Pressure Characterization of NASA Great Horned Owl (GHO) Combustor

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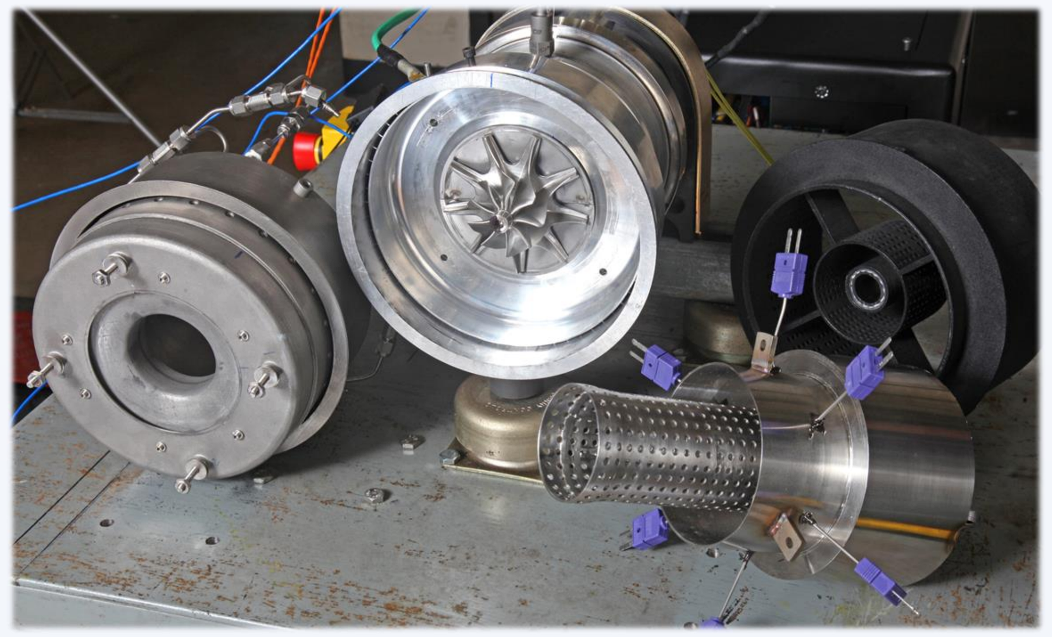
ABSTRACT

As part of the Great Horned Owl (GHO) program, Southwest Research Institute (SwRI) developed an innovative 7kW gas-turbine generator for Unmanned Aerial Vehicles (UAVs), focused on advancing UAV power systems by meeting weight, fuel efficiency, and noise goals. Previous testing in 2021 revealed that the current design could not meet the performance goals of low-pressure drop and flame stabilization.



To address these issues, this research investigated the combustor design and conditions through physical measurements, computational fluid dynamics (CFD) modeling and analysis, and additional experimental cold flow testing. Geometric discrepancies were identified as a primary cause of pressure loss, leading to a new CFD model (Ver2) and proposed design improvements. The findings provide insights for future combustion system enhancements.

OBJECTIVES

The primary objectives of this research were to:

- Characterize the combustor's pressure drop and
- Use information to propose design improvements for the annular gas turbine combustor

METHODOLOGY

The method used to characterize pressure drop across a combustor involved an investigation of analytical and experimental analyses. Initial testing in 2021 encountered challenges with lightoff, prompting the need to understand previous cold flow data, previous CFD (Ver1) cold flow analyses, and physical measurements of the combustor geometry.

Thus, cold flow predictions were evaluated and analyzed to reflect the pressure drop and the flow patterns.

Previous cold flow tests served as the benchmark for the subsequent CFD (Ver2) analysis to be used for a comparative assessment and help identify areas for potential CFD model enhancement.

