Engine Combustion of Hydrogen Produced by Anaerobic Bacterial Wastewater Treatment

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MOTIVATION

- Current wastewater treatment comprises 2% of total U.S. electricity consumption and contributes 45 Tg CO_2-equiv. to Earth's atmosphere[1,2]
- Researchers at the University of Minnesota are developing an economically and environmentally favorable alternative:
  - Acetogenic bacteria encapsulated in silica membranes break down waste compounds in water
  - The bacteria produce gaseous hydrogen (H_2) as a byproduct[3,4]
- This study investigated the feasibility of combusting bacterially produced hydrogen in an engine-generator to create clean, renewable energy

OBJECTIVES

- Modify a Honda 1kW engine-generator to run on gaseous hydrogen instead of gasoline
- Determine the fuel-air ratio and H_2 concentration of the engine's intake charges as a function of load
- Characterize the engine's emissions as a function of load to evaluate its environmental impact

PROCEDURE

- A Honda EU1000i 1kW genset was fitted with a custom aluminum airbox, high-performance air filter, and inlet port for gaseous H_2
- The genset was run at wide-open throttle on H_2 supplied by a gas cylinder, at constant speeds of 5500, 5750, and 6000 RPM
- A flowmeter and metering valve were used to adjust H_2 flow to maintain speed, which was measured by a magnetic sensor
- An adjustable load bank incrementally increased load on the genset until constant speed could not be maintained
- At each load, emissions were sampled for 30 seconds by a Raman laser gas analyzer (LGA) and a wideband oxygen (O_2) sensor

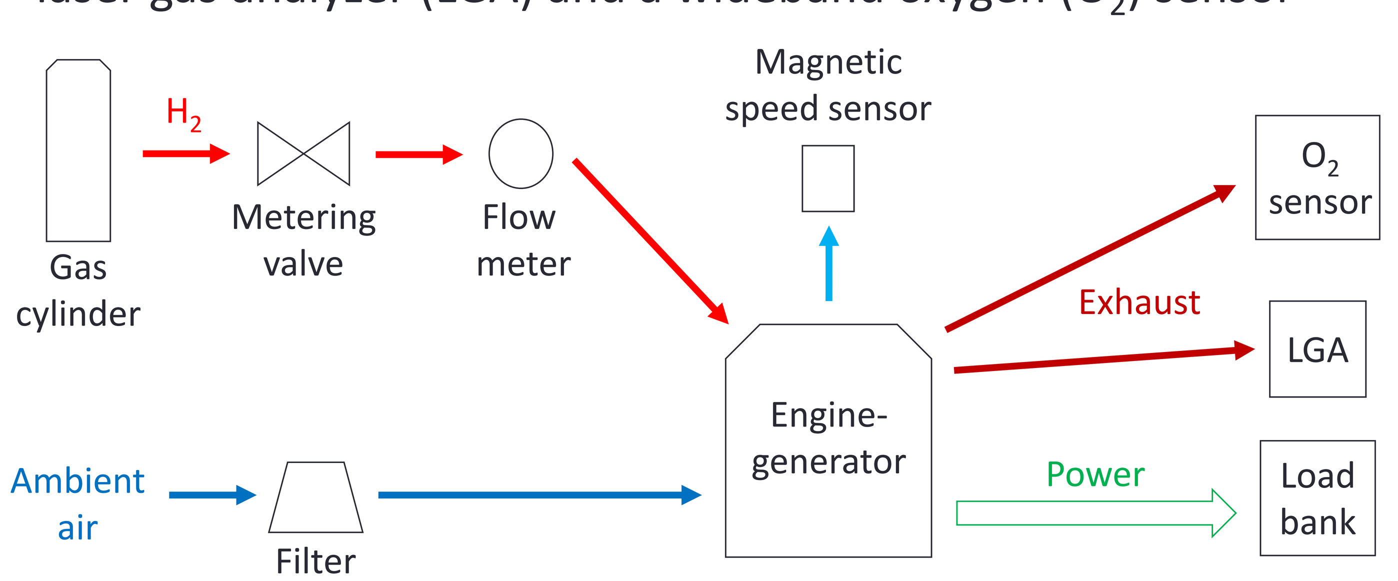

Figure 1: Experimental design.

