Effect of Hydrogen Addition in Flameless Combustion with Kerosene

Mudit Sood, Mohammad Kalamuddin Ansari, Saran Solagar, Sudarshan Kumar
Indian Institute of Technology Bombay
Mumbai, India

1 ABSTRACT

Using hydrogen as a fuel or fuel enhancer has the potential to be employed in sustainable energy sectors. It displays promise as an energy carrier for future power sources without contributing to carbon emissions. It is light, storable, energy-dense, and produces no direct emissions of pollutants or greenhouse gases. Additionally, when hydrogen is added to conventional fuels, it leads to a decrease in CO_2 and CO emissions, thereby expanding the stability limits due to its wide flammability limits. However, the inclusion of hydrogen increases reactivity and reduces the ignition delay, causing combustion to initiate locally at a faster rate compared to the mixing time scale. This localized combustion generates high-temperature regions, which in turn promotes the formation of NOx due to hotspots being formed.The objective of this study is to comprehend the behavior of combustion when hydrogen is added under flameless conditions. While previous investigations have proposed multiple thermal inputs, this particular study focuses on a single experimental campaign. The assessment involves adding up to 20% hydrogen by mass to kerosene while maintaining a constant thermal input of 20 kW. The findings indicate that the gradual addition of hydrogen in kerosene results in reduced NO_x emissions.

2 Experimental Investigation

The experimental setup used in the present investigation is depicted in Figure 1. Danfoss 0.287 mm Nozzle is used for injection of fuel, after due calibration for 9 bars to 20 bars. A stainless-steel cylinder is used to store Kerosene which is further pressurized by Nitrogen gas stored in a separate cylinder. Hydrogen is injected through a 2mm Nozzle which is drilled axially in the combustor. Air is injected through a 3mm air swirler into the planum of the combustor which further redistributed into the Primary, Secondary and Dilution zones. R and K Type thermocouples are used to measure the chamber and wall temperatures respectively. Testo350 Gas Flue Analyzer is used to measure the emissions from the combustor.

Correspondence to: thinkmudit@gmail.com

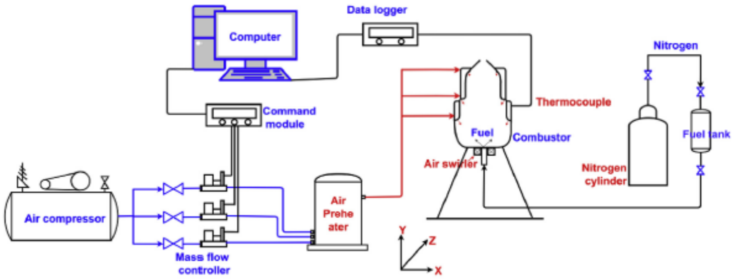


Figure 1 – Schematic Representation of Experimental Setup

3 Reactant Dilution Ratio

Basic requirement to achieve Flameless Combustion is to have required recirculation of the so as to bring down the peak temperatures which reduces the NO_x formation. Appropriate Dilution Ratio is to be maintained so as to the get the desired thermal output. Dilution Ratio (R_{dil})can be measured using the following equation:

$$R_{\mathrm{dil}} = \frac{|\dot{m}_{\mathrm{axial}}| - (\dot{m}_{\mathrm{ox}} + \dot{m}_f)}{(\dot{m}_{\mathrm{ox}} + \dot{m}_f)}$$

where $\dot{m}_{\mathrm{axial}}$ is the total mass flow of hot combustion products at a given plane in the combustor, normal to the axis of the combustor, $\dot{m}_{\mathrm{ox}}$ is the oxidizer mass flow rate and $\dot{m}_f$ is the fuel mass flow rate.

4 Results and Discussion

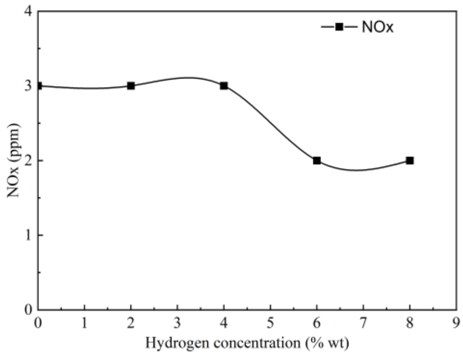


Figure 2(a) - NO_x emissions with increase in Hydrogen concentration

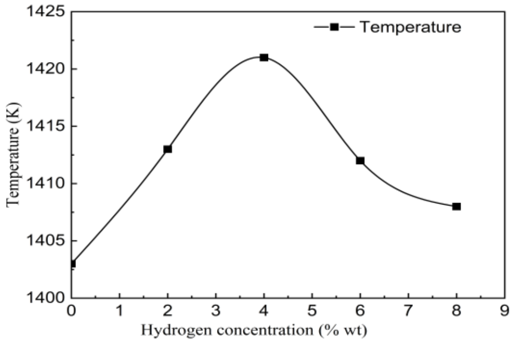


Figure 2(b) – Chamber Temp variation with increase in Hydrogen concentration

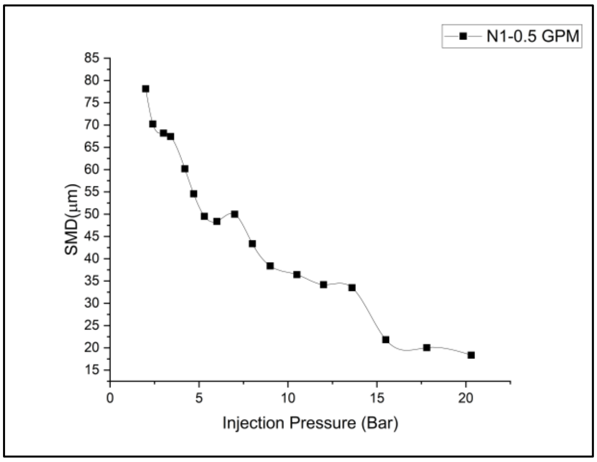
.

Figure 2(a) -It is observed that NO_x decreases as percentage of Hydrogen is increased as it is a carbon less fuel and also the appropriate recirculation reduces the peak temperatures in the combustor. Figure 2(b) - It can be seen that peak temperature of 1420K is reached at 4% of Hydrogen concentration but it reduces and further, due to improper burning. Table 1 shows the effect of pressure on SMD and hence burning efficiency.

Table 1: SMD at Different Pressures.

Sr No	Injection Pressure (Bar)	SMD (mm)
1	2	78.15
2	3	68.2
3	4.2	60.2
4	5.3	49.52
5	6	48.39
6	7	50
7	8	43.37
8	9	38.4
9	10.5	36.45
10	12	34.19
11	13.6	33.51
12	15.5	21.84
13	17.8	20.04
14	20.3	18.36

Figure 3: Variation of SMD with Injection Pressure



References

[1] Perpignan, A. A., Rao, A. G., & Roekaerts, D. J. (2018). Flameless combustion and its potential towards gas turbines. *Progress in Energy and Combustion Science*, *69*, 28-62.

[2] Derudi, M., Villani, A., & Rota, R. (2007). Sustainability of mild combustion of hydrogen-containing hybrid fuels. *Proceedings of the Combustion Institute*, *31*(2), 3393-3400

[3] Sharma, S., Chowdhury, A., & Kumar, S. (2020). A novel air injection scheme to achieve MILD combustion in a can-type gas turbine combustor. *Energy*, *194*, 116819.

[4] Cavaliere, A., & De Joannon, M. (2004). Mild combustion. *Progress in Energy and Combustion science*, *30*(4), 329-366..