Ammonia and hydrogen use for industrial heat and power generation Part I (Project 40),

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IDRIC MIP 5: Energy Vectors for Industrial Decarbonisation

Background

Our approach to industrial decarbonisation is through transitioning of Gas Turbines (GTs), Internal Combustion engines (ICEs), boilers and furnaces to utilise zero carbon fuels (ZCFs) such as biogas, hydrogen and ammonia. The industrial challenges in transitioning to ZCF based power generation arise due to the different thermo-physical properties, fundamental flame properties, combustion dynamics and emissions performance of ZCFs and their blends, compared to fossil fuels **[1]**.

Some identified industrial challenges and risks with high hydrogen contents in the fuel are:

- Operational Safety e.g. DSEAR and ATEX
- Autoignition and Flashback **[2]**
- Increased NO_x emissions **[2]**
- Combustion oscillations and reduced life-time of components **[2]**.
- Reduced heat quality

Unlike hydrogen, ammonia has lower reactivity and higher ignition energy demand, giving narrow flammability limits. Compared to fossil fuels, ammonia doped flames are prone to produce higher NO_x emissions when the significant amount of fuel-bound nitrogen is oxidised **[3]**.

Objectives/Work Packages

Establish an embedded strategic partnership with the South Wales Industrial Cluster (SWIC), as illustrated in **Fig.1**.

WP1- Development of zero carbon fuel experimental facilities and models.

WP2- Develop and deliver an experimental programme to quantify extinction characteristics for zero carbon fuels at elevated temperature and pressures using a pressurised counter flow burner, as shown in **Fig.2.**

WP3- Appraise existing industrial burner designs for fuel switching.

WP4- Quantify the operability and performance of an optically accessible generic turbulent swirling gas turbine combustor operating with zero carbon fuels at elevated pressure and temperature, see **Fig.3**.

WP5- Working closely with SWIC industrial partners and OEMs, provide pathways to zero carbon fuel based demonstrators like the world-first' integrated green ammonia demonstration plant which Cardiff University developed with Siemens and the University of Oxford, see **Fig.4**.

WP6- Upskill SWIC members on zero carbon fuel safety and utilisation through bespoke training.

WP7- Inform the 'Life-cycle analysis' of zero carbon fuels as part of Project 12 "Development of an open-source toolkit to design and evaluate the performance of low carbon fuels infrastructure for industrial clusters".

Progress

The project is establishing itself well with the SWIC though industrial partner CRPlus where we have an EPSRC Centre for Doctoral Training (CDT) student Ben White placed. CRPlus are leading the South Wales Industrial Cluster Plan. We have two further CDT student James Bain and Elena Boulet placed with RWE in Pembroke and Quantum ES in Merthyr Tydfil respectively.

WP1&2 activities have been progressing well with continued commissioning work being conducted on the pressurised counter flow burner. The first atmospheric data set for methane extinction strain rate were taken in Jan 22 with the experimental methodology being developed over subsequent test campaigns in Feb 22 (See **Fig.2)**. There has been a bit of a set back with two identical bespoke 3D printed water cooled burner nozzles developing leaks. These are critical to the rig and potential solutions are currently being investigated.

WP3 activity has involved meetings with stakeholders where potential options for burners for fuel switching were discussed.

WP4 test campaign is due to start in May 22 and will investigate different fuelling strategies for gas turbine combustor operation with high concentrations of hydrogen and hydrogen/ammonia blends at elevated conditions of pressure and temperature. The aim of the test campaign is to widen the operating envelope with high concentrations of hydrogen >60%vol and minimise NOx.

WP5 demonstration activity is progressing well with Quantum ES and CDT student Elena Boulet. Elena plans to demonstrate the operation of a spark ignition engine on a blend of hydrogen and ammonia. The engine is currently being built and commissioning studies should commence in May/June 22.

WP6- Discussions with HyCymru with input into a pilot skills mapping exercise on hydrogen for the Welsh Government.

References

[1] S. Taamallah, K. Vogiatzaki, F.M. Alzahrani, E.M.A. Mokheimer, M.A. Habib, A.F. Ghoniem 2015, 'Fuel flexibility, stability and emissions in premixed hydrogen-rich gas turbine combustion: Technology, fundamentals, and numerical simulations', Applied Energy, vol. 154, pp. 1020-1047.

[2] ETN, 2020,'Hydrogen Gas Turbines, the path towards a zero carbon gas turbine', ETN Report, Brussels, Belgiu

[3] A Valera-Medina, H Xiao, M Owen-Jones, W.I.F. David, P.J. Bowen 2018, 'Ammonia for power',Progress in Energy and Combustion Science, vol. 69, pp. 63-102.

