EMPIRICAL AND NUMERICAL INVESTIGATION OF TURBULENT FLOWS IN A NOVEL DESIGN BURNER FOR AMMONIA/HYDROGEN COMBUSTION

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1. INTRODUCTION

- Ammonia is a carbon-free fuel that is cheaper for long term storage and transportation than most other hydrogen carrier alternatives.
- High NOx and flame instability remain challenges in applications of this fuel, and should be considered in the design for these fuels.
- Swirl burners are commonly used in gas turbines, but these are relatively new for ammonia-hydrogen combustion, with limited studies.
- Therefore, the present work explores the performance of NIK15, a novel NH_3/H_2 burner at rich conditions to guide the future development of gas turbine combustors that meet stringent requirements of the EU Industrial Emissions Directive.

2. METHODOLOGY

- Star-CCM+ v19.3 was employed for CFD modelling of the burner.
- A 3D RANS realizable k-epsilon model was selected for the numerical simulation.
- For experimental validation, one dimensional Laser Doppler aneomometry (LDA) was employed with an even 300L/min air flowrate across all burner inlets.

Table 1 - Boundary conditions for CFD

Parameter	Value
Swirler walls	Adiabatic
Burner section	Symmetry (120°)
Swirler walls	Adiabatic
Inlet velocity	1.30 m/s
Inlet temperature	300K
Method	Segregated flow, isothermal
Walls	No slip
Swirl	0.8
Blend	70-30 (vol%) ammonia-hydrogen

