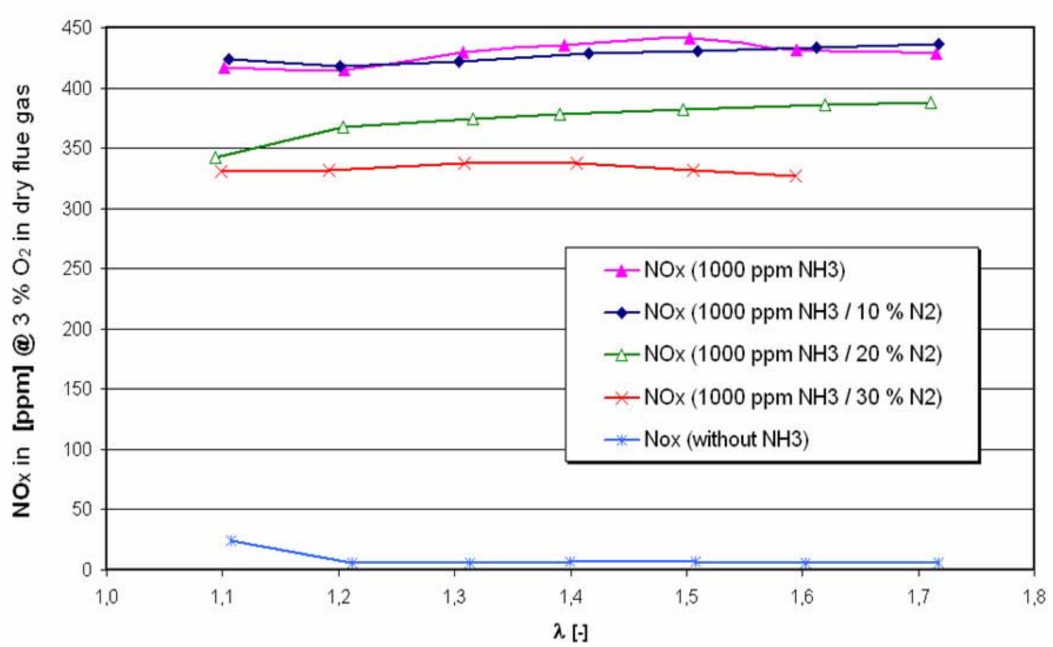


Figure 5: Measured NO_x emission values for BioSwirl burner at 30 kW_{th}

Generally, the following conclusions could be derived from these experiments:
For mixtures without ammonia CO and NO_x emission values lower than 10 ppm can be achieved. The presence of ammonia in the gas mixture leads to a strong increase of NO_x emission values. The admixing of low amount of flue gas to the combustion air does not lead to essential reduction of NO_x. However, higher amounts seem to more efficient. So for example an admixing of 30 vol.- % flue gas amount led to about 25 % NO_x reduction, as seen in figure 5. Regarding CO emission, measurements confirmed that there is no influence on CO level by the presence of ammonia as well as by the flue gas admixing. Furthermore a stable combustion was reached at any time.

5. Scale-up of BioSwirl burner from 30 kW_{th} to 2 MW_{th}

GWI scaled up the BioSwirl burner from 30 kW_{th} to 2 MW_{th} using the scale up criteria for constant velocity and constant ratios of air to gas momentum. From the results of both scale-up criteria the gas diameter for 2 MW_{th} has been determined. According to experiences owned by GWI the length of the conical air distributor for 2 MW_{th} has been set up. To realise similar mixing conditions of gas and air the arrangement of air holes on the air distributor was chosen similar to the conical air distributor of the optimised original COSTAIR burner. The air holes geometry guarantees a similar opening ratio, i.e. similar pressure drop as at GWI experiments. This way ensures approximately the same inlet momentum ratios of air to gas as at the small scale burner for 30 kW_{th}. Through numerical simulations additional modifications on the arrangement of air holes has been made. Figure 6 shows the typical distribution of temperature profile of the BioSwirl burner for 2 MW_{th}.

