Students presenting research posters at the 2023 Future Fuels CRC Research Conference:

Poster abstracts:

Reza Abdollahi: 'Methane pyrolysis in molten metal bubble column reactor for hydrogen production'

Reza Abdollahi (reza.abdollahi@adelaide.edu.au), Mehdi Jafarian & Graham J. Nathan

Centre for Energy Technology, School of Mechanical Engineering, University of Adelaide, SA 5005, Australia

Abstract:

In this study, novel configurations for methane pyrolysis using a molten catalyst bubble column reactor are proposed. These configurations aim to achieve efficient conversion of methane at temperatures below 1000 °C through the recycling of a portion of the hot reactor product gas. Three recycling approaches are assessed: ejector, compressor, and a combination of compressor and turbo-expander. The study evaluates their performance compared to a reference cycle without recycling, focusing on methane conversion and thermal heat requirements. Results show that recycling can significantly enhance methane conversion, with the third configuration achieving a maximum improvement of 165%. Specifically, when recycling 80% of hot products using this third approach, methane conversion increased from 17.8% to 47.2%. Furthermore, the study suggests the possibility of a configuration with zero net CO_2 emissions by utilizing renewable power and some hydrogen product for combustion to meet process heat demands. These findings offer promising insights into sustainable methane conversion processes.

Abdulaziz Alahmadi: 'Combustion instability of hydrogen/natural gas flames'

A. Alahmadi (alahmadia@student.unimelb.edu.au), F. Poursadegh, M. Talei and Y. Yang

The University of Melbourne

Abstract:

This study investigates combustion instability (CI) in turbulent hydrogen/natural gas flames with varying boundary conditions. CI arises from the interaction between flame dynamics and chamber acoustics, causing pressure oscillations, flame destabilisation, and potential system failure. With CI often addressed during the costly testing phase of gas turbine development, understanding its mechanisms is crucial. This poster presentation demonstrates a specialised burner, designed to confine a turbulent flame, where various flame stabilisation methods can be explored. Dynamic pressure measurements showed that increasing the Mach number at the combustor's exit induced low-frequency disturbances, leading to flame blowoff and flashback. In addition, unstable flames exhibited pressure fluctuations up to four times higher than stable flames.

Salman Al-Saeedi: 'The future of coating repairs: Keyhole mitigation of corrosion under disbonded pipeline coatings'

Salman Al-saeedi (salsaeedi@deakin.edu.au), Bob Varela, Mike Tan

Deakin University / Institute for Frontier Materials

Abstract:

This research focuses on finding alternative ways to prevent further corrosion under disbonded coatings (CUDC) on buried pipelines and drastically reduce their operational costs. A review of CUDC has identified three potential ways to stop corrosion by modifying the local environment around the defect; by elevating pH levels to promote passivation, enhancing local conductivity, or depleting oxygen content. Laboratory tests found that environments of pH 13 can prevent corrosion of bare steel surfaces over wet and dry cycles. Sealing the crevice entrance was found to be capable of stopping corrosion independently of the crevice geometry and is not affected by wet-dry cycles. Enhancing local conductivity was not successful in preventing corrosion of long crevices due to the large current densities required to protect steel in non-saturated soil environments. A modified hydro excavation tool was devised to access a buried pipeline and apply a filler capable of producing one of the previous ways.

Thomas Anthony: 'Catalysts for efficient conversion of hydrogen into future fuels'

Thomas Anthony (thomas.anthony@adelaide.edu.au),[a] Christian Doonan,[a] Christopher Sumby[a]

[a]*Department of Chemistry and Centre for Advanced Nanomaterials, University of Adelaide, SA, Australia;*

Abstract:

Methanol is an important industrial chemical and chemical precursor with emerging use as a fuel in the transportation sector. Current methods of manufacturing methanol result in significant carbon emissions due to utilising syngas feedstocks (H_2, CO and CO_2) derived from fossil fuels. One possible low emission alternative is the production of green methanol through the direct conversion of renewable hydrogen and waste carbon dioxide (CO_2). However, research into an improved catalytic system is necessary to facilitate a transition to this process, as the current industrially utilised catalyst is not optimised for CO_2 rich feedstocks. This research investigates the use of metal-organic frameworks (MOFs), which are high surface area, porous materials with chemically mutable structures as precursors to novel multicomponent catalysts capable of efficiently converting CO_2 and H_2 to methanol.