Findings from the analysis revealed discrepancies within:

- Inlet and outlet pressures between 2021 Cold Flow and Ver1 CFD
- Liner orifice diameter sizes between Ver1 CFD and measured actual average

BOUNDARY CONDITIONS

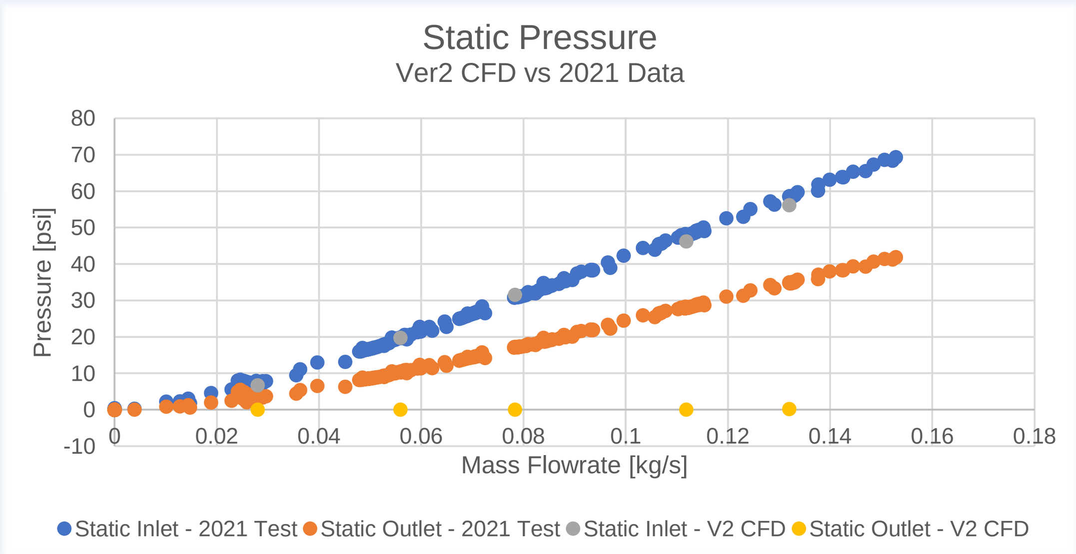
The pressure loss throughout the combustion chamber reflects the airflow distribution, as air moves in the direction of decreasing pressure. Therefore, the pressure loss must be decreasing to maintain desired flow and reduce the risk of overheating and damage to the turbine blades. The pressure loss depends on many parameters, especially the chamber design and working gas flow rate. The table below presents the system conditions replicated by the test rig ordered by the turbine operational speeds.

Speed [rpm]	Mass Flow [kg/s]
25000	0.0280
50000	0.0559
70000	0.0783
100000	0.1119
118000	0.1320

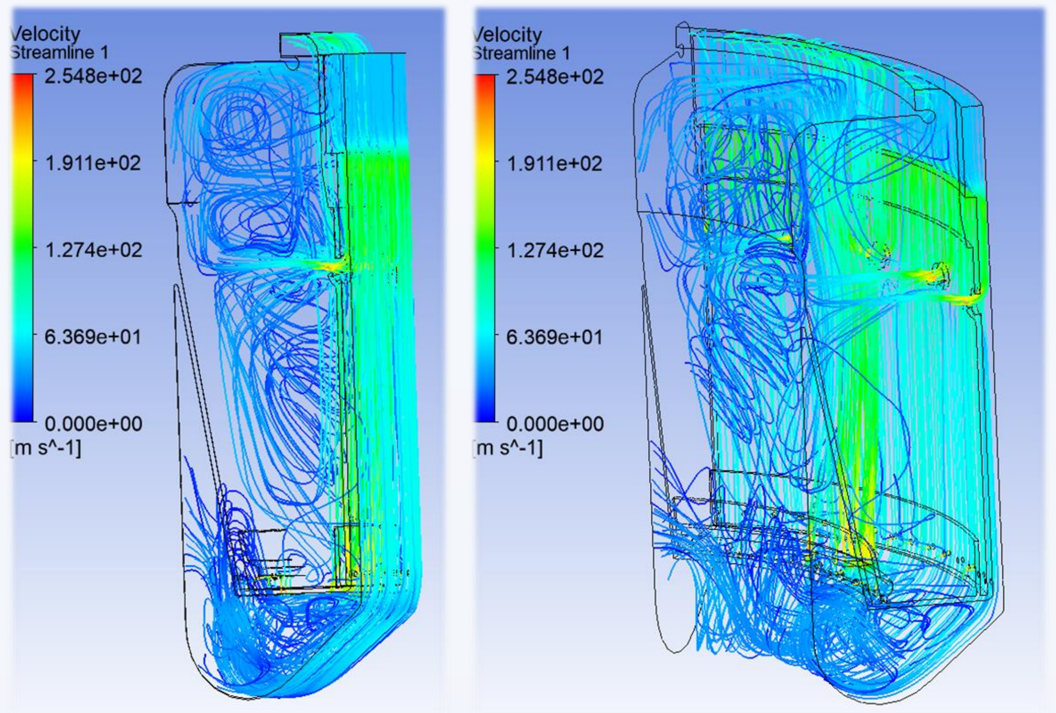
Continuing with the investigation into pressure loss throughout the combustor, specific areas of interest were chosen as the inlet and outlet of the combustor.