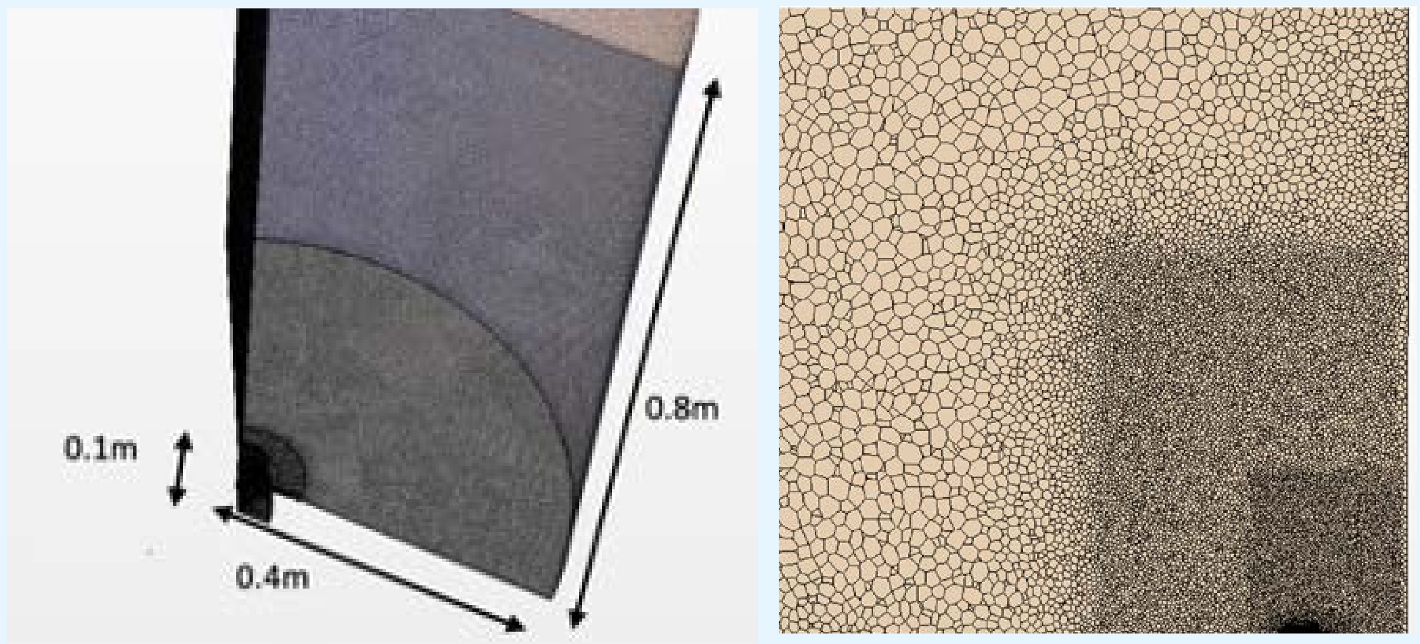

Figure 1 - Burner dimensions and mesh

3. RESULTS AND DISCUSSION

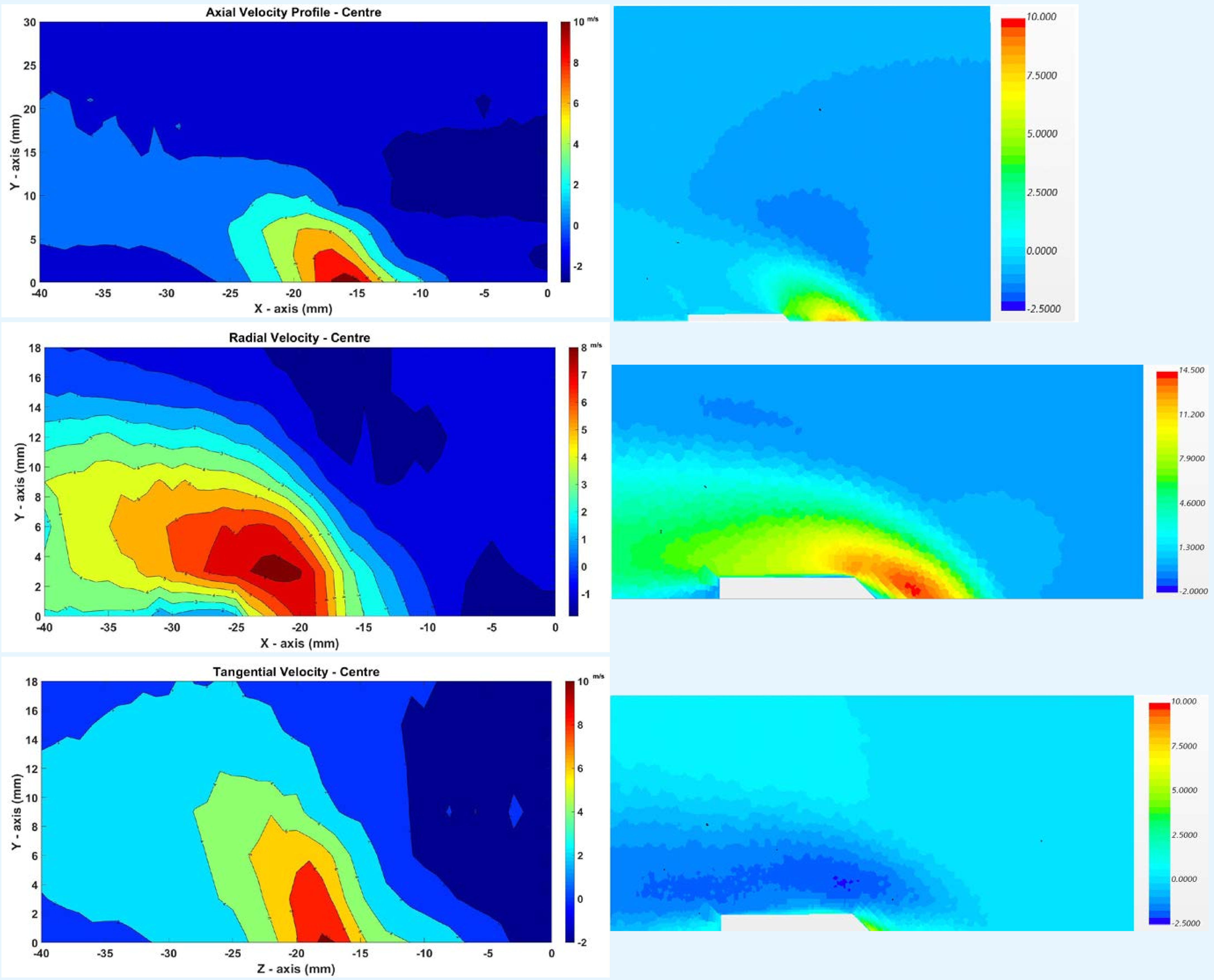

Figure 2 - Axial plane velocity vectors: axial (top), radial (centre), tangential (bottom)

