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RESEARCH PROJECT:

Design of Porous Media Combustor with

Structured and Stochastic Lattice Structures.

Summary

Recognition

I would like to express my gratitude to all those who have supported and contributed to the successful completion of this research project until now. First and foremost, I would like to thank my supervisor and ***Assoc. Prof. Beni Cukurel*** for providing valuable guidance, insights, and encouragement throughout the project. Your mentorship and expertise have been instrumental in shaping the direction and scope of this research.

I would also like to thank ***Prof. Joseph Lefkowitz*** and the lab researchers and assistants at his lab who will provide technical support and assistance during the experiments and simulations, that are to come. Your dedication and expertise will be crucial in ensuring the accuracy and reliability of the results.

Furthermore, I would like to acknowledge the contribution of my supervising colleague and post-doctoral fellow ***Dr.Mahesh Nayak-Guguloth*** who provided constructive feedback and suggestions during the research process. Your insightful comments and discussions have helped me to refine and improve the design and methodology of this project.

Finally, I would like to express my appreciation to the ***Turbomachinery and Heat Transfer Laboratory*** that supported this research project. Without your support, this project would not have been possible.

You may find the members of the Lab at this link: ***https://bcukurel.net.technion.ac.il/people***

Thank you all for your support, encouragement, and dedication to this project.

Introduction

Combustion systems are essential in various industries, ranging from power generation to manufacturing processes. Porous media combustion burners are a unique type of combustion system that operate by passing a fuel-air mixture through a porous material, such as a ceramic foam, to create a stable and efficient flame. In this research project, a small-scale porous media combustor was designed in SolidWorks to burn an ammonia-air mixture in a lab setting.

The increasing demand for energy and the depletion of traditional fossil fuel resources have motivated researchers to explore alternative and unconventional fuel sources. One of these unconventional fuels is ammonia, which has the potential to become a significant source of clean energy due to its high hydrogen content and low carbon emissions. However, the combustion of ammonia is challenging due to its high ignition temperature and low laminar flame speed. Porous media burners have shown promise in enhancing the combustion characteristics of unconventional fuels.

Small-scale porous media combustion burners that burn ammonia-air mixtures have several advantages over traditional combustion systems. They offer improved heat transfer, reduced emissions, and higher thermal efficiencies, making them an attractive option for small-scale applications. Additionally, they are compact and require minimal maintenance, making them an ideal choice for space-limited applications.

This report aims to provide a comprehensive overview of the design and development of a small-scale porous media combustor that burns an ammonia-air mixture, including its operating principles, design considerations, and applications. Furthermore, the report will explore current research trends and future directions in the development of small-scale porous media combustion burners that burn ammonia-air mixtures.

Overall, the report will highlight the potential of small-scale porous media combustion burners that burn ammonia-air mixtures as an innovative and efficient technology for various applications, such as space heating, cooking, and portable power generation.

Literature Review

Previous research has shown that the use of porous media burners can enhance the combustion characteristics of unconventional fuels, more recently at the ***Stanford University*** with a single flow configuration, which is radial inward flow. Several flow configurations have been studied in our case, including radial inward flow, radial outward flow, and reversal axial flow. Indeed, the combustor design has been conceptualized to be modular and house the three previous configurations.

The experimental setup includes measuring temperature distribution, pressure drop, and gas emission characteristics using a gas analyzer and gas chromatography.

The flow rates of fuel and air are controlled using a mass flow controller to ensure the equivalence ratio of test conditions.

Experimental Design

The experimental setup includes a mixing chamber located upstream of the burner, where NH3 and air are fully mixed following non-return valve (NRV) and flashback arrestor (FA).

The exchangeable Porous Inert Media (PIM) geometry has an outer diameter of 60mm and a variable axial length. The burner will be instrumented with a NI c-DAQ control system to measure pressure and temperature. The flow configuration includes both radially inward and outward flow in a single combustor, for now.

The present report focuses on the assumption of radial inward flow configuration, which can be simplified to the radial outward flow as well.

