EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CM 1404
STSM title: Development of Numerical Simulation Tools for High efficiency, Fuel Flexible and Low Pollutant Gas Recirculation Burners
STSM start and end date: 24/07/2017 to 31/08/2017
Grantee name: Pio Bozza

PURPOSE OF THE STSM

The purpose of the Short Term Scientific Missions (STSM) was focused to acquire skills and tools in order to develop small-scale burners (1 - 10 kW) with high performance in terms of energy saving, fuel flexibility and pollutant reduction. For this purpose, it has been firstly developed, at Consiglio Nazionale delle Ricerche – Istituto di Ricerche sulla Combustione (CNR - IRC) in Italy, a small scale burner operating in MILD combustion with high level of recirculation. This was obtained by means of a cyclonic flow-field configuration. In particular, the burner was designed and realized to be integrated in micro scale CHP cogeneration systems for energy production (<50 kWe).

The final target of the STSM was the acquisition of competences to fill the gap between lab-scale and industrial burners. For this aim the STSM was carried out at WS – Wärmeprozesstechnik (Renningen, Germany), a company specialized on highly efficient, low emission burner systems for industrial furnaces. Activities include research, engineering and design, production, sales and service worldwide.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

At the beginning, during the STSM, the activities concerned experimental tests with industrial and pilot burner prototypes operated with burned gas recirculation. Thus, the performance of the combustors have been evaluated. For a performance evaluation, a test have been carried out on a burner WS Rekumat at P = 30kW installed on a ceramic radiant tube furnace (Fig. 1).

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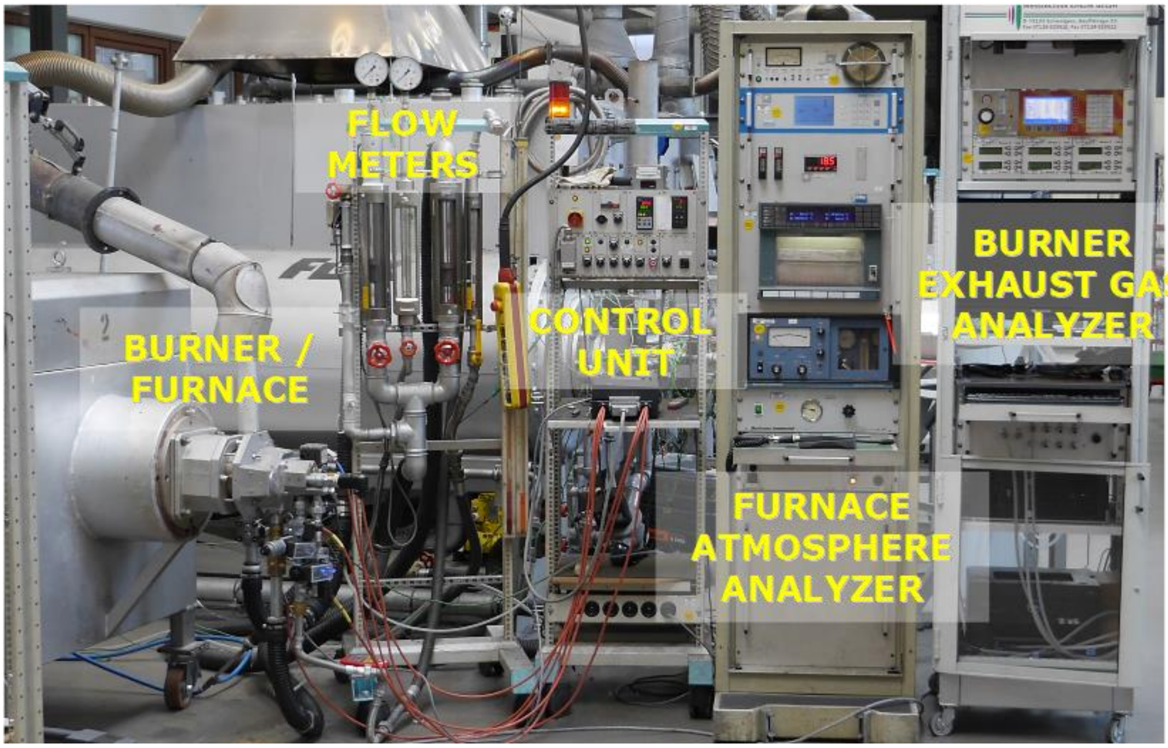

Fig. 1 Experimental apparatus of the Rekumat Flox burner and the diagnostic instruments

Then, an optimization of the geometrical configuration have been performed by means of CFD computations, tested with the OpenFOAM code. Several setups and working conditions of a gas recirculation burner have been evaluated in order to define valuables models compared to both lab-scale and industrial scale devices. In fact, fast simulations by means of a CFD tool with low computational cost represents an important task to design/verify new combustion concepts. In particular, three mesh configurations and five values of the thermal Power on an industrial device (WS MegaFlox) have been taken into account in order to verify the possibility to adopt the model on a fast request. This is a fundamental issue in the industrial field due to the necessity of matching the regulation time of the device and the calculation time for predict the working conditions.

