Metal-Supported Solid Oxide Fuel Cells for Rapid Thermal Cycling

Kyle J. Horn, Mechanical Engineering
Mentor: Dr. Ryan J. Milcarek, Ph.D.
School for Engineering of Matter, Transport and Energy (SEMTE)

Objective: to improve rapid thermal cycling and mechanical ruggedness of solid oxide fuel cells by investigating various fuel cell geometries and supports

Background

Solid Oxide Fuel Cells (SOFCs) are a highly efficient, fuel flexible type of fuel cell with high operating temperatures ([600-900]°C) [1,2]. They operate by means of electrochemical half reactions taking place at an anode and a cathode, separated by a ceramic electrolyte. These half reactions force electrons to travel though an external circuit where they can be utilized as current to produce work.

SOFCs in particular have several hurdles to overcome before successful commercialization, these include: high cost of production (materials and manufacturing), failure due to rapid thermal cycling, failure due to mechanical shock, unreliable sealing, and failure due to oxidation at the anode [3].

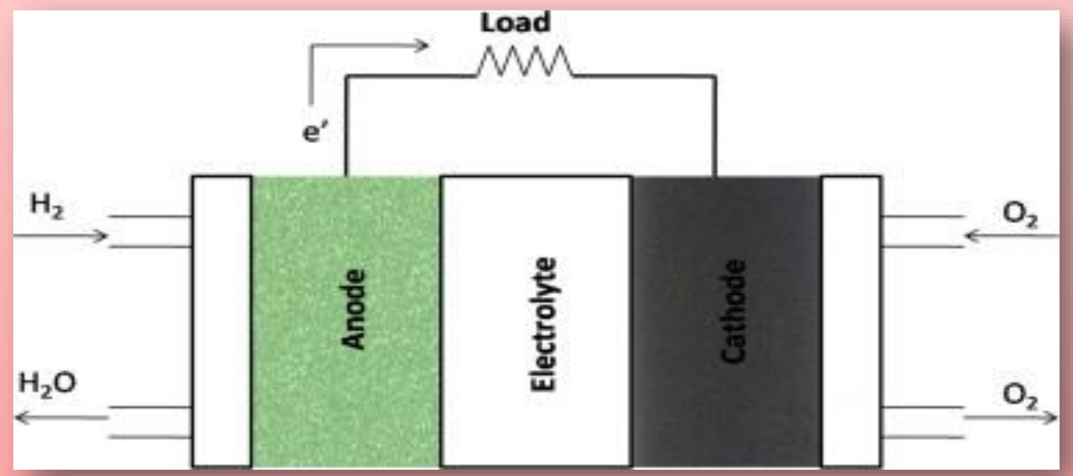

Figure 1: Schematic of single solid oxide fuel cell [2].

Methods and Results

The Planar MSCs were tested in a FFC setup to understand how the system performs without sufficient thermal management. Propane was used as the fuel in equivalence ratios of 1.5 to 4, at 0.5 intervals alongside fuel + air flow rates of 400 sccm to 600 sccm, in 50 sccm intervals. The distance between the flame and the fuel cell was approximately 1 cm throughout the duration of testing.

