Alternative Aviation Fuel Chemistry-Performance Correlations Towards a Sustainable Future

PURDUE UNIVERSITY Discovery Park
NEPTUNE CENTER FOR POWER AND ENERGY RESEARCH

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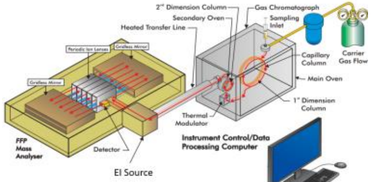
Goal: Establish a databank of conventional and alternative aviation fuel constituents to be utilized to develop correlations between chemical composition, engine performance, and material performance. We also aim to seek further opportunities to collaborate with US military personnel.

Composition ⟷ Property ⟷ Perfomance

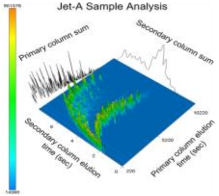
Dimension 1:

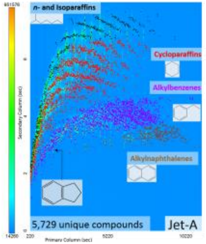
Thousands of molecules, most of them unknown, make up the currently used jet fuels. Using an advanced analytical separation method, two-dimensional gas chromatography coupled with high-resolution time-of-flight mass spectrometry (GC/GC/TOF/MS), compound classes in conventional and alternative were identified and molecular structures of the compounds were determined.

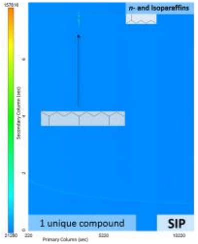


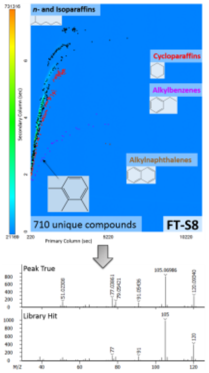
Method:

Compounds in complex fuels were separated using GC/GC with separation technique based on boiling point and polarity. The GC/GC separation of Jet-A is plotted on blue background on the left. The black outlines show separations obtained using only one column.





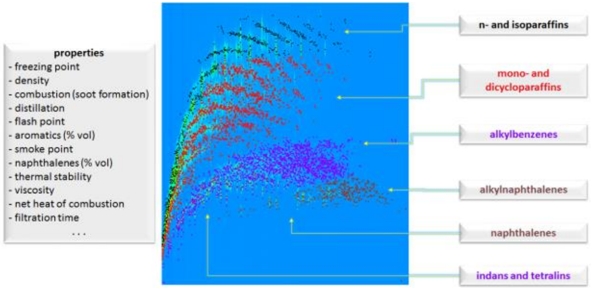




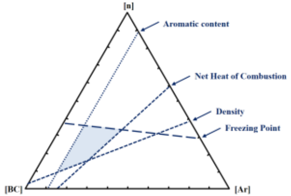
Dimension 2:

An increasing number of blending components are getting approved as an alternative pathways to enable the deployment of aviation "drop-in" fuels. This challenge has been recognised since 1980s. It is a highly agreed upon consent that fuel composition affects the performance. However, the way this relationship works is still a "black box". We aim to de-mystify the pertinent steps. Our focus is fuel property analysis based on chemical constituent identification. Consecutive benefits in terms of cost and time saved throughout the fuel approval process are predicted to be greatly significant which will serve as the much needed incentive for future alternative fuels manufacturing.

Property-composition relationships:



Hydrocarbon groups dependence on fuel properties and its complexity



weight fractions of: n-alkanes [n], branched plus cyclic saturates [BC], and aromatics [Ar]

The representative constituents of jet fuel

Dimension 3:

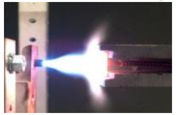
The gas turbine engine is of the utmost importance for generating electrical power and/or thrust in Naval aircraft. The hot sections of gas turbines are typically comprised of superalloy turbine blades; many of which have additional thermal protection provided by a ceramic thermal barrier coating or TBC. Both the superalloy blades and TBC can be attacked by corrosive species found in the environment and individual constituents of CMAS that can come from biofuels.

Simulating how impurities interact in the gas turbines:

Spray process of CMAS primary constituents found in biofuels

Simulation of gas turbines hot section through ablation

1.-Gas turbines operate at 1300ºC-1400ºC; always trying to increase temperature for efficiency gains; ablation process simulation capability is up to 2200ºC when testing TBCs.
2.- The developed process simulates how impurity atoms come into a gas turbine after burning thousands of gallons of fuel.



Microstructure comparison due to the effect of Biofuel impurities

1.-For engine temperatures greater than 1250ºC, Biofuels impurities melt and infiltrate the TBC resulting in delamination.
2.-Biofuel impurities cause macroscopic delamination and microstructural changes.