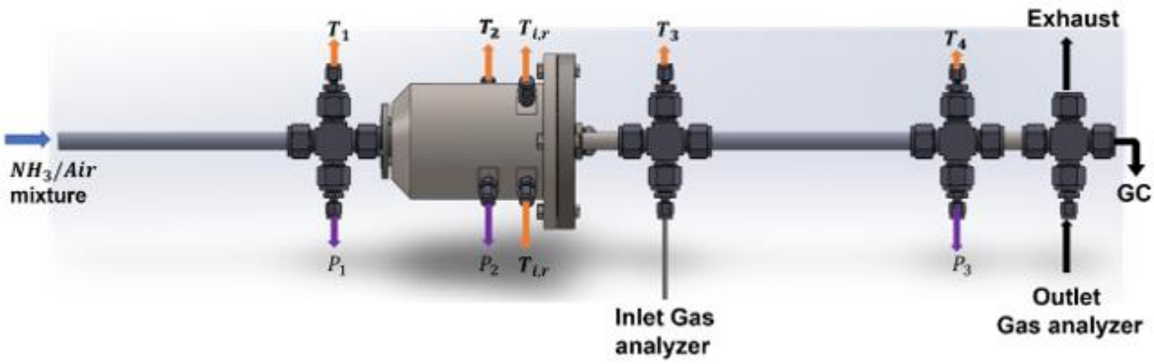


Figure 1 : Porous Media Combustor Design

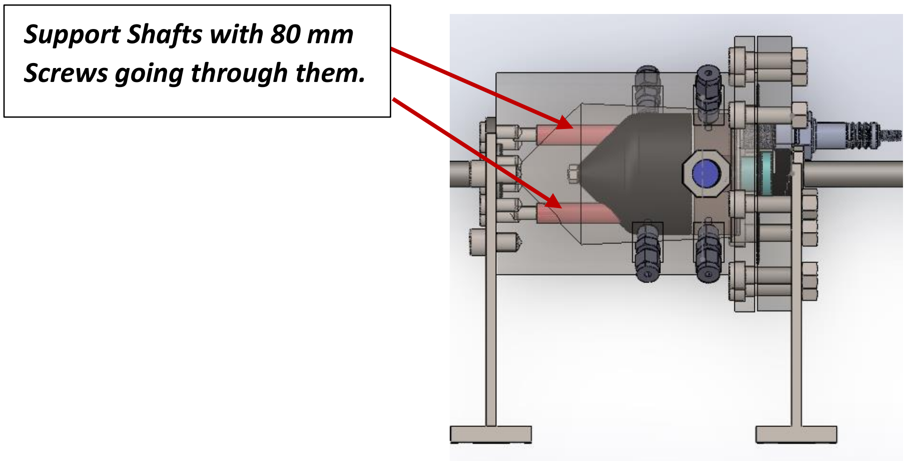


Figure 2: Porous Media Design (Side View)

To support the overall inner structure composed of the black cone and the radial outwards cone, support shafts of 60mm with 80 mm screws inside have been designed with specific length tolerances to let the porous media fit and sit on the setup after screwing the flange to the casing.

