Tools for the prediction of alternate biofuels for aerospace applications

Kendal Bushe

Summary:

We are developing computational fluid dynamics models for the turbulent combustion of biofuels in the aerospace engine context. The phase of the work we are at right now is that we need to be able to include predictions of particulate matter formation and emission, and we need to be able to estimate the effects of heat transfer with cold surfaces inside the combustor, in addition to predicting the impact of varying the fuel composition on the pollutant emission rates and performance of engines running on these biofuels.

About the projects

While one can imagine stationary power solutions like hydro, solar, geothermal, wind, etc. in the future, and while one can imagine battery solutions for land-based modes of transportation, and one can even imagine battery solutions for short-haul flights, one cannot imagine a functioning electric solution for long-haul flight: the power density one can achieve with batteries is just way too low. So we are likely to be using bio-fuels for aerospace applications in the medium- and even long-term. The current efforts to make bio-fuels for aircraft are, frankly, extremely myopic - almost like the plan is to address the next quarter and not the next quarter century: they are trying to develop bio-sourced drop-in replacements for the existing fossil fuels. The production of these fuels is extremely inefficient, expensive and has a very low yield. I say this is myopic because, in my view, it's obvious that, 50 years from now, we don't want to still be trying to match the combustion properties of whatever comes out of the refinery on the distillation curve of crude oil ... when we no longer use crude oil for anything (hopefully)!.

If we go back to the drawing board and consider fuels that would conceivably work for aircraft, we want a fuel that has no carbon-carbon bonds (carbon-carbon bonds lead to particulate matter formation during combustion, and we want to minimize that at the source, having no opportunity for after-treatment in a jet engine). We need the fuel to be liquid at STP, although we could tolerate having to have a modest pressure in order to keep the fuel a liquid. The best fuels are likely to be methanol, dimethyl ether (DME) or polyoxymethylene dimethyl ethers (OMEs). These are relatively easy to make from biological feedstocks with high yield and high efficiency (or so I've been lead to believe!).

We know these can burn; we don't know what running existing jet engines on these fuels will do to the engines or to the emissions - in the case of the latter question, we're pretty sure this will be a very good thing, reducing both particulate matter emissions and emissions of oxides of nitrogen, both of which either immediately or after subsequent reactions in the atmosphere, lead to worse warming effects than CO2.

What we need is a tool that we can use to estimate what the effects will be - a tool we can use in the design of future engines. That tool would be CFD and one of the most critical components of the CFD code will be the model used to estimate the effects of turbulence on the chemical reaction rates inside the combustion chamber. That's where this work comes in. We have developed a model for how turbulence and chemistry interact and we have been testing this against many different laboratory-scale flames with great success.