Fig. 2 Example of Numerical simulation of the Temperature profile inside the section of the MegaFlox Plant

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The following results have been obtained performing the experimental tests on the WS Rekumat operated with natural gas installed in a ceramic radiant tube in a furnace. The test have been carried out in order to evaluate CO and H2 emission of the burner running at maximum Power inside the radiant tube and inside the furnace. Furthermore, it is also a relevant test to evaluate the safety performance of the burner coupled with the radiant tube. For this reasons, two experimental test have been operated under the following conditions:

Test 1: P = 29 kW, T = 1060°C, O2ex = 3%

In the first test, the Oxygen level at the exhaust was controlled to be fixed at approximately O2ex = 3% as a reference emission value for the furnace application. In particular the Oxygen content in the exhaust gas was O2ex = 3.3%. The working Temperature was fixed at 1060°C as the maximum working Temperature reference value in which the Rekumat burner can be operated. Results shows that emission inside the radiant tube were CO = 1 ppm and H2 = 0 ppm, while in the furnace the emission were CO = 0 ppm and H2 = 0 ppm. This means that the burner worked in the optimal conditions and no CO and H2 have been registered in the furnace.

Test 2: P = 29 kW, T = 1060°C, O2ex = 0.4%

In the second test, the Oxygen level at the exhaust was controlled to be fixed at approximately O2ex = 0%, thus working near the stoichiometric mixture inlet conditions. In particular the Oxygen content in the exhaust gas was O2ex = 0.4%. The working Temperature was fixed at 1060°C as the maximum working Temperature reference value in which the Rekumat burner can be operated. Results showed that when the emission inside the radiant tube were CO = 81 ppm and H2 = 317 ppm, the emissions in the furnace were, in the same way as the previous case, CO = 0 ppm and H2 = 0 ppm. This means that the burner, even though it worked in the stoichiometric conditions, CO and H2 are very low and no CO and H2 have been registered in the furnace, proving the safety working conditions of the device.

Differently from the experimental tests, the numerical work has been focused on the development of numerical tools for the fast simulation of the performance of a MW burner (WS MegaFlox). In this frame, the two step reaction mechanism used were taken by Westbrook and Dryer (W&D) [1]. The kinetic constant was derived from Wunning [2] and the results compared with Djerv [3]. The fluid-dynamic model taken into account was the k-epsilon model because it is the best to couple with the given geometry. In the following are shown some results about the axial velocities of the main flows inside the furnace (Figure 3), for 5 different values of the thermal power and 3 values of the cells number of the mesh by varying the distance from the exit of the burner. In this case, Figure 3 shows that the values are quite independent from the number of cells. Further comparisons with the experimental tests are necessary to confirm the accuracy of the given results in terms of well prediction, but interesting results are given in order to obtain a fast simulation.