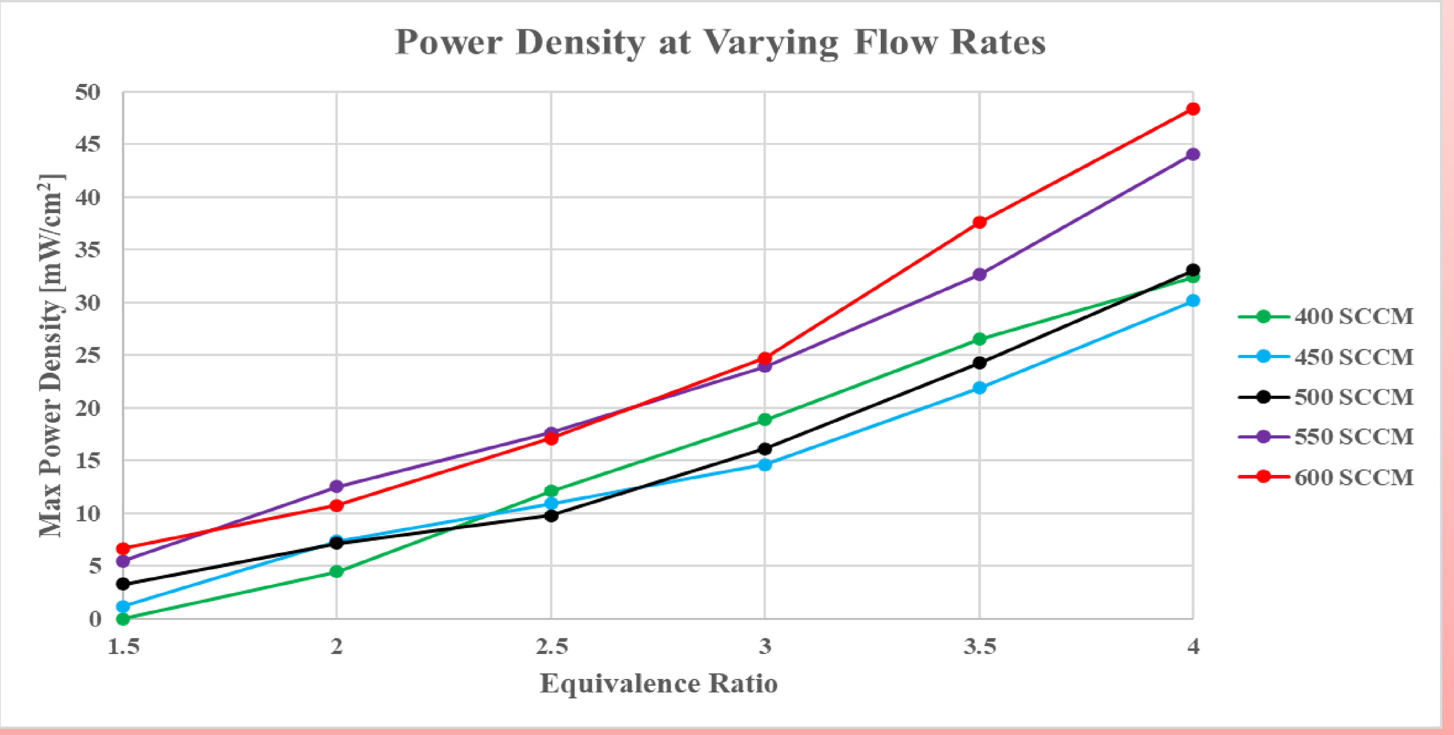

Figure 4: Power density as a function of equivalence Ratio for the tested flow rates in the preliminary setup.