Fig.1 South Wales Industrial Cluster

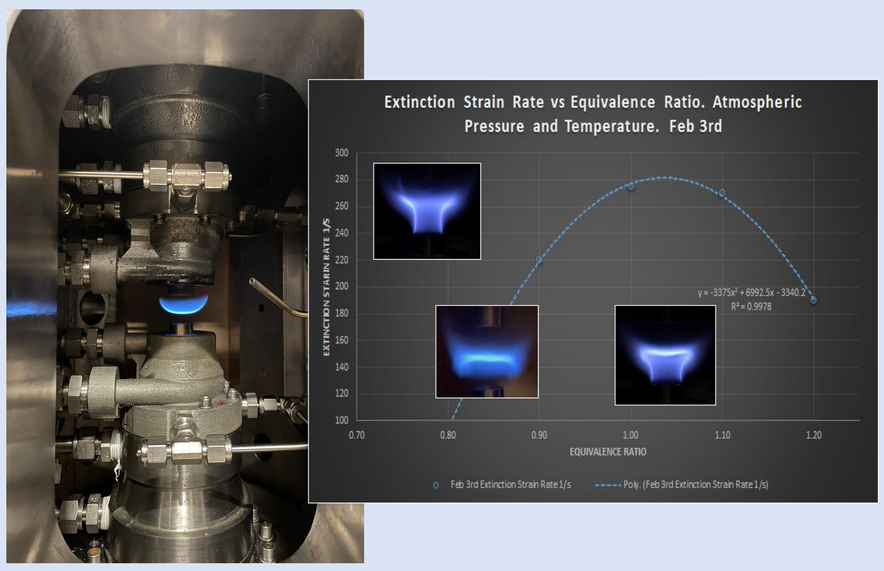

Fig.2 Fundamental Combustion Studies. Counter Flow Burner

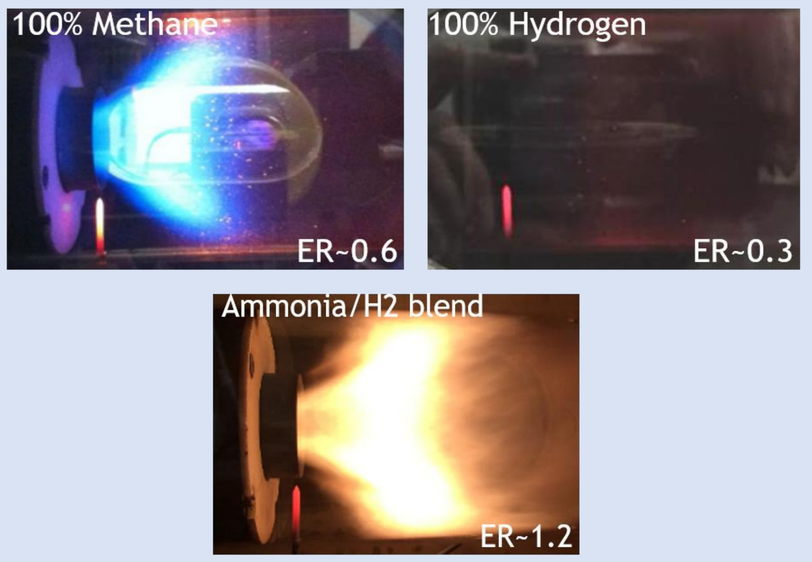

Fig.3 Applied GT Combustion

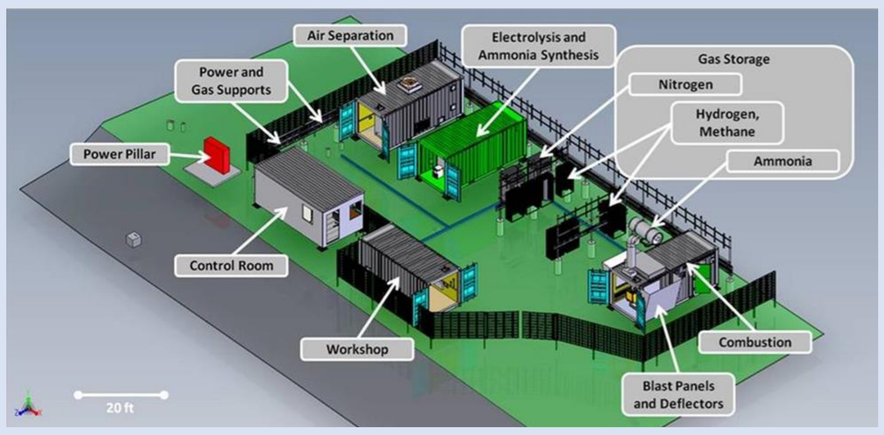

Fig.4 Integrated ammonia demonstration plant at STFC, Oxford