Sharin Fernando: ‘Silica nanoparticle formation and deposition during biomethane combustion: A numerical study’

T.S.M. Fernando (tommageshari@student.unimelb.edu.au), K.M. Ng, M.R. Yosri, E. Goudeli, M. Talei

The University of Melbourne

Abstract:

Understanding siloxane decomposition and subsequent silica nanoparticle formation and deposition during biomethane combustion is essential in utilising biomethane in domestic appliances and internal combustion engines. This poster presentation highlights the numerical analysis of silica formation and deposition in a novel biomethane burner. Large Eddy Simulations (LES) coupled with the population balance equation (PBE) using the Method of Moments (MoM) are employed to model the flow field and particle formation process. The particle deposition is then numerically analysed by incorporating a thermophoretic deposition model within the water-cooled probe of the burner. The generated results are first validated against the silica particle number density by directly solving the PBE using the sectional method. The thickness of the deposition layer is then compared against the past literature data, showing a good agreement.

Felipe Gomes: ‘An Exploratory Study of Hydrogen/Natural Gas Interactions on Autoignition’

F.A.F. Gomes (fferreiragom@student.unimelb.edu.au), M. Talei, Y. Yang

The University of Melbourne

Abstract:

Introducing hydrogen into the current fuel mix offers significant potential for carbon emission reduction. A critical aspect is understanding hydrogen's chemical interactions with conventional hydrocarbon-based fuels, which vary across diverse applications. This study numerically examines fuel autoignition when blending hydrogen across different combustion scenarios, as an additive or primary fuel source. Scenarios include combining hydrogen with natural gas in internal combustion engines (ICE), employing it in combustors with moderate or intense low-oxygen dilution (MILD), and using it in rotating detonation engines (RDE). The ignition delay iso-contour method is used to investigate autoignition reactivity as hydrogen blending levels change. Findings reveal complex interactions between hydrogen and natural gas, often non-linear and non-monotonic. This underscores the challenges in designing combustion systems effectively. The research also highlights the practical utility of the ignition delay iso-contour method for evaluating autoignition reactivity across various combustion conditions.

Muhammad Umair Manzoor: ‘Numerical Modelling of a Hydrogen Fuelled Internal Combustion Engine’

M.U. Manzoor (manzoorm@student.unimelb.edu.au), M.R. Yosri, F. Poursadegh, M. Talei, Y. Yang, and M.J. Brear

The University of Melbourne

Abstract:

This work presents a numerical study of normal and knocking combustion of hydrogen in the cooperative fuel research (CFR) engine. This study is the first to simulate this problem in the CFR engine. This engine is relevant to spark-ignition engines as it examines the knock susceptibility of different fuels and explores fuel-engine interactions under a controlled environment. Using the Reynolds Averaged Navier Stokes (RANS) framework, a single compression ratio and four different spark timings are considered to investigate the transition from normal to knocking combustion. The results are validated against the experimental pressure trace data for both normal and knocking combustion. It is shown that for knocking cases, an initial auto-ignition hotspot appears near the exhaust valve, where the unburned temperature is higher than the rest of the domain. A secondary auto-ignition spot is generated from temperature inhomogeneities, and the two auto-ignition flames eventually merge.

Kha Meng Ng: ‘Experimental investigation of silica nanoparticle deposition during biomethane combustion’

K.M. Ng (kng5@student.unimelb.edu.au), T.S.M. Fernando, M.R. Yosri, E. Goudeli, M. Talei

The University of Melbourne

Abstract:

Biomethane, which is purified biogas, can be used as renewable natural gas and is produced from organic waste. It can potentially replace 20% of the energy supplied by natural gas in Australia. However, when combusted, impurities in biogas, such as siloxane, can decompose and form silica nanoparticles, which then deposit on the internal surfaces of appliances. This causes significant adverse impacts, such as fouling, sensor failure, overheating, increased CO emissions, and catalyst deactivation. This poster presentation shows a novel biomethane burner consisting of (i) a fuelling system to premix natural gas, air, and siloxane, (ii) a laminar flat flame burner with a height-adjustable sample probe, and (iii) a HEPA filter-equipped exhaust system, designed and built to understand the characteristics of the silica particle formation and deposition.

Fred Omoarukhe: ‘Development of a Hydrogen-fuelled Domestic Gas Cooktop Burner’

Fredrick Omoarukhe (fredrick.omoarukhe@adelaide.edu.au), Douglas Proud, Neil Smith, Peter Ashman

Center for Energy Technology, School of Chemical Engineering, The University of Adelaide, South Australia, 5005 Australia

Abstract:
In recent years, there has been a growing imperative to transition to cleaner energy sources and decarbonize the energy sector due to the significant adverse effects of CO_2 emissions on the environment. Renewable hydrogen gas has been identified as a key substitute for natural gas, enabling the transition to low-carbon energy systems. However, due to the significant differences in the combustion properties of hydrogen and natural gas, they cannot be directly substituted. This project aims to explore new burner design prototypes for an existing cooker appliance to use hydrogen as the only fuel source. This modification to existing cooker appliance offers a viable option for expensive and time-consuming appliance replacement. Two new prototypes with a maximum heat input of 6MJ/hr have been assessed for performance, in comparison to an existing natural gas burner. The results have allowed development of design guidelines for 100% hydrogen domestic cookers.

