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Hydrogen Fuel Switch and the Challenges it Poses

Introduction

- **Climate change** - Complex global challenge; main factor is our overdependence on fossil fuels [1].
- **Fuel burners** are used extensively within industrial settings and currently, most burners **use fossil fuels** to provide power [2].
- This PhD will focus on the **fuel switch to hydrogen** - looking at the context of paint curing for the automotive industry with Toyota as a sponsor.
- The **painting process** - Most energy intensive processes a vehicle undergoes in manufacturing taking up 36% of the energy used [3].
- The **majority of this energy is provided in the form of natural gas**, which is a cleaner fossil fuel than most [2].

The Painting Process

- When painting a car its important to layer each coating in the correct order:
- The first coat is **electrodeposition**, which protects the car from rust, chemical and mechanical degradation. [3]
- After that the **primer** is applied to the body to ensure the colour is evenly distributed. [3]
- The **base coat** is then applied to give the car it's colour before finally having the **clear coat** applied to give it a glossy or matte finish.
- The oven has a line of inline burners all the way down the conveyors all of which use natural gas, which contribute to 41% of the plants total gas [3].

The Challenges

- Switching the burners to run on hydrogen instead of natural gas isn't as easy as simply substituting one fuel for the other.
- The first issue to consider is the **increased moisture content** the combustion of hydrogen produces. [4]
- **Hydrogen temperature control** is another issue that needs to be considered. When compared with natural gas, hydrogen has a higher enthalpy of combustion leading to a higher flame temperature. [5]
- Due to the increased temperature of hydrogen combustion, there will be an increased generation of **thermal NO_X**.
- Increased NO_X for curing can discolour the paint layers as well as being hazardous to human health with **strictly controlled limits** (EN 14792:2017 dictates 1300 mg/m^3 for combustion plants [6]).

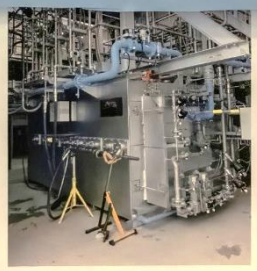
Electrodeposition: A painting process where a car body is submerged in a charged chemical bath to create a uniform, corrosion resistant primer layer.

Primer Coat: A coating applied via automated spray to smooth out surface imperfections and provide a uniform colour for topcoat application.

Top/Clear Coat: The application of the basecoat and the clearcoat, which together provide the vehicle's colour and finish whilst also providing its final protective shield.

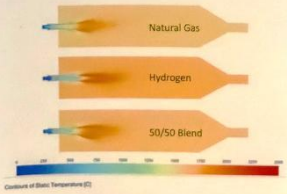
Experiments

- To ensure that the fuel switch does not impede on the process quality we have planned a set of experiments:
- The first experiment is a **flame temperature experiment** using a specific hydrogen burner.
- The next experiment will look at **how NO_X affects the colour** of each layer and in what quantities.
- The experiments will also look at the **burner flow rates** and various **gas species analysis'** at the Sheffield Transitional Energy Research Centre.



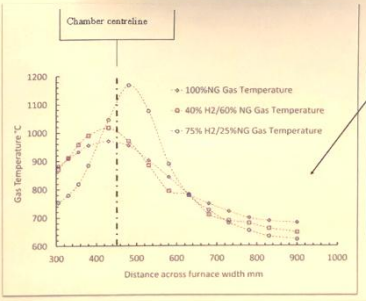
Simulation Work

- We will also use **computational fluid dynamics** research.
- This model will simulate the changing **air flow and hydrogen burner combustion products**.
- The model will take into account the **chemical interactions, mass and momentum** calculations, **heat and energy.**
- This model can then determine if using hydrogen in the burners will cause **quality control issues**. [7]



Future Research

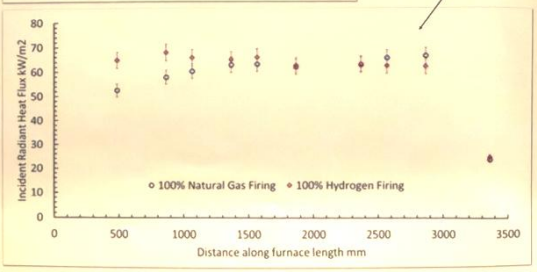
- Toyota are looking to lead the transition to the decarbonisation. TMUK have a commitment to be carbon neutral by 2030 and carbon zero by 2040.
- The research could be applied in a much broader range of applications such as paint adherence and **NO_X limitations** in relation to hydrogen fuel applications.
- Further research could include a **life cycle analysis** of industrial sectors when green hydrogen is used or the development of new advanced **NO_X reduction techniques** to limit exposure.



Description of Figures

This graph depicts the **gas temperature across the width** of the furnace for different gas fuel blends [8]

This graph displays the **radiant heat flux across the length** of the experimental furnace. [8]



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