Data analysis and development of a reduced order model of a industrial MILD combustion furnace fed with Benzene-doped Coke Oven Gas mixtures

Data-Driven Engineering 2021/2022

April 2022

Description of the dataset

The dataset assigned for this project contains experimental measurements of a quasi-industrial furnace situated in the combustion laboratory at the ATM department at ULB [4, 3]. This experimental campaign investigated the effect of Benzene addition in a typical coke oven gas (COG) gaseous mixtures, which can be used as a fuel since it contains H_2 and CH_4, while the rest of the mixtures is composed by CO, CO_2 and N_2 [2].
The dataset can be loaded from the .csv file *Data_Benzene.csv* and it consists of 36×74 matrix. Each row of the matrix correspond to a certain experimental condition, namely a certain benzene % at a given equivalence ratio ϕ. The first column represents the benzene %, the second column the equivalence ratio ϕ, while the other 72 columns contains the value of the temperature sampled in a given location. In particular, the temperature is sampled on a 8×9 experimental grid of physical locations inside the combustion chamber, as represented in figure 1. In particular, the experimental measurements are sampled along the radial coordinate X at 0, 10, 15, 20, 30, 40, 60 and 100 mm, while on the axial Y coordinate at 70, 80, 100, 150, 200, 250, 300, 400, and 500 mm. To be visualized, each observation in the dataset has to be reshaped in a matrix coherent with the grid dimensions.

Task 1: Data visualization and interpretation

Get some first insights into the data by representing them in a readable form: use graphs, histograms, scatter plot to help you highlighting correlation and understanding the relationships between the variables. In particular, we are interested in the effect of the benzene percentage and the equivalence ratio on the flame structure.

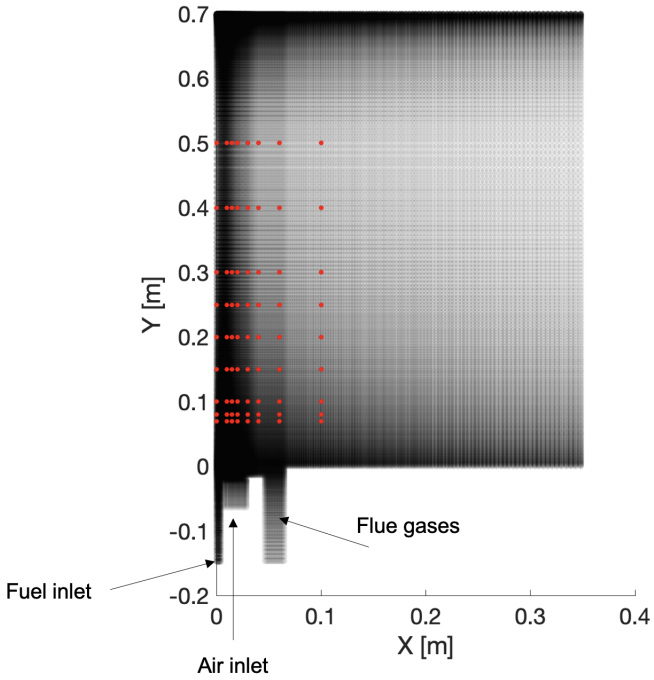

Figure 1: Schematic view of the ULB furnace. The red points represent the experimental sampling locations

Task 2: Clustering and Dimensionality Reduction

Try to get more insights in the data by using unsupervised learning techniques. More specifically, try to represent the data in a lower dimensional manifold, so that they can be better visualized. Try to use dimensionality reduction techniques and clustering to highlight group of similar points or operating regimens, if there are any.

Task 3: Reduced Order Model development

Now you have to build a reduced order model (Digital Twin [1]) of the furnace. In particular, we are interested in predicting the temperature at **every** location in the chamber given the equivalence ratio and the percentage of benzene. You may use a combination of dimensionality reduction and regression techniques. You can quantitatively compare more methods, in term of performances in reproducing the experimental data.

Assignement report

You have to condense all the tasks in a written report, by presenting and commenting the results in a qualitative and quantitative way, helping you with graphs and tables. At the end, you need to produce one .pdf file. For every issue, you can write to matteo.savarese@ulb.be on TEAMS or via e-mail.

References

[1] Gianmarco Aversano, Marco Ferrarotti, and Alessandro Parente. Digital twin of a combustion furnace operating in flameless conditions: reduced-order model development from cfd simulations. *Proceedings of the Combustion Institute*, 38(4):5373–5381, 2021.

[2] Marianna Cafiero, Véronique Dias, Alessandro Stagni, Phuc Danh Nguyen, Milena Nowakowska, Axel Coussement, Hervé Jeanmart, and Alessandro Parente. The effect of benzene on the structure of low-pressure premixed h2/ch4/co-air flames and related no formation at different equivalence ratios. *Combustion and Flame*, 232:111510, 2021.

[3] M. Ferrarotti, M. Fürst, E. Cresci, W. de Paepe, and A. Parente. Key modeling aspects in the simulation of a quasi-industrial 20 kw moderate or intense low-oxygen dilution combustion chamber. *Energy & Fuels*, 32(10):10228–10241, 2018.

[4] M. Ferrarotti, D. Lupant, and A. Parente. Analysis of a 20 kw flameless furnace fired with natural gas. *Energy Procedia*, 120:104–111, 2017. INFUB - 11th European Conference on Industrial Furnaces and Boilers, INFUB-11.