RESULTS

- Each of the three speeds was tested on three separate days, and the mean of exhaust and H_2 flowrate measurements across the three days was taken
- Equivalence ratio, which indicates how rich or lean the engine burns, was directly measured by the O_2 sensor and calculated via exhaust composition measurements of the LGA:

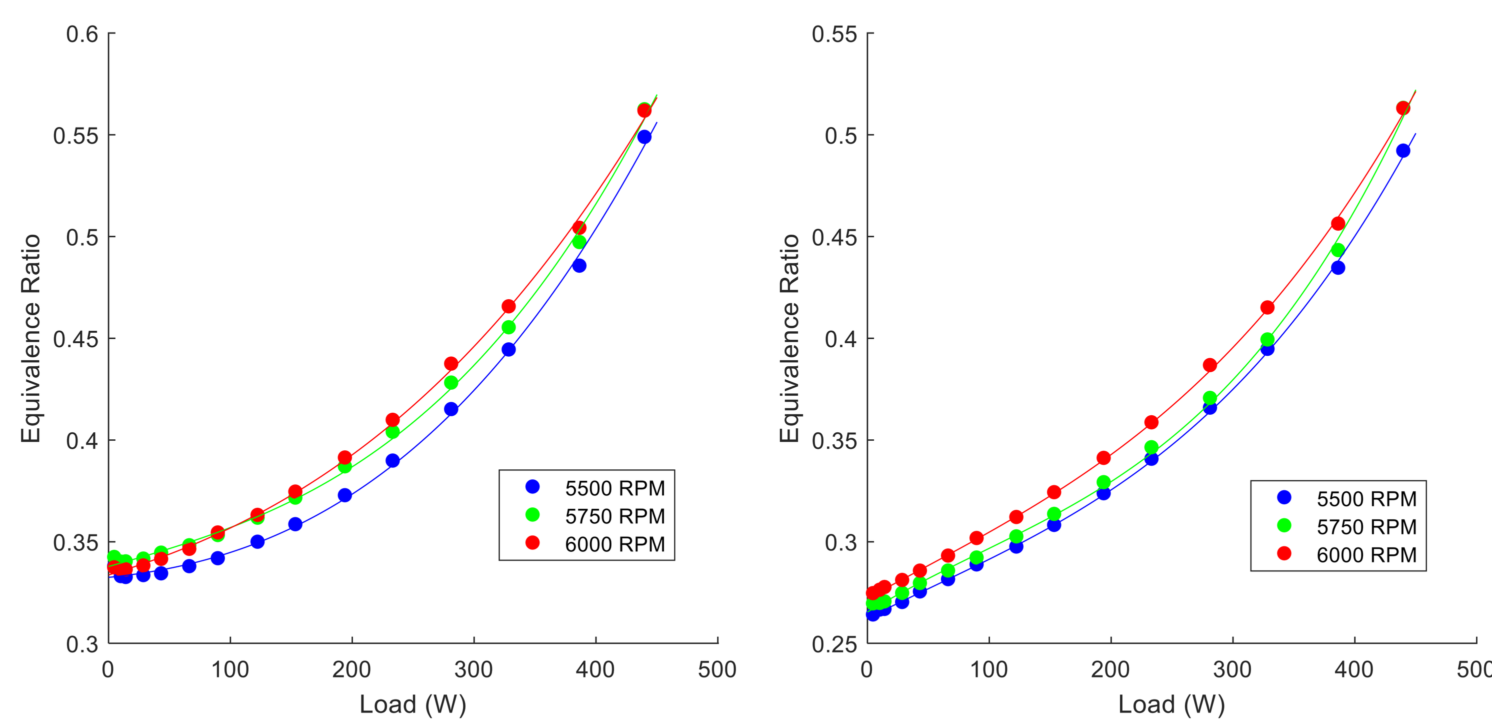

Figure 2: Equivalence ratio versus load, measured by O_2 sensor (left) and calculated via LGA (right).