RESULTS

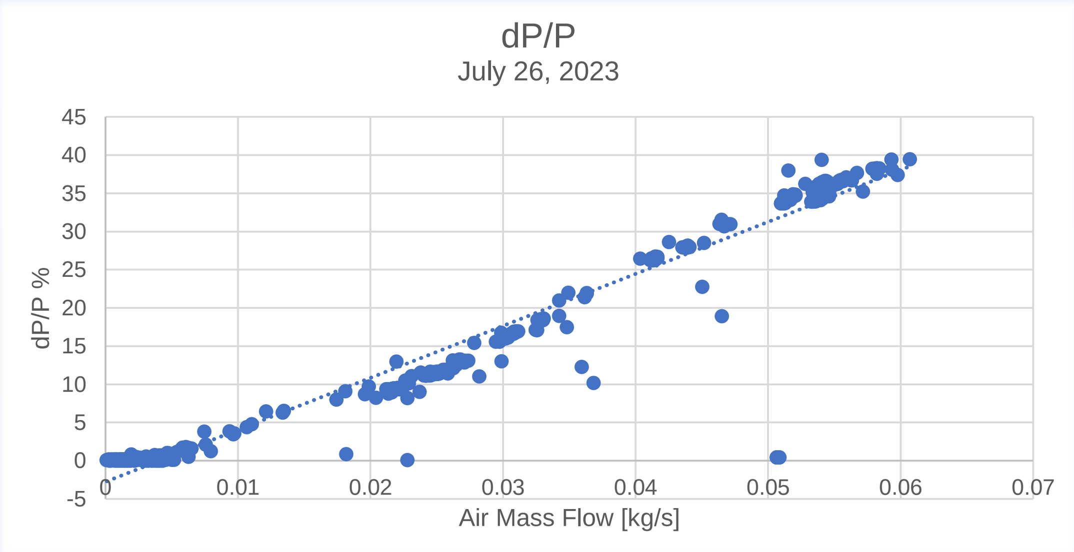
By introducing the refined geometry in CFD Ver2, the accuracy of the combustor's representation was significantly improved, leading to more reliable results and valuable insights for future design and analysis, as shown in the figure below.



The results revealed the input static pressure matched the experimental data, which shows the potential use for this model to make predictions. While the model was unable to produce comparable results for the outlet pressure, the inlet pressure results are deemed to be a great sign and can predict the combustor and its behavioral response within given conditions. The following figure reveals the simulated velocity streamline of the combustor.



Additional cold flow tests were conducted to validate the findings from the CFD simulations and previous testing and to gain more comprehensive insights into the complex flow behavior within the combustor. This testing integrated both static and differential pressure probes. The combination enabled the calculation of dynamic pressure, providing a more comprehensive overview of the flow behavior. The calculated dP/P values obtained from the DAQ are outlined below.



The collective outcomes derived from these refined tests and analyses are as follows:

- Measured liner hole sizes significantly smaller than designed due to manufacturing tolerances with DMLS process
- New CFD matches pressure drop predictions to previous test data
- CFD predicts deep jetting from undersized cooling holes and impingement on far liner wall. A liner re-design will be necessary
- Measured cold flow dP/P was higher than predicted in previous testing due to suggested deep jetting

CONCLUSIONS & FUTURE WORK

This research has made significant strides in understanding the intricate interplay between pressure drop, cold flow dynamics, and CFD simulations in the GHO combustor system. The comprehensive approach, incorporating both experimental data and advanced simulations, has paved the way for future advancements in the combustion system design. By addressing the identified issues and implementing the proposed liner redesign, future work may aim to enhance combustion efficiency and ensure sustained performance and reliability. SwRI plans to use the GHO machine for instrumentation development, as a test bed for new technologies such as ceramic or additive manufactured parts, and as a component in a hardware-in-the-loop system.

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