CFD analysis for Digital twin of a cyclonic burner operating in MILD conditions with hydrogen/ammonia mixtures.

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KAUST Research Conference:
AI for Energy
6-8 March 2023

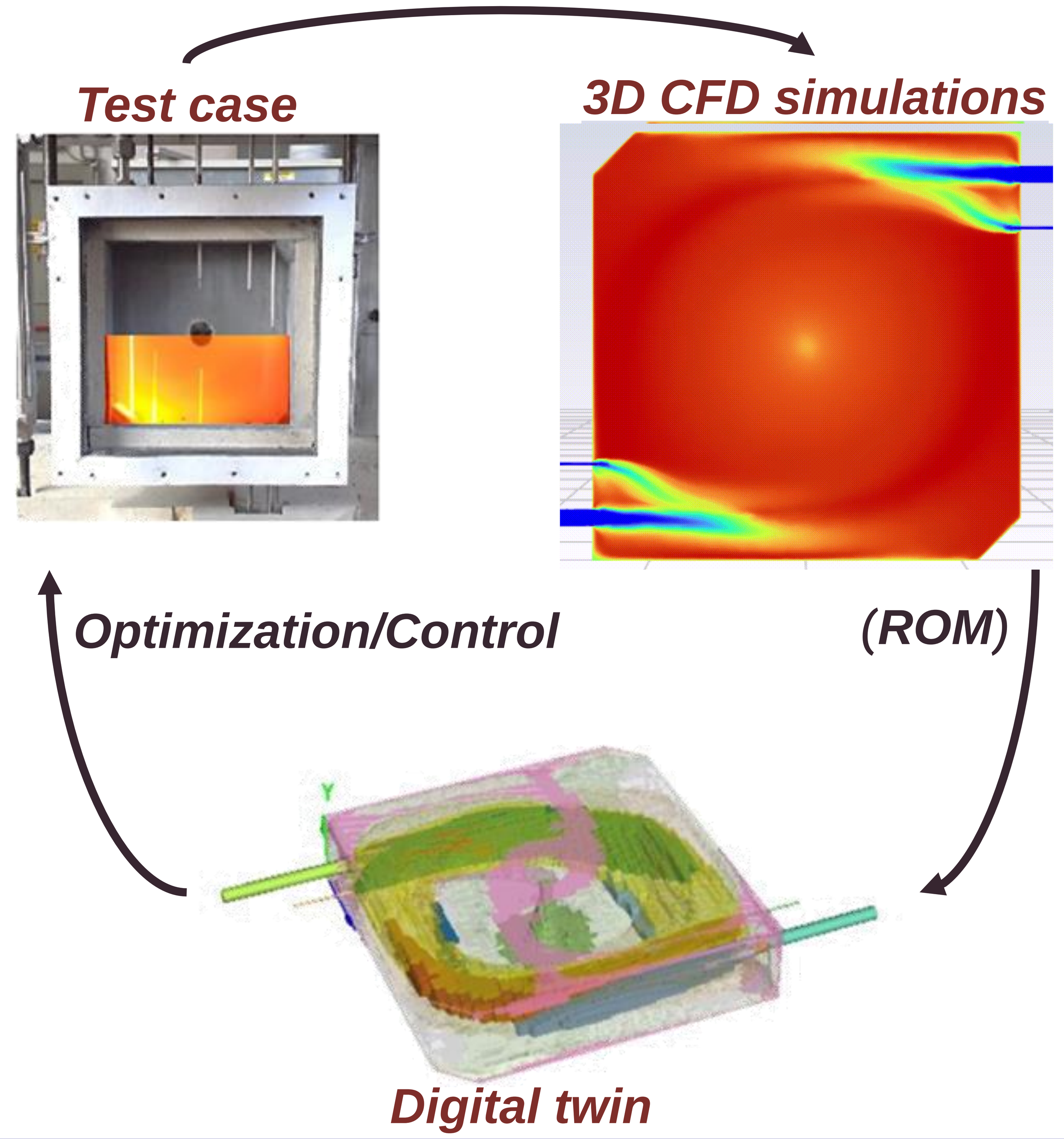
Introduction

The present work investigates the thermo-chemical conversion of Hydrogen blends with ammonia in an innovative combustion system, such as the ***Laboratory Unit CYclonic*** *(****LUCY****) burner. This reactor can operate in* ***Moderate or Intense Low-oxygen Dilution*** *(****MILD****) combustion conditions due to a strong internal recirculation of burned gases.*

Such combustion process needs adequate numerical models for the characterization of its fluid-dynamical and thermo-chemical behaviors.