- The engine automatically runs very lean (i.e. combustion leaves excess air) due to H_2's wide flammability limits
- Equivalence ratio increases with load yet never exceeds .6, likely limiting power output to <500W regardless of speed
- The LGA also sampled exhaust to determine its composition:

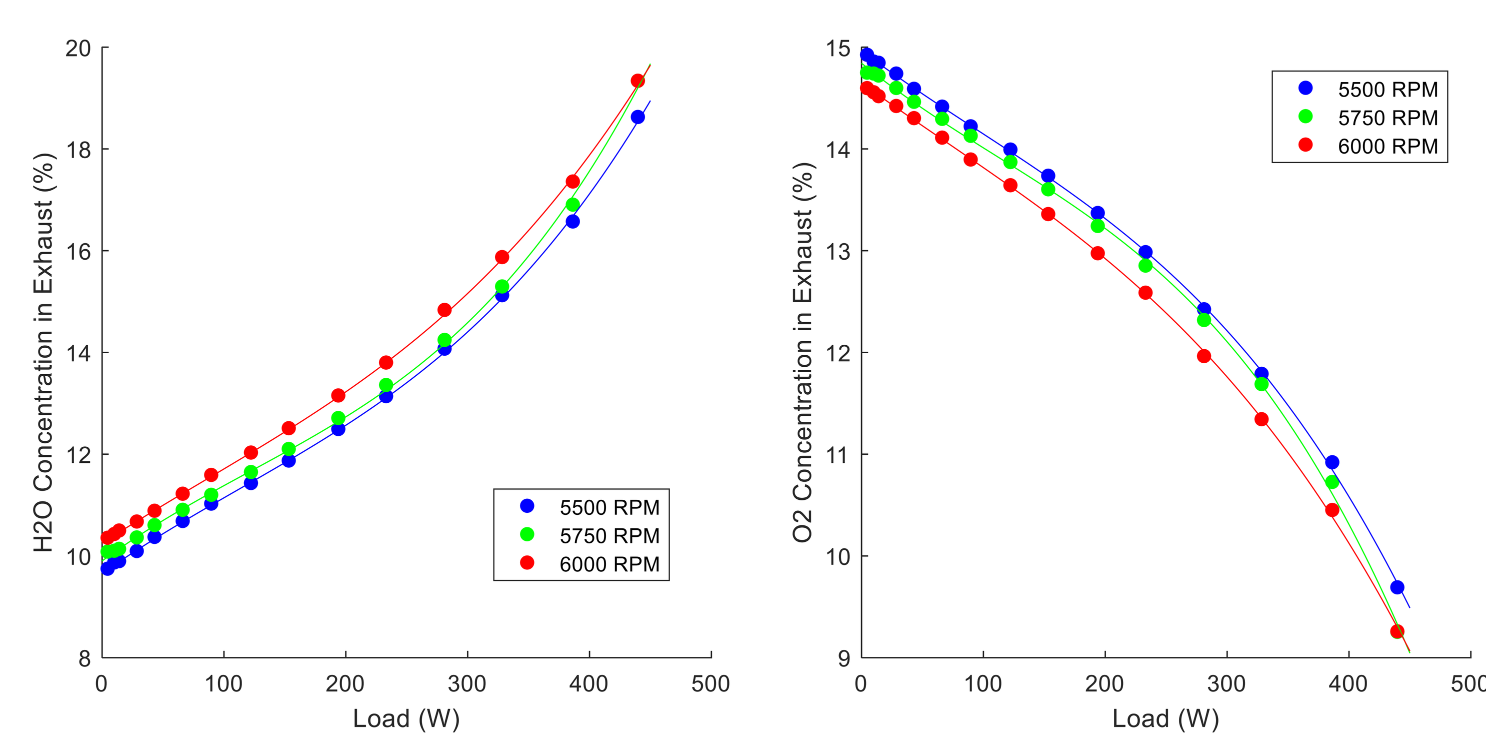

Figure 3: Volume concentrations of H_2O (left) and O_2 (right) in exhaust versus load.

