Section IV: Discussion

The work at present aimed to address the fundamental need for improved injection processes within the rotating detonation engine as well as a simplified and standardized method for determining the success of injector schemes using novel homogeneity quantification analysis strategies. This project aimed to configure a two-dimensional computational model of the rotating detonation engine, construct a simple mixing analysis for radial, axial, and triplet injection schemes, and iteratively adjust injection variables to increase fuel-air proportional equivalence. In pursuing the described methodology, all these objectives were achieved.

Two-dimensional computational models for each tested existing injection scheme were developed, utilizing standardized parameters from previously completed works. Transient, density-based CFD simulations were employed to predict fluid flow in different injector variations to determine the most effective configuration that produces a homogenous fuel-oxidizer mixture. From this, the axial-triplet injection scheme was advanced and acted as a base foundation for improvement of mixture homogeneity in a short-term iterative phase. In doing so, the newly developed injection scheme improved mixture homogeneity by 2.3% and reached a level of 99.2% density-based homogeneity. This improvement in fuel-oxidizer homogeneity can facilitate a complete, powerful consumption by cyclical detonation waves to improve thrust and thermal efficiency of the engine.

This work introduces novel methods for injection modeling based upon parameters used in previous works. The limitations of this model include limited integration with larger-scale RDEs, which are to be used in rocketry and stationary energy generation applications, and this model is based upon fundamental simplifications to enable a fast-paced iteration process. Throughout this project, countless failures and challenges were faced during the computational modeling phase due to inexperience using software and understanding fundamental fluid dynamics concepts. However, these challenges were addressed by seeking advice from field experts and validating results with previous research.

In pursuing this research, the improved triplet injection scheme and thorough iterative methodology can be applied to aerospace and rocketry, ventilation systems, and stationary energy generation. This study effectively evaluates injector scheme performance in a novel way, utilizing homogeneity measures rather than comparing complex detonation wave parameters to optimize levels of combustion. In utilizing this simplified model, wider research surrounding injection geometry can be pursued, while the results presented may be reinforced using the commonly studied detonation wave characteristics to define injector scheme effectiveness.

Future Research

To continue efforts in enhancing mixing and general experimental RDE efficiency testing, this work can be furthered by implementing a passing detonation wave and validating the results found in this simplified model in real-world environments. In addition, more iterative adjustments may be made with other injection variables, including mass flow rates, plenum pressures, or specified fuel-rich or fuel-lean regions within the detonation channel. To further validate the applicability of this work, it is important to investigate the applications and implications of simplified research configurations.

Section V: Conclusion

Through the iterative adjustment of injection-specific variables, the objective of reducing mixture inhomogeneities in rotating detonation engine detonation channels was successfully achieved. This study introduces a novel method for comparing injector geometry performance, utilizing a simple computational mixing model to better understand how variable adjustments contributed to the injector's effectiveness. In pursuing this methodology, fuel-oxidizer mixture homogeneity was improved by over 2%, reaching high levels of homogeneity relative to existing injector schemes. With the stated improvements, this research holds applications in improving combustor efficiency by promoting consumption of fuel within the chamber. RDEs, being one of the most exciting developing technologies, could have the opportunity of replacing existing propulsion and energy-producing systems, with this study bringing modern propulsion research closer to achieving experimentally optimal levels of thrust and power to be applied in an interplanetary future.