Aircraft Fleet Design and Operations to Reduce the Environmental Impact of Civil Aviation

Geoffrey Bower
Advisor: Prof. Ilan Kroo
Aircraft Aerodynamics and Design Group

Introduction

The environmental impact of today’s civil aircraft fleet is typically examined with respect to three externalities: noise, local air quality, and climate change. In the long term, it is generally agreed that climate change is the most important and costly externality. Air traffic growth typically mirrors growth in gross domestic product, at about twice the annual percent increase. Figure 1 below shows the expected air traffic growth through 2025 as projected by Boeing^1.

Alternative Fuels

As the price of kerosene rises and availability comes into question, aircraft designed to use alternative fuels will be required. In the short term, fuels with the most promise are synthetic kerosene and bio-butanol. Both of these fuels have similar properties to kerosene and will require few changes to aircraft.

In the long term, the use of cryogenic liquid hydrogen (LH\textsubscript{2}) is most likely. LH\textsubscript{2} has three times the energy density of kerosene, but $\frac{1}{4}$ the density for the same energy content. This leads to aircraft that are volume limited. An advantage of LH\textsubscript{2} aircraft is the lack of CO\textsubscript{2} emissions; the only combustion products are H\textsubscript{2}O, NO\textsubscript{x} and some particulates.

Future Work

The degree to which these design and operational changes reduce the environmental impact requires further research. It is not clear what measure indicates minimum environmental impact. There are a number of common measures used, but none are universally accepted.

A design framework is needed to evaluate these changes at a concept design level. Past research at Stanford has used the PASS aircraft synthesis tool to evaluate some trades between environmental impact and cost\(^2\).

To assess the civil air network level performance these tools need to be modified and expanded. Higher fidelity noise and emissions predictions need to be incorporated, as well as air traffic network analysis and the ability to handle alternative fuels such as liquid hydrogen.

The problem is also well suited to the use of multi-fidelity analysis tools and hierarchical decomposition approaches to optimization. Ultimately, this research will lead to civil aircraft design concepts with reduced environmental impact.

References