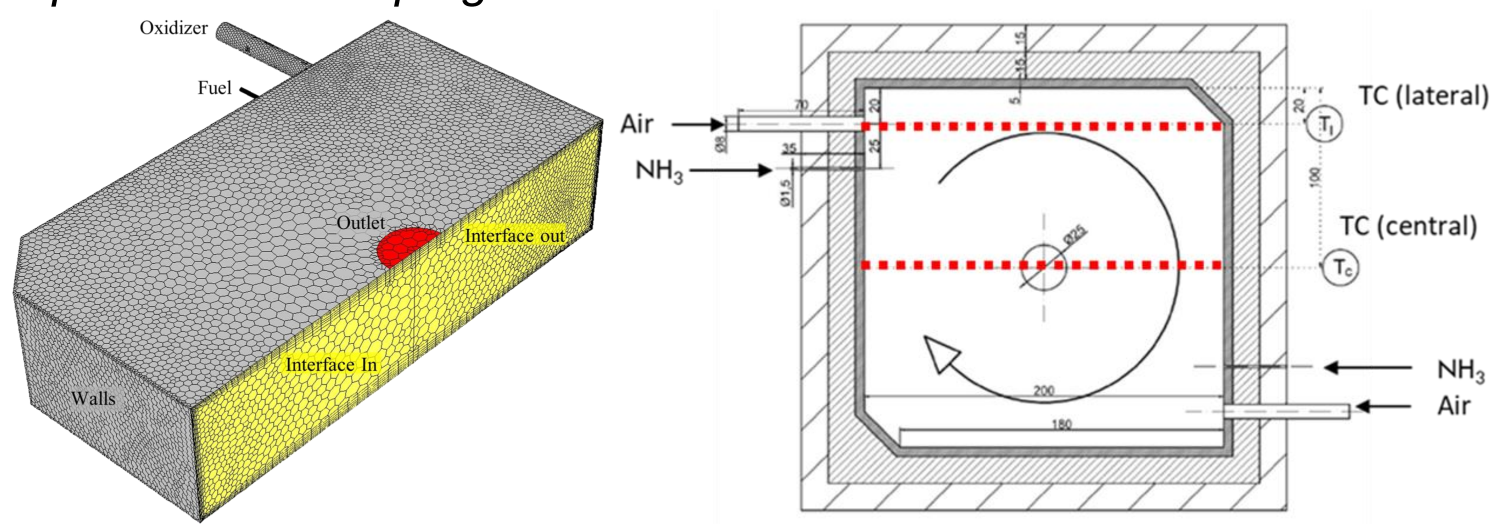
Computational Fluid Dynamics *(****CFD****) methods are applied to predict Ammonia/Hydrogen combustion in MILD regime to create a reliable models that can be used for generating a* ***Digital Twin*** *via* ***Reduced Order Methods*** *(****ROM****).*

Model development and validation



Methodology

A ***polyhedral*** *mesh with* ***periodic condition*** *with 300k cells was thus generated, validated on data collected from numerous experimental campaigns.*