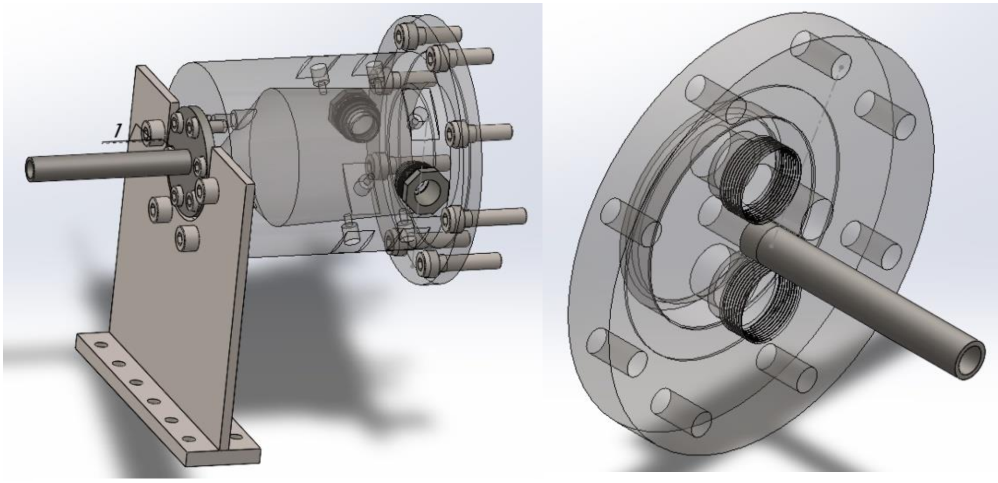


Figure 3: Sub Assembly 1 & 2 of the Burner

To be able to manipulate and change configurations, two sub-assemblies were designed to make it easier to disassemble the combustor. Indeed, sliding stands will be on each side of the assembly to separate the Flange to the overall assembly (Casing+Screws+Cone+Foam).

Experimental Procedure

The experimental procedure includes the following steps:

- Set up the experimental test facility according to the designed diagram.
- Measure the temperature distribution, pressure drop, and gas emission characteristics using a gas analyzer and gas chromatography.
- Control the flow rates of fuel and air using a mass flow controller to ensure the equivalence ratio of test conditions.
- Instrument the burner with a NI c-DAQ control system to measure pressure and temperature.
- Conduct the experiment with the assumed radial inward flow configuration.
- Analyze the experimental data to determine the combustion characteristics of pure ammonia burning using porous media burners.

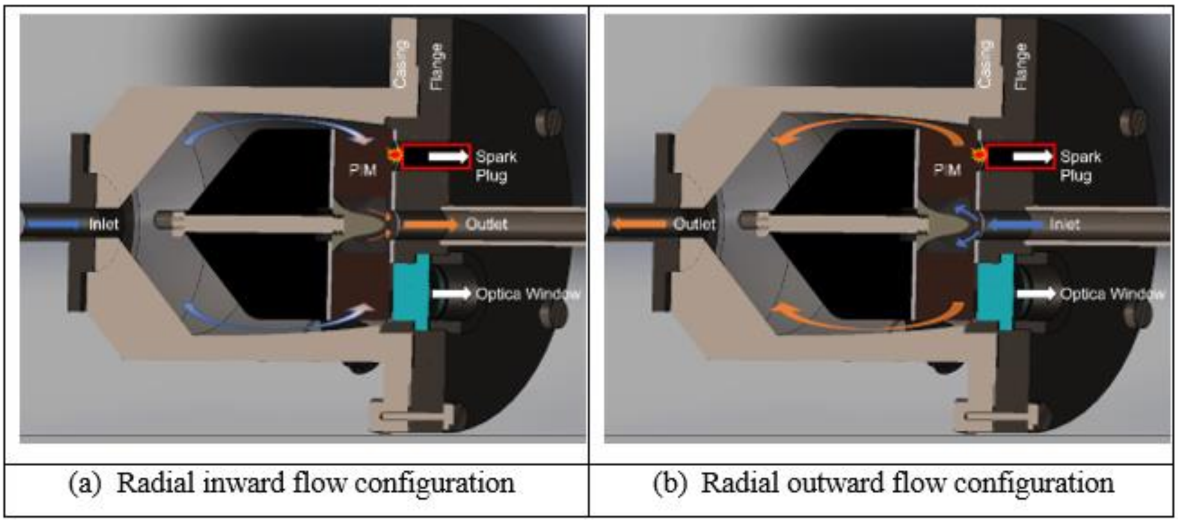
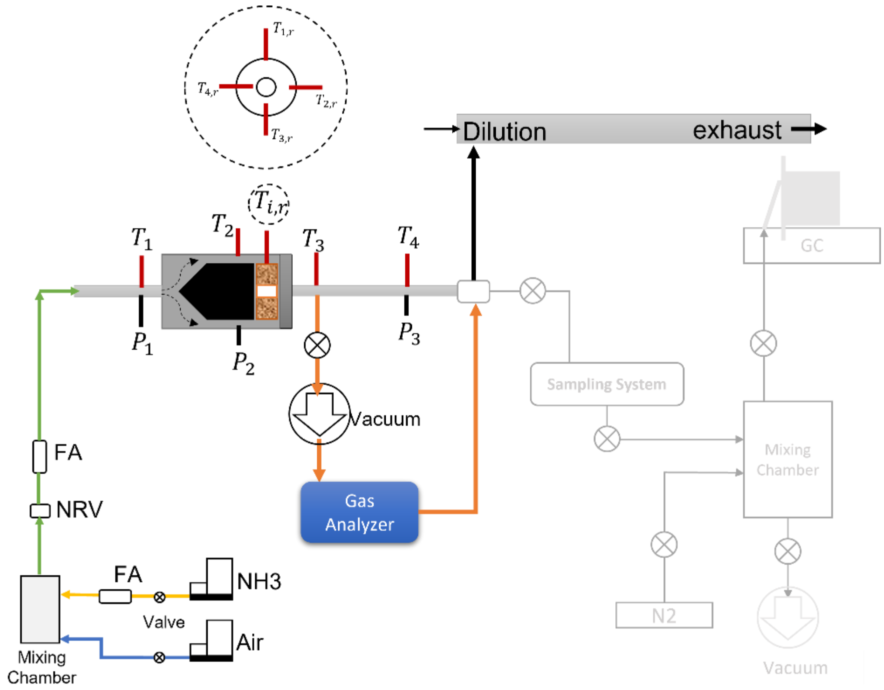


