Undergraduate Thesis Prospectus

Particle Image Velocimetry Analysis of Turbulent Counterflow Flames in High Pressure Extinction Conditions

(technical research project in Aerospace Engineering)

Regulatory Barriers to Civil Air Travel

(STS research project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How can civil aviation become more accessibly in the United States?

Air travel is the fastest and safest method of long-distance transportation, shuttling 2.4 million people and 58,000 tons of cargo on United States airliners every day and accounting for over 5% of U.S Gross Domestic Product (Airlines For America, 2019). Yet, a 2018 survey reported that over half of Americans had not flow in the previous year (Jackson, 2018), and air transport is a mere .035% of U.S. domestic cargo transport by weight (Bureau of Transport Statistics, 2019). Technical and social factors limit the accessibility of civil aviation, including fuel economy, noise pollution, environmental impact, regulatory barriers, public perceptions, and economic inequality.

Particle Image Velocimetry Analysis of Turbulent Counterflow Flames in High Pressure Extinction Conditions

How can particle image velocimetry analyze extinction limits of high pressure turbulent counterflow flames?

This is an independent, solo project conducted in the Aerospace Engineering Department with direction from reactive flow laboratory principal investigator professor Harsha Chelliah. University of Virginia alumni John Wilder agreed to assist with conducting research.

Efficient gas turbine engine design requires high accuracy computational simulation before full scale development. Presently, there is limited literature on the high pressure turbulent flame conditions for computational model basis. As stated by Geyer, Kempf, Dreizler, and Janicka (2005), there exists a significant need for continued turbulent combustion studies focused on flame characterization. Continued experimentation into near extinction and extinction limits of high pressure conditions will allow for higher accuracy modeling of experimental gas turbine engine combustors. Higher accuracy models will allow for the development of higher efficiency gas turbine engines.

Sarnacki, Esposito, Krauss, and Chelliah (2011) emphasize the importance of local flow strain rates relation to extinction and turbulence characterization of the flame structure. The local strain rate and turbulence intensity act as quantifying values for the flame condition. These values can be determined from measurements of the velocity profile of the flow structure surrounding the flame (Boldman & Brinich, 1977). Sarnacki, Esposito, Krauss, and Chelliah utilized a particle image velocimetry (PIV) system to analyze the velocity profile of the flow structure around a flame in a high pressure counterflow burner. Their experiment analyzed low pressure, laminar extinction conditions of ethane, ethylene, propane, and n-butane flames.

Method of Experimentation

The same PIV system and burner used by Sarnacki, Esposito, Krauss, and Chelliah will be used for this project. The counterflow burner, designed by Hazelgrove, Le, and Levick (2010), utilizes conservation of momentum to create a stationary flame in the center of the burner. A pair of co-annular nozzles aligns pressurized gas jets. The internal set of nozzles eject air and fuel, and the external set eject nitrogen for shielding purposes. The internal set is also connected to nitrogen to conduct dilutions necessary at high pressures. The burner has three quartz windows to allow for PIV laser introduction into the system and camera observation. A fourth side plate hold a pressure sealed ignitor.

The PIV laser sheet (at 532 nm wave length with two pulses 10 ns apart) with particle seeding from the airside jet will facilitate measurement of the two-dimensional flow field between the opposed jets. In previous work, the same laser system with an intensifier and optical filters rather than seeding particles was used to quantify the amount of soot generated by the flame. Typically, 50 velocity images are used to obtain the velocity field for a laminar case. For turbulent flames, a higher number of velocity images are needed to quantify the mean and fluctuating velocity components.

The goals of this project are the confirmation of PIV system accuracy (reproduction accuracy of published low-pressure regime flow characterizations) and the collection of high-pressure regime turbulent flow characterization at near flame extinction and flame extinction conditions for an ethylene-air flame. The limiting pressure constraint is a 30 atmosphere test pressure. This is the pressure safety limit of the counterflow test apparatus. The limiting fuel constraint is ethylene given the safety concerns of storage and use of industrial jet fuel.

Regulatory Barriers to Civil Air Travel

How do critics of FAA regulations advance their agendas?

In the imbalance of power between U.S. civil aviation and its regulator, the Federal Aviation Administration (FAA), critics contend FAA has the advantage. The FAA is the only regulatory agency in the 21st century to have completely stopped all daily activities of the industry it regulates. Following attacks of September 11th 2001, FAA grounded all non-military aircraft for public safety (Donnelly, 2001). This necessary safety precaution set a precedent of extraordinary regulatory authority. 18 years later, U.S. civil aviation remains exposed to regulatory abuse.

Under the cover of due commitment to the safety of the public, the FAA can take advantage of emerging threats to excuse bureaucratic overreach. In a regulatory battle between the FAA and drone developers and users, the Commercial Drone Alliance (CDA), a trade association, contends FAA is excessively limiting the market. The Commercial Drone Alliance argues that “saying ‘no’ to UAS is saying ‘yes’ to the alternative” (West, 2018). Some consumers agree. The FAA posted a series of YouTube drone safety videos which were received poorly by drone enthusiasts. Their views are summed up succinctly by commenter Jones Drones (2019): “‘Your drone should never operate’ <---True FAA Feelings.” FAAs State and Local Regulation of Unmanned Aircraft Systems (UAS) Fact Sheet (FAA, 2015) solidifies the FAA’s position: “Unmanned aircraft systems (UAS) are aircraft subject to regulation by the FAA to ensure safety of flight, and safety of people and property on the ground.”

Regulatory Inefficiency

The Airline Deregulation Act of 1978 substantially deregulated U.S. civil aviation (ADA, 1978). The act permitted airlines to establish independent routes subject to FAA approval, and to retain responsibility for engagement in competitive pricing. FAA retained responsibility for safety regulations. 40 years of increasing regulations followed as FAA adopted safety standards to aviation innovations. In 2014 the Mercatus Center of George Mason University found that air transportation was the 6th most regulated industry in the United States (Ubaydli & McLaughlin, 2014).

Airlines for America (AFA), an airline trade association, and General Aviation Manufacturers Association (GAMA), an association of manufacturers, regard FAA safety regulations as excessive. According to AFA, many FAA regulations are “unnecessary and costly” and limit “jobs and… economic growth” (AFA, n.d.). Similarly, GAMA petitioned

Congress to remove “unneeded barriers to aircraft certification” warning that inaction would “weaken our nation’s aviation leadership” (GAMA, n.d.).

In a 1986 investigation of FAA, a National Research Council concluded: “On balance, it is not possible for the Committee to determine the facts concerning the effectiveness and adequacy of FAA enforcement and inspection” (NRC, 1986). Given the three subsequent decades of increasing regulation, a second study of the FAA’s regulatory efficiency is advised.

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