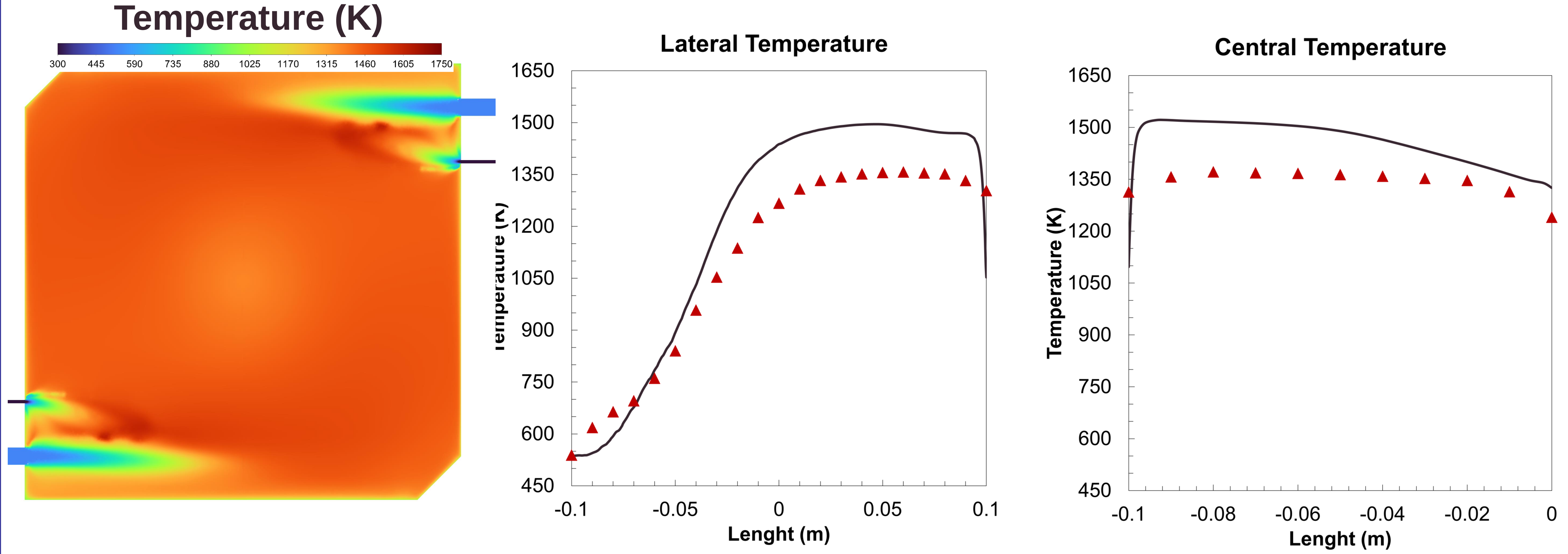
Numerical simulations were performed using ***Fluent*** *software from the* ***ANSYS 2022 R2*** *package, specifically the following table shows the boundary conditions entered for the case under consideration.*

BOUNDARY CONDITIONS	
Thermal Power	7 kW
Equivalence Ratio	1.0
Oxid	Air
Oxid Temperature	515 K
Oxid Velocity	31.33 m/s
Fuel	50% H_2 - 50% NH_3
Fuel Temperature	298 K
Fuel Velocity	173.35 m/s
Bulk Temperature	500 K
Heat Transfer Coefficient	50 W/(m^2 K)

As a result of a thorough sensitivity analysis, the following models were chosen:

- ***Reynolds Stress Model*** *(****RSM****) for turbulence with Enhanced Wall Treatment setting for near wall Treatment;*
- ***Flamelet Generated Manifold*** *(****FGM****) model to describe the Turbolence-Chemistry;*
- ***Discrete Ordinate*** *for modeling the internal radiation the reactor and the spectral properties of the gas were evaluated with the* ***Weighted-Sum of Gray Gases*** *(****WSGG****) model.*

Results



OUTLET SPECIES				
	Molar Fraction NO_x	*Molar Fraction H_2*	*Molar Fraction O_2*	*Molar Fraction NH_3*
Experimental value	*0.000621*	*0.002068*	*0.008174*	*0.000192*
Simulation	*0.004482*	*0.002359*	*0.033569*	*0*

Summary

- *Simulations obtain temperatures comparable to those recorded by thermocouples with a maximum deviation of 100 Kelvin degrees in the recirculation zone.*
- *Remarkable performance in terms of Stabilization of the oxidation process and Low Pollutants has been verified in a wide range of operating conditions.*
- *Preheating the oxidizer inlet flow allows to reach very low NO_x emissions for stoichiometric and rich mixtures, while for lean mixtures lower emissions have been obtained without preheating.*
- *For higher Thermal Power, the minimum NO_x shifts toward higher equivalence ratios, according to the lower maximum working temperatures.*

Open Issues

- *LES simulations based on the optimized model.*
- *Model and grid validation for different ammonia-hydrogen mixtures and feeding conditions.*
- *Creation of a digital twin model based on the simulations performed.*