- Besides N_2, which is inert, only water vapor and excess oxygen from the engine running lean are emitted during operation
- Negligible amounts of H_2 emitted suggest complete combustion, likely due to hydrogen's high flame speed
- Harmful pollutants like CO_2 and CO are not emitted because no carbon exists in fuel, so engine provides clean power

RESULTS

- Along with exhaust, intake characteristics were also measured:

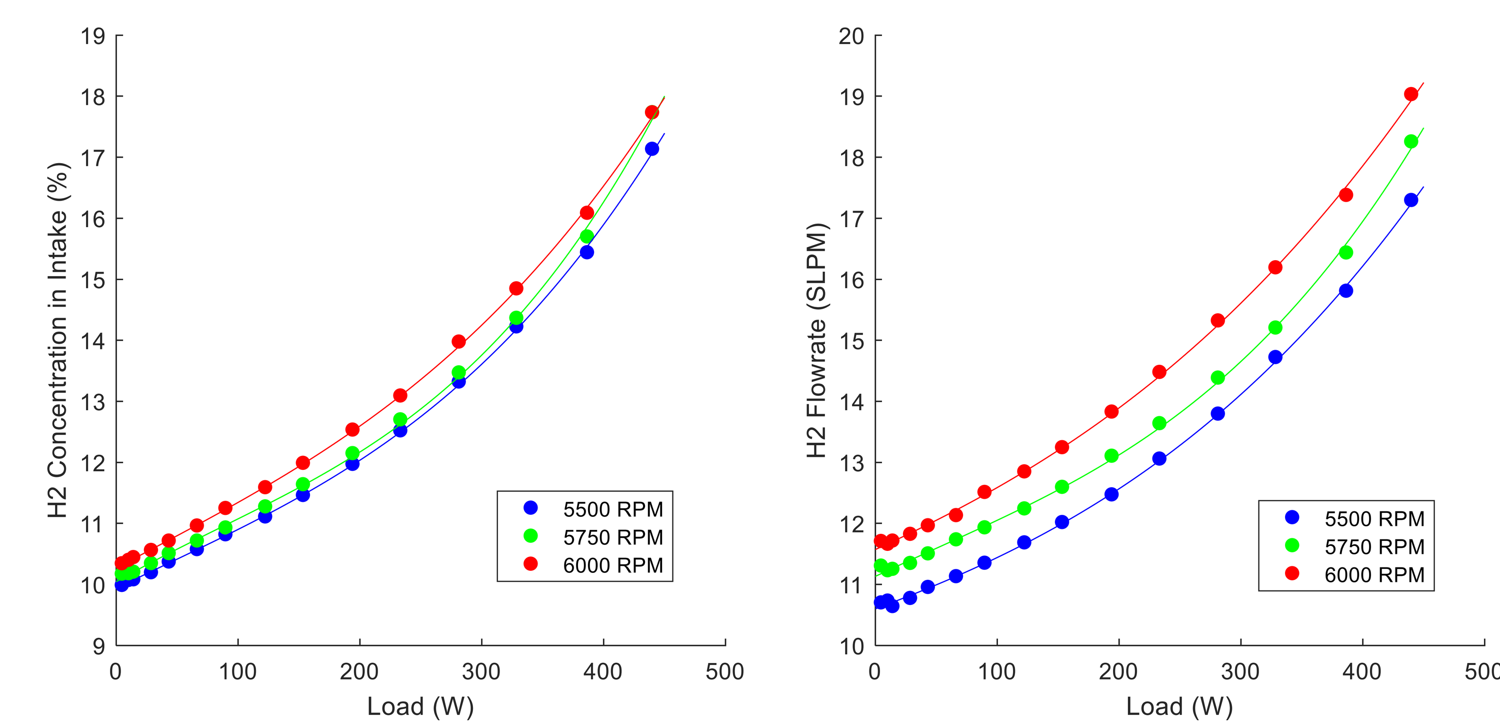

Figure 4: H_2 volume concentration (left) and flowrate (right) into engine versus load.

- Volumetric flowrate of H_2 into the engine increases to maintain speed as load increases, but equivalence ratio never exceeds .6 (Fig. 2), suggesting mass flowrate increases less rapidly

CONCLUSION

- A genset powered by hydrogen releases no harmful emissions and automatically runs lean, at the expense of limited power output
- Further investigation into H2 mass flow is required to determine why the engine cannot run richer to provide more power

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