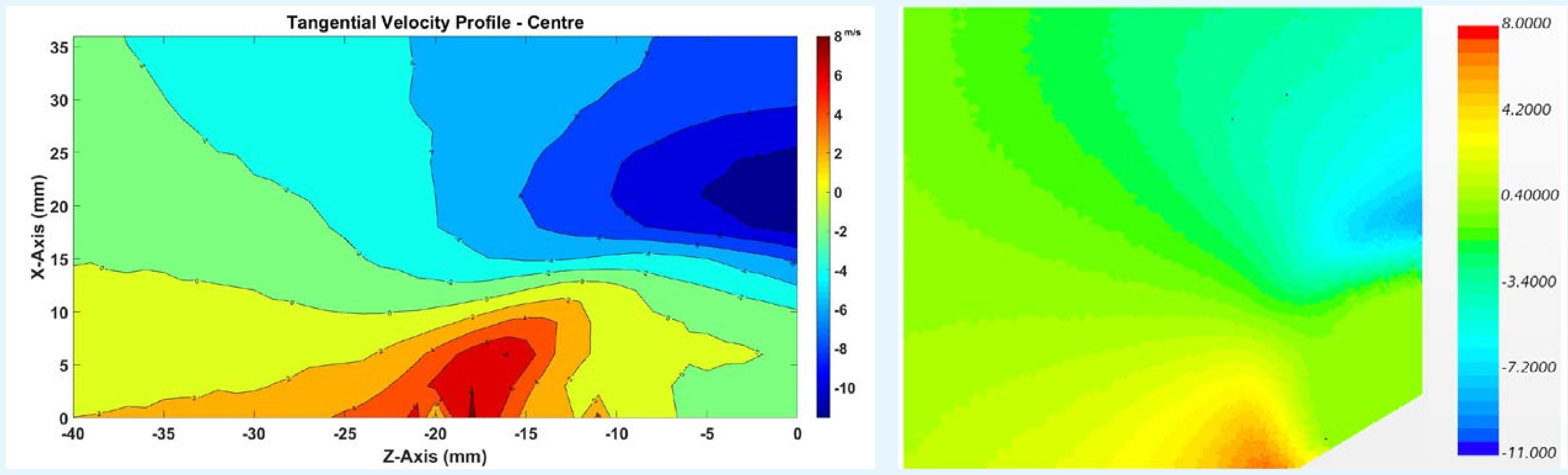

Figure 3 - Cross-section plane velocity vector: tangential

- All experimental data was taken from 3mm above the burner edge and compared with CFD results.
- Realizable K-Epsilon model was found to give closer prediction of epxerimental data over the standard k-epsilon and k-omega SST models.
- Experimental and numerical predictions show general agreement in flame shape, values and trends, however numerical simulations placed the flame at a lower height relative to the burner.
- Both experimental and numerical results show a promising flow profile with a flat, anchored flame and central recirculation zone, suggesting good mixing and increased residence times.
- The best correlation was seen for the axial and radial velocity vectors with most discrepancy in the tangential velocity vector.
- The cross-section plane suggests a cyclic repeating pattern with reasonable agreement given that the view was limited to a 1/3 section of the burner.

6. CONCLUSIONS

- The hydrodynamic performance of a novel design of the NIK15 burner, optimized for combustion of rich ammonia-hydrogen flames was quantified.
- Experimental and numerical data was in general agreement, especially in the case of the axial and radial velocity vectors.
- This gives confidence to continue the progression with the existing mesh and physics models to more advanced simulations, such as the addition of chemistry solvers.

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