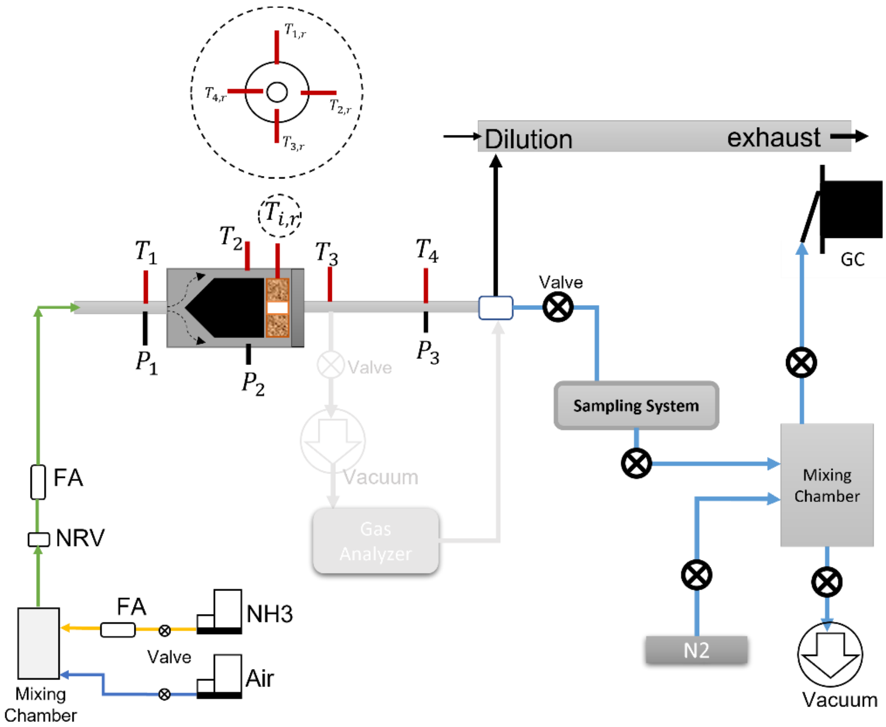
Figure 4: Cross sectional view of the combustor

As you can see, the inner diameter of the Casing was imagined having a linear deflection, from the Inlet towards the outlet of the setup. This was suggested as an upgrade to the previous design which now helps with the pressure drop of the mixture, in the chamber.

To ease the flow distribution in the chamber, during Radial Outward flow Configuration, a small cone, that is in the porous medias inner diameter, was added. A small shaft, bolted from the other side and going through the black cone, was added to support this structure.