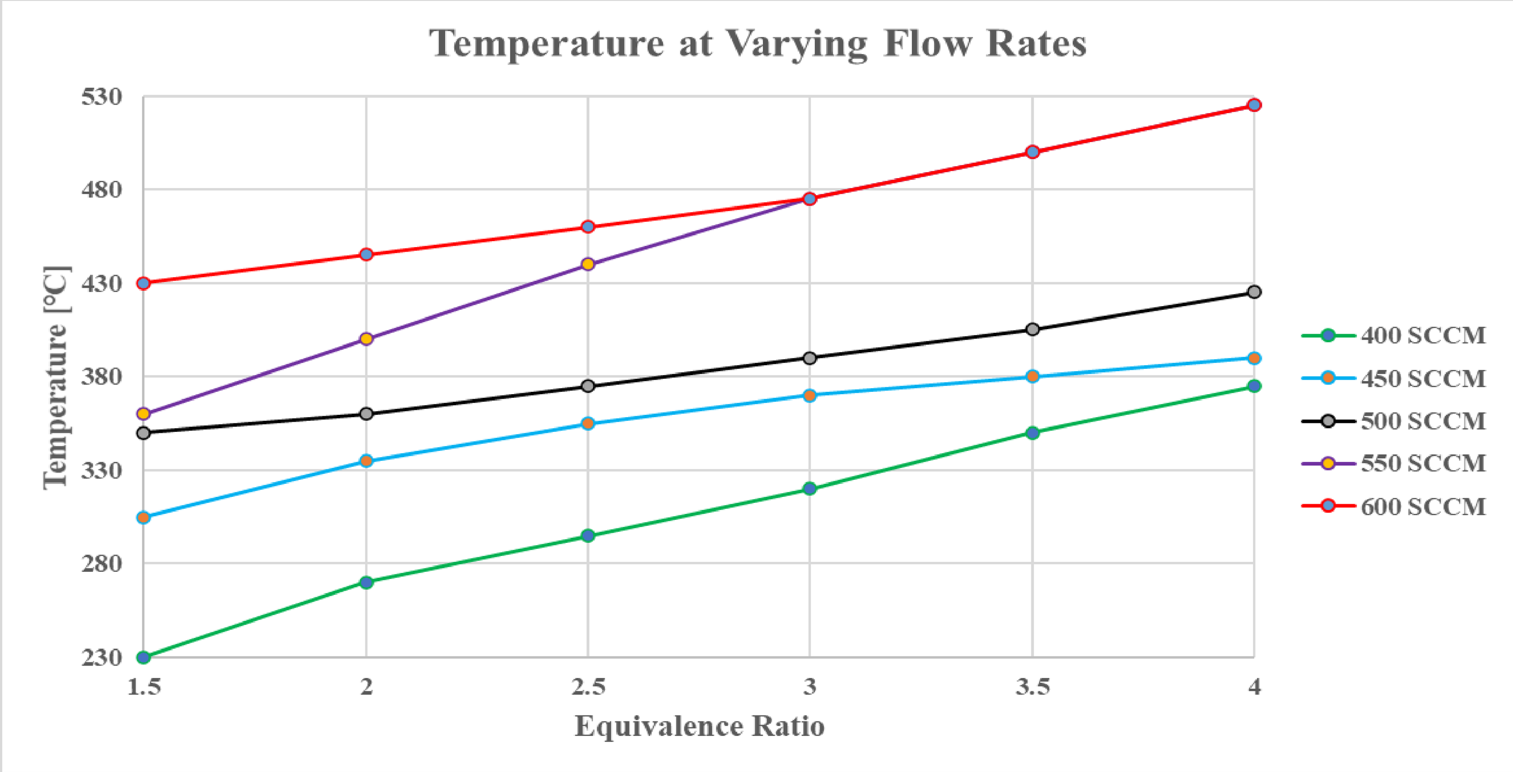

Figure 5: Temperature as a function of equivalence Ratio for the tested flow rates in the preliminary setup.

The impact of temperature is illustrated in the comparison of Figure 4 and Figure 5; since temperature is a key factor in the power density (and thus efficiency) of the MSC FFC SOFC system, a reactor design that significantly improves the heat retention from the flame and distributes that heat to the incoming air for the cathode is critical. The mitigation of heat loss is the focus of future work.

Supports & Configurations

Cell supports include electrolyte-supported cells (ESCs), cathode-supported cells (CSCs), and anode-supported cells (ASCs). These historic approaches have poor mechanical shock tolerance (CSCs), slow temperature ramp rates (ASCs), and comparatively high operating temperatures in the world of SOFCs (ESCs) [3,4]. By using metal-supported cells (MSCs), a number of these issues could be eliminated [3].