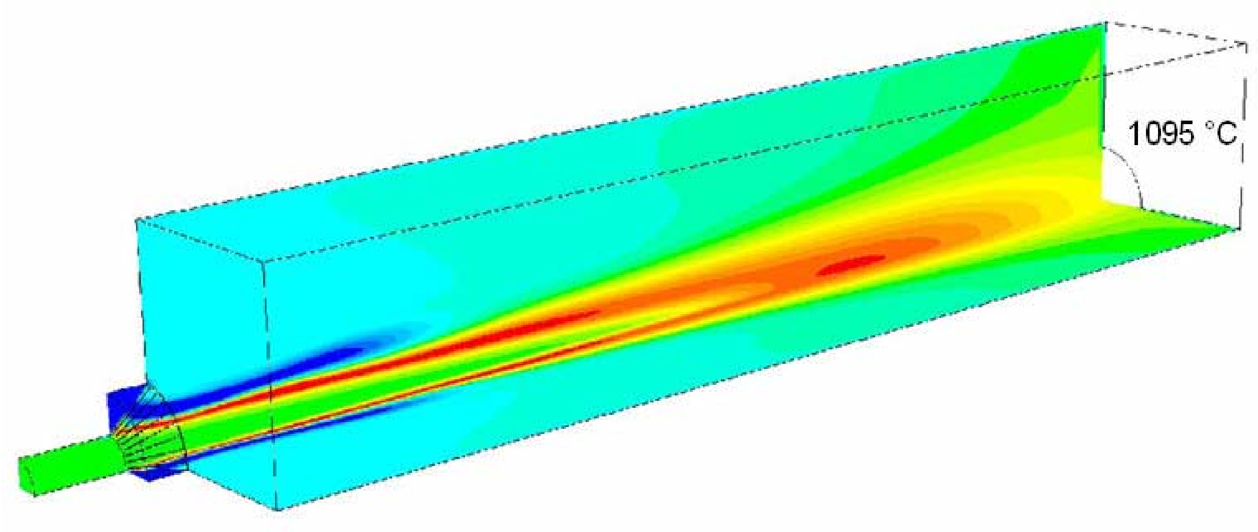


Figure 6: Calculated temperature distribution of TPS BioSwirl burner at 2 MW_{th}

6. Experimental Results of TPS BioSwirl burner at 2 MW_{th}

TPS manufactured this new BioSwirl burner and integrated it to the existing furnace as seen in figure 7a. Figure 7b shows the air distributor for this burner.

Figure 7a: Connected BioSwirl burner for 2 MW_{th} at TPS furnace

Figure 7b:

Air distributor for 2 MW_{th}

TPS carried out several test campaigns to validate the combustion performance and pollutant behaviour of the burner. The fuels used were wood pellets and rapeseed cake. NO_x values achieved without admixing of recirculated flue gas to the combustion air were in the range 200 - 250 mg/Nm^3 for wood pellet and 800 - 1400 mg/Nm^3 for rapeseed cake at 6% O_2. With admixing of external recirculated flue gas to the combustion air, NO_x emission values were reduced essential, as shown in Figure 8.

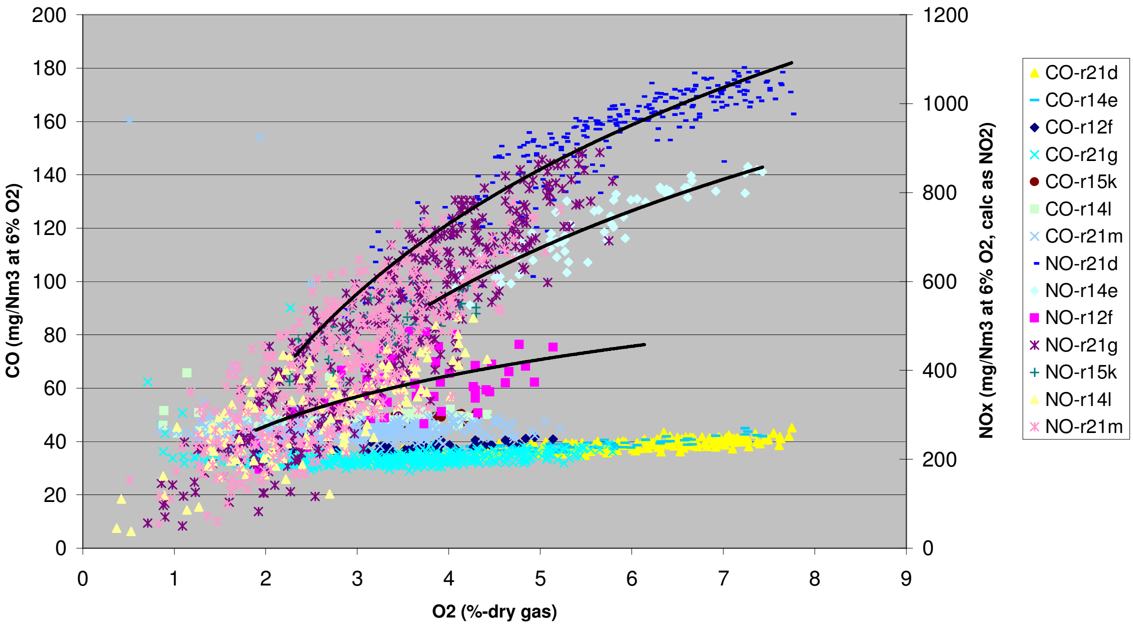


Figure 8: NO_x and CO emission values of BioSwil burner for rapeseed cake at 2 MW_{th}

With flue gas recirculation NO_x values fell to the range 150 - 200 mg/Nm^3 for wood pellet and to the range 400 – 800 mg/Nm^3 for rapeseed cake. The emission values of CO were more or less unaffected by the flue gas recirculation. They are in the range of 50 - 70 mg/Nm^3 when wood pellet was used and approximately 40 mg/Nm^3 when rapeseed cake was used. Consequently, the development work during the project has led to a reduction of NO_x emissions by about 25% for wood pellet and about 50% for rapeseed cake. It is believed that a part of the observed reduction in NO_x emissions was due to improved flame stability during the tests with flue gas recirculation, compared to previous tests without flue gas recirculation.

7. Conclusions

The results achieved proved the high potential of the developed burner technology for efficient combustion of low grade biofuels. The applied adconcept of continuous air staging leads to a stable combustion process and an essential reduction of NO_x and CO emissions.

Acknowledgment

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