Lean Blowout Working Group Update

Motivation and Objectives

Lean Blowout (LBO), a combustor stability limit, is a key criteria for alternative jet fuel certification.

The LBO WG aims to predict possible deleterious LBO behavior of alternative jet fuels via identifying the limiting physical process and properties. This identification is done through experimentation of various NJFCP fuels in various rigs at appropriate conditions.

Identifying these properties and developing test methods can guide fuel development and help streamline the certification process.

Experimental Methods

Fuels

Category A: Three Conventional (Petroleum) Fuels

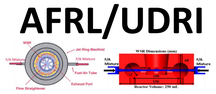
- "Best" case (A-1)
- "Average" (A-2)
- "Worst" case (A-3)

Category C: Nine "Test Fluids" With Unusual Properties

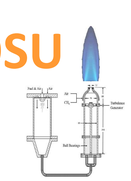
- C-1: low cetane, narrow boiling (downselected)
- C-2: bimodal boiling, aromatic front end
- C-3: high viscosity
- C-4: low cetane, wide boiling
- C-5: narrow boiling, full fuel (downselected)
- C-6 and C-6a: high cycloparaffins (not available)
- C-7 – blended fuel with maximum achievable cycloparaffins (~62 vol%)
- C-8 – blended fuel with maximum aromatics (25 vol%)
- C-9 – modified alternative fuel that has maximum DCN (63)

Rigs

AFRL/UDRI

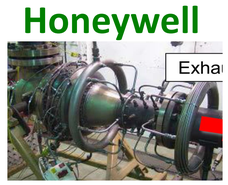


OSU



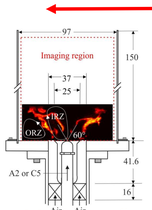
NASA

Honeywell

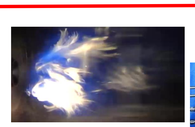


More fundamental

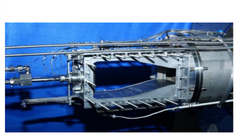
More "Product-like"



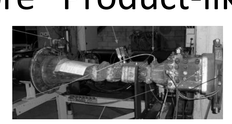
Univ. of Cambridge



Georgia Tech

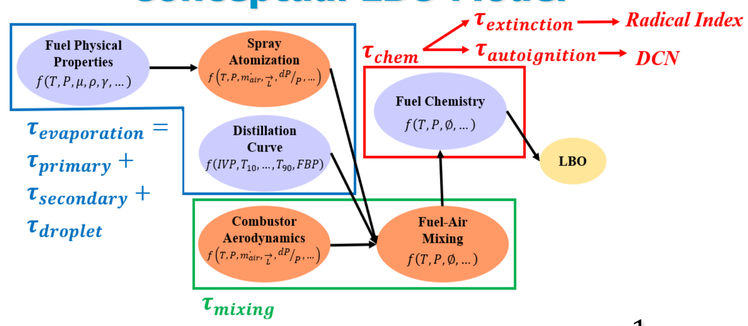


AFRL/UDRI Referee Rig



Univ. Sheffield

Conceptual LBO Model



$$\phi(LBO) \sim \left(\frac{1}{\tau_{chem}} + \frac{1}{\tau_{evap}} + \frac{1}{\tau_{mix}}\right)^{-1}$$

Two time scales relate fuel properties to LBO:

- $\tau_{evaporation}$
  - The summation of break-up and droplet characteristic times.
- τ_{chem}
  - The characteristic time for extinction and autoignition to occur.

Fuels can be difficult to atomize and evaporate (long $\tau_{evaporation}$) or extinguish and take too long to autoignite (long τ_{chem}).

Summary

Previously, we showed that all but one LBO experiment showed first-order DCN dependency (τ_{chem}). The only rig that did not show this dependency was the Honeywell Auxiliary Power Unit rig, which showed a strong dependency on distillation properties and viscosity ($\tau_{evaporation}$).

Cold fuel and air experiments in the Referee Rig have recently shown the same distillation and viscosity property dependency ($\tau_{evaporation}$) which corroborates earlier hypothesis.

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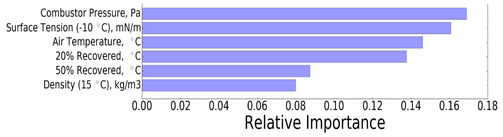
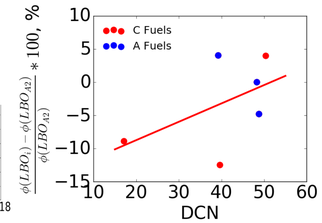
Results and Discussion

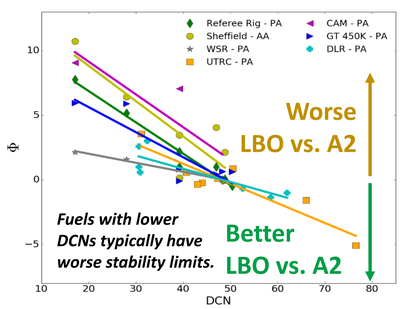
Evaporative Time Scale Limited LBO ($\tau_{evaporation}$):

3 rigs that examine LBO limits show first order DCN dependence; Honeywell, Referee Rig (low temperature), and GE9X (lower T and dP/P).

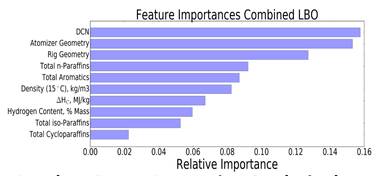




Chemical Timescale Limited LBO (τ_{chem}):



10 rigs that examine LBO limits show first order DCN dependence.

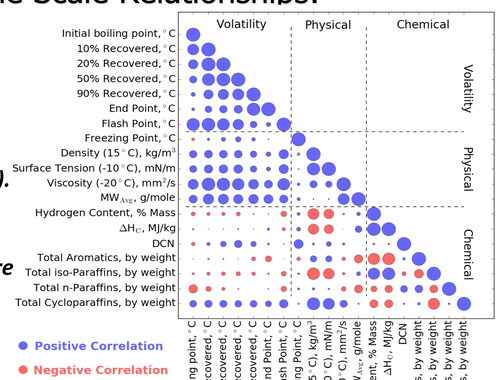


Random Forest Regression Analysis show that the derived cetane number, DCN, of a fuel is the best predictor of the stability limit of a fuel.

Fuel Property Time Scale Relationships:

For cold conditions and small injectors, volatility properties such as the 20% recovered temperature are the most important for LBO ($\tau_{evaporation}$).

For hot conditions and large injectors, chemical properties are the most important for LBO (τ_{chem}).



Pearson Correlation of Category A and C fuel properties. Marker size scales with the absolute Pearson Correlation between fuel properties, from zero to one. Positive correlations are marked in blue while negative correlations are marked in red. The properties are further broken down into volatility (distillate), physical, and chemical properties.

Conclusions and Next Steps

The previous hypothesis of dilating evaporating evaporation time scales is corroborated with recent cold LBO data in the Referee Rig.

AIAA Book Chapter writing in progress,
Additional test campaigns are in progress, and
Several archival papers are in progress

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