(a)



(b)

Figure 5: A tentative schematic diagram of experimental setup (a) Using a Gas analyzer, (b) Using a Gas Chromatography (GC)

Assembly Instructions

To assemble the burner the following shall be done,

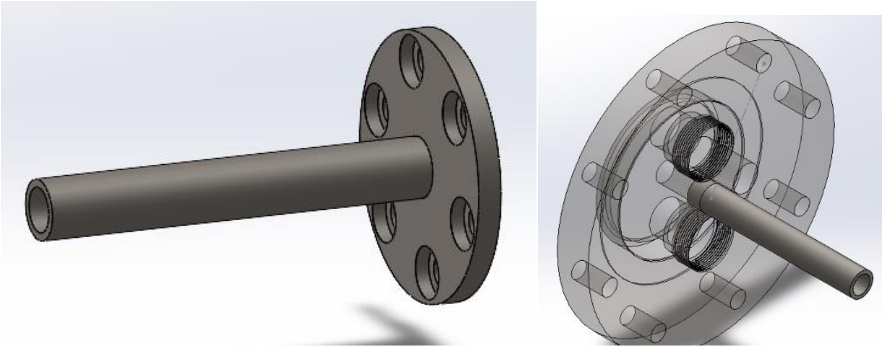


Figure 6: Sub assembly of Inner & Outer Flange

A ½" inch pipe will be welded to a small chamber in the Inner and the Outer Flange, to leak proof the setup.

Attached to this word document is a .AVI File of the complete disassembly of the burner. For further details, check out the file named: ***Assemblyv6_final.avi***

All the parts that compose the burner are made of these 2 materials: Stainless Steel & Steel. The previous materials are chosen for each part, in a way that they alternate from steel to SS steel, to avoid that the parts stick to each other under 700°C burning conditions. The choices of the materials have been declared in the technical drawings.

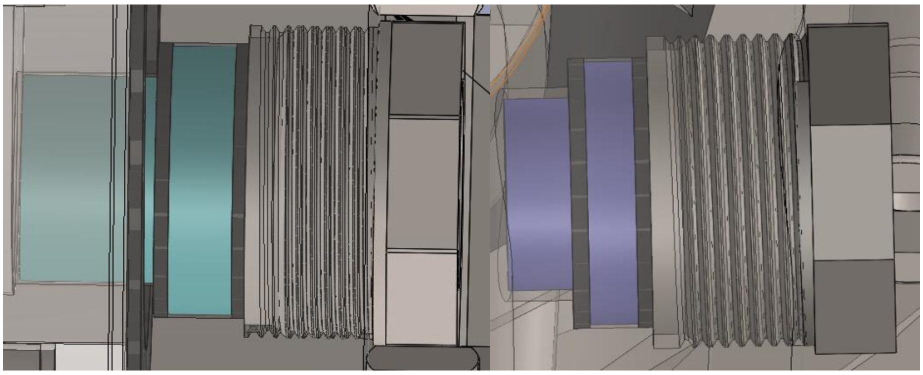


Figure 7: Assembly of the Sapphire Windows on the Flange and on the Casing (respectively)

For both of the Window fittings, an undercut of 2mm was applied for manufacturing reasons. During the project, there was a need to compress the graphite rings that are sandwiching the windows. Both the graphite rings had a compressibility ratio of 1 μm combined. In the case of the Casing, the pressing on the graphite rings was applied on the inner surface of the Casing, after the threading of the Seal (Red line above). In the Flanges case, the pressing was made on the outer surface of the Flange, before the threading of the Seal. (Red line above)

Results and Discussion

The results of the experiment will potentially provide insights into the combustion characteristics of pure ammonia burning using porous media burners. The temperature distribution, pressure drop, and gas emission characteristics will be analyzed to determine the effectiveness of the porous media burner in enhancing the combustion of ammonia. The data will be compared with previous studies to validate the effectiveness of the experimental setup.

Limitations

One of the limitations of this project is the lack of information on the optimal porous media configuration for enhancing the combustion of pure ammonia. Further research is required to determine the most effective porous media configuration for pure ammonia burning. Additionally, the safety risks associated with the combustion of ammonia need to be addressed to ensure the safety of the experimental setup, as well.

Conclusion

In conclusion, the experimental demonstration of pure ammonia burning using porous media burners is a promising area of research that has the potential to become a significant source of clean energy. The experimental setup includes measuring temperature distribution, pressure drop, and gas emission characteristics using a gas analyzer and gas chromatography. The flow rates of fuel and air are controlled using a mass flow controller to ensure the equivalence ratio of test conditions. The results of the experiment will provide insights into the combustion characteristics of pure ammonia burning using porous media burners, which can be further optimized to enhance the combustion efficiency of ammonia.