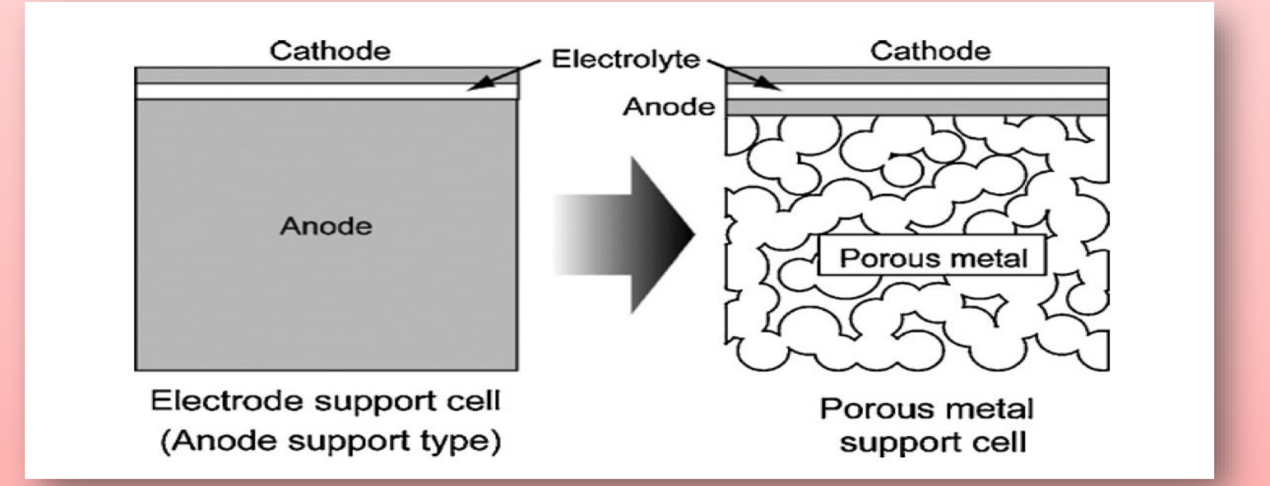

Figure 2: Schematic representation of anode supported cell (ASC) and metal-supported cell (MSC). Only a thin portion of the anode layer, as required for electrochemical function is retained in the MSC design [3].

Recent research by Dr. Milcarek has shown that using Flame-assisted Fuel Cells (FFCs) can drastically increase the number of thermal cycles a cell can handle [5]. There is currently insufficient research on the ability of planar SOFCs to effectively thermally cycle in a FFC configuration, and the impact that a metal-support would have in the setup, and thus is the focus of this investigation.

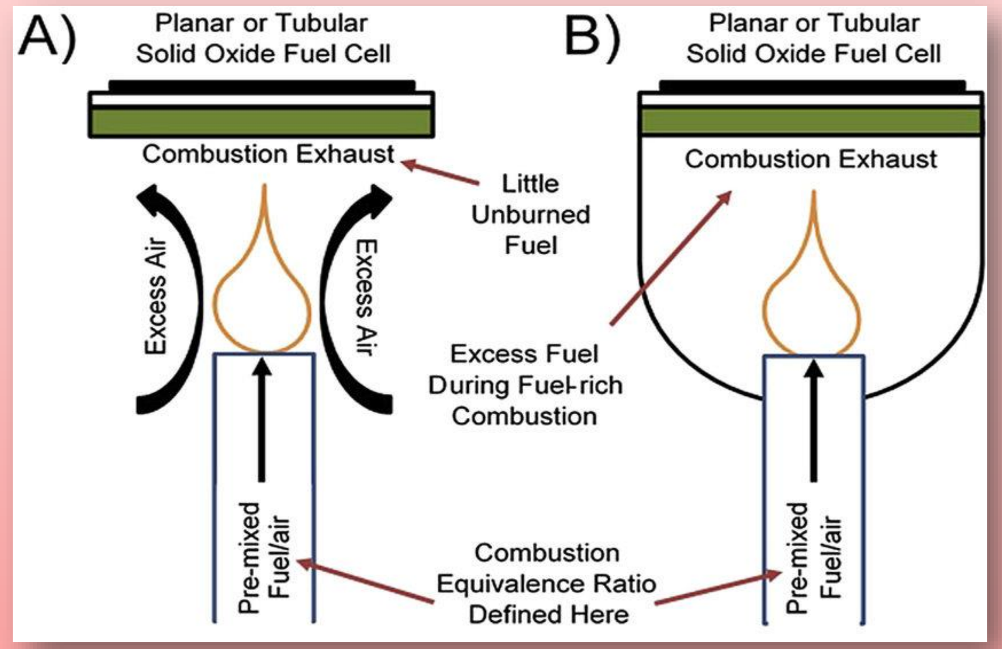

Figure 3: Schematic of the A) direct flame fuel cell (DFFC) setup compared to the B) flame-assisted fuel cell (FFC) setup [5].

Next Steps

The continuation of this work will be the construction of the improved MSC FFC SOFC reactor geometry seen in Figure 6. The design features improved thermal management and is expected to yield far greater efficiencies and power densities of cells operating at steady state conditions and during rapid thermal cycling.