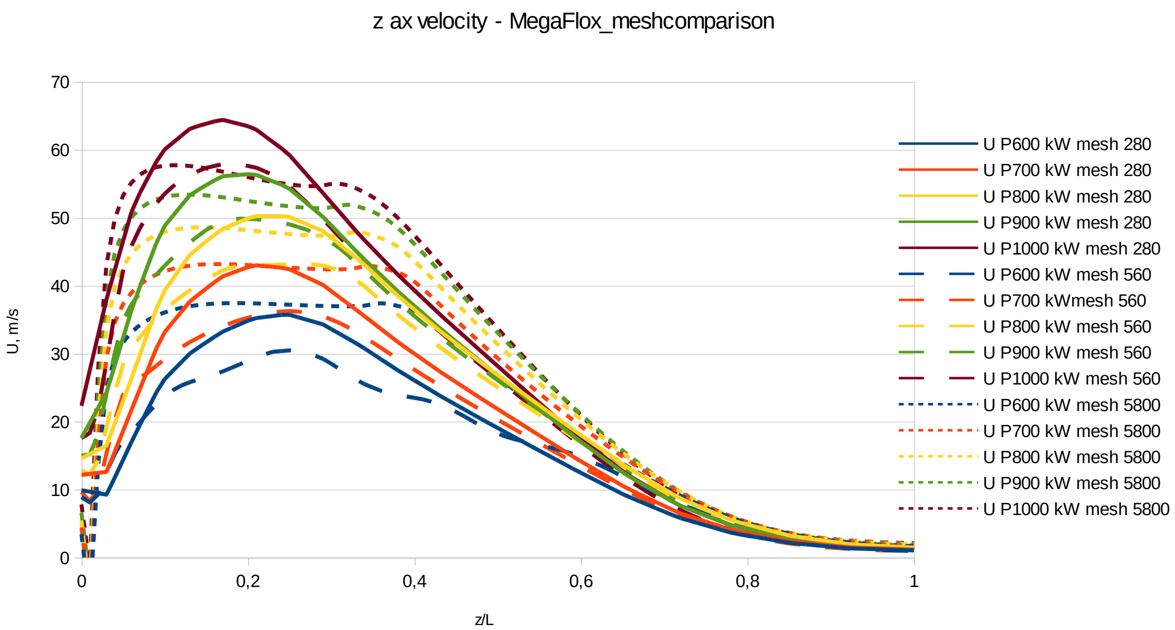

Fig. 3 Axial velocity profile inside the MegaFlox by varying the mesh cells

The results in term of Temperatures inside the furnace are reported in Figure 4. It is possible to see that the Temperature profiles are not well predictable by reducing the number of cells of the mesh. In fact a huge difference has been observed by reducing the number of cells with a reduction factor of 10. Also in this case, further comparisons with the experimental tests are necessary to confirm the accuracy of the given results in terms of well prediction, but interesting results are given in order to obtain a fast simulation.

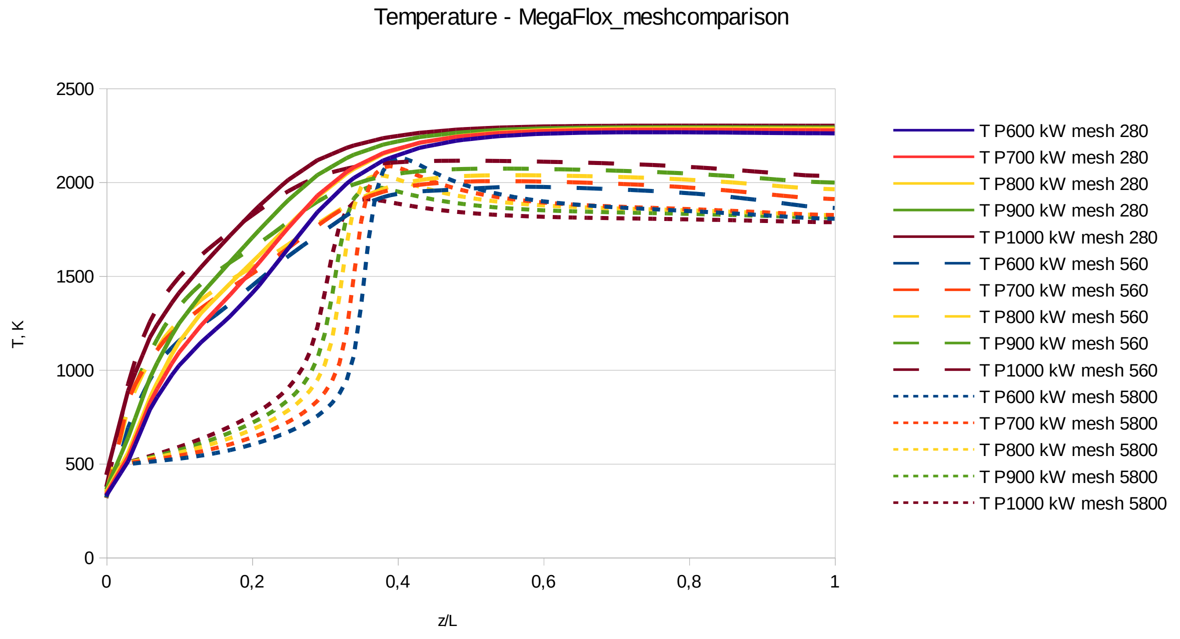

Fig. 4 Temperature profile inside the MegaFlox by varying the mesh cells

[1] Westbrook, C.K., Dryer, F.L.: Simplified Reaction Mechanism for the Oxidation of Hydrocarbons Fuels in Flames. In: Combustion Science and Tehnologies (1981)

[2] Wunning, J. G., Flammelose Oxidationvon Brennstoff, RWTH Aachen University (1996)

[3] Djerv, M., A Global Approach for the Fast Simulation of Flameless Oxidation Burners Fed with Variable Fuel Mixtures, University of Stuttgart (2014)

FUTURE COLLABORATIONS

WS - Wärmeprozesstechnik is involved, as industrial partner, in the SMARTCATs COST Action CM1404 in partnership with CNR – IRC. In previous meetings and conferences organized within COST action framework, there were plenty of opportunities to discuss problems relative to the optimization strategies to improve burner performances. The collaboration with WS – Wärmeprozesstechnik durint the STSM has been a fruitful opportunity to increase the knowledge on geometrical configurations, designing and sizing of industrial burners.

In addition, the collaboration with WS - Wärmeprozesstechnik represented a good opportunity to consolidate the connection between CNR-IRC/DICMaPI and the WS - Wärmeprozesstechnik and to promote joint activities in the SMARTCATs COST Action with the submission of proposals within the European H2020 CALLS in the next future.