Nithin Joseph Vattappara: ‘Development & Validation of Quality Assurance Tests for Choosing the Right Two-part Epoxy Pipeline Coatings’

Nithin Joseph Vattappara (njosephvattappa@deakin.edu.au), Bob Varela and Mike Yongjun Tan
Deakin University / Institute for Frontier Materials

***Abstract*:**

Australia’s extensive network of steel pipelines depends on robust corrosion protection. While cathodic protection provides some security, the external barrier coatings provide the first line of defence. In recent decades, liquid applied 100% solids two-part epoxy coatings have gained prominence for Field Joint Coatings due to their ease of use and superior properties. The current Australian standard Pre-Qualification Tests (PQTs) are considered to be not reliable for liquid applied epoxy coatings selection because they fail to assess the coating barrier properties and its degradation. Existing ISO and ASTM PQTs, evaluate water and ionic permeation resistance, but do not account for these coatings' uniqueness. This oversight affects their temperature-based acceleration and neglects factors like air bubbles, potentially yielding misleading outcomes. Our research seeks to enhance these standards in order to ensure the selection and deployment of right coating in the field. This is being achieved by factoring in the distinctiveness of liquid applied epoxies, developing more reliable test acceleration methods and producing more dependable results.

Peng Zhang: 'Hydrogen embrittlement behaviour of a high-strength pipeline steel and its weldment'

Peng Zhang, Mike Yongjun Tan, Majid Laleh, Tim Hilditch, Anthony E. Hughes, Ross K.W. Marceau.
Deakin University

Abstract:
Although hydrogen embrittlement (HE) has been the subject of extensive research over the past century, a systematic study on the HE susceptibility of steels under different electrochemical charging conditions has been lacking. This study specifically targets this knowledge gap by evaluating the HE behaviour of a typical pipeline steel X65 after hydrogen-charging in acidic, neutral, and alkaline electrolytes that simulate various industrial environments. In addition, HE behaviour of weldment on pipeline steel has not been investigated thoroughly. The current study revealed the HE susceptibilities of different zones of weldment (i.e., weld metal (WM), heat-affected zone (HAZ), and base metal (BM)). The result show that the X65 steel is susceptible to HE. The most significant ductility loss were observed in specimens charged in an acidic electrolyte, while the least was found in an alkaline electrolyte. Among three zones, WM is the most susceptible zone to HE on X65 pipeline steel, followed by HAZ and BM. Ti-rich inclusions, M/A constituents are identified as the key crack initiation sites under the influence of hydrogen.

Yuecheng Zhang: 'Compatibility of Plastic Piping with Future Fuels'

Yuecheng Zhang (yuechengz@student.unimelb.edu.au), Mohamed H. Abdellah, Sandra E. Kentish, Colin A. Scholes

Department of Chemical Engineering, The University of Melbourne

Abstract: Future fuels, especially methanol, ammonia (NH_3) and dimethyl ether (DME), have gained significant attention as a substitute for conventional fossil fuels, owing to the high volumetric energy density and the ability to synthesise from hydrogen. The compatibility of commercial HDPE pipes and associated elastomers with these future fuels was investigated with methane as the reference. Given the highly condensable nature of future fuels, a substantially higher solubility coefficient and corresponding permeability were found in the polymeric material, especially in elastomers. Also, the leaching of additives from the commercial elastomers into methanol was observed due to the favourable interactions, leading to a deterioration in the mechanical properties. On the other hand, HDPE demonstrated robust compatibility with methanol and NH_3, maintaining similar mechanical properties as methane after aging. However, the interaction with DME led to a notable decline in HDPE mechanical performance, particularly tensile stress and elongation at break.

NOTE: Shreshtha Gupta is presenting a poster titled **'Hydrogen mixing in natural gas distribution network'** (from *RP3.2-12 : Addressing Hydrogen Blending Issue: Gas Mixing, Demixing, and Hydrogen Analysis*) but this poster is ineligible for the prize. (Only student research is eligible for this)

'Hydrogen mixing in natural gas distribution network'

Shreshtha Gupta (shreshthakumar.gupta1@unimelb.edu.au), Yi Yang, Mohsen Talei
The University of Melbourne