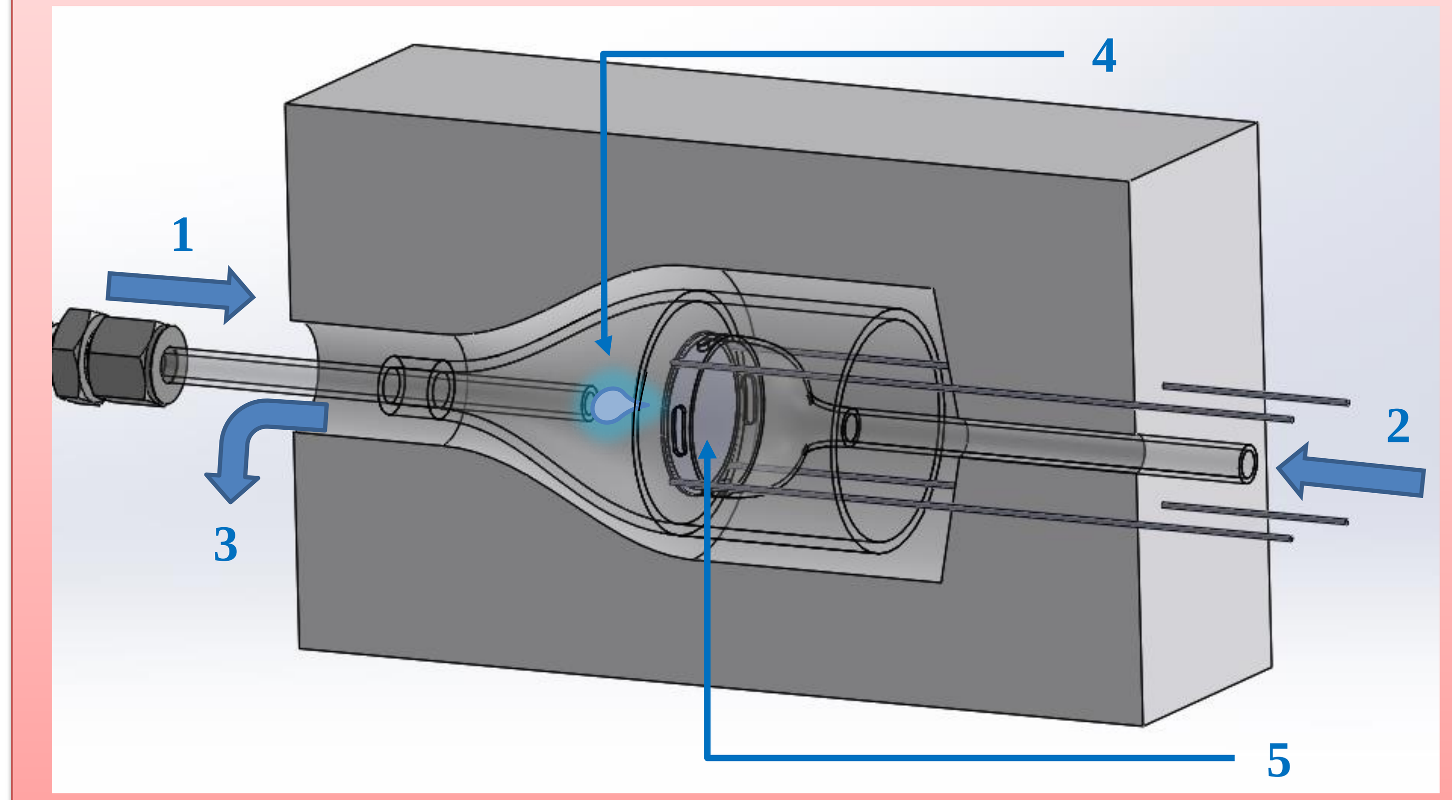

Figure 6: MSC FFC SOFC Reactor geometry that will be constructed and used in future investigations.

1. *Fuel + Air Mixture*
2. *Cathode Air Inlet*
3. *Exhaust*
4. *Propane Rich Flame*
5. *Metal Supported SOFC*

References and Acknowledgements

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[2] (Prakash, Kumar, & Aruna, 2014). "Properties and development of Ni/YSZ as an anode material in solid oxide fuel cell: A review". Renewable and Sustainable Energy Reviews 36: 149-179
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Ira A. Fulton Schools of Engineering
Arizona State University