DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

The Aviation Fuel and the Passenger Aircraft for the Future – Hydrogen

Task for a *Master Thesis*

Background

Our planet is a finite entity and as such also energy stored on it is finite. Our planet offers carbon-based fossil fuels (coal, oil, and gas) ready to be used. Burning these fuels releases CO2 into the finite atmosphere of our planet which leads to global warming. The question is simply, if taking from one limited reservoir and releasing into another limited reservoir may empty the first reservoir or may overfill the second reservoir within the foreseeable future. Whatever happens first (a reservoir being empty or overfilled) will be the limiting factor for the system. What will happen first? We live in a growing fossil fuel economy where emptying and filling takes place at an increasing rate. At what speed do we want to approach the inevitable. The question is will fossil fuel get too scarce and thus too expensive to be used? Or will CO2 levels reach climate effects (droughts, flooding, severe storms) the earth's growing population cannot cope with? Air transportation is one part of the growing carbon economy and has to carry its share in problem solving. The related research question for aviation is here: What is the best fuel strategy for passenger air transport in a post-fossil fuel era? In a post-fossil fuel era energy will come from renewable energy (wind, solar, bio-mass ...). Most forms of renewable energy (wind, solar ...) will be available primarily as electricity. Electrical energy could be stored in batteries; alternatively, energy could also be converted into a chemical form (gaseous or liquid fuel) to be stored on board. Other forms of renewable energy (like bio mass) could be converted directly to drop-in fuel. The best fuel option for passenger aircraft becomes visible only if aircraft are designed with all iterations and snowball effects for the energy option selected. **Three Master Theses have been set up as a trilogy** to investigate this:

The Aviation Fuel and the Passenger Aircraft for the Future –
a) Batteries, b) Hydrogen, c) Bio Fuel, Synthetic Fuel

a) Batteries: In a post-fossil fuel era (regenerative) energy will exist first of all as electricity. To avoid energy conversions (always going along with energy losses), it

makes sense to try direct storage and use of electricity. But batteries are heavy – a contradiction to the first rule in aircraft design: "Watch the weight!"

b) Hydrogen: Hydrogen production from electricity is simple through electrolysis and today with 70 % already quite efficient. Hydrogen powered aircraft have already been built and have been flown successfully. Hydrogen is a tested technology in aviation that will work. It makes sense to look again at this concept with new ideas to limit investment and to avoid a bulky aircraft.

c) Bio Fuel, Synthetic Fuel: The best fuel is the fuel we have today. Kerosene has a high energy density by weight and by volume. Drop-in fuels are those renewable fuels which can be blended with today's fuel and can be utilized in the current infrastructure and with existing equipment. Drop-in fuels generally have similar parameters and can be blended at various ratios up to 100 %. The challenge here is with availability of bio fuels compared to the huge demand. In a post-fossil fuel era synthetic fuel will come from a power to liquid (PTL) process based on regenerative energy. Will it be possible to scale up the processes fast enough and to deliver at a compatible price? The challenge here is the fuel and not the aircraft.

Among the three options, **hydrogen may be the most promising alternative** as new aviation fuel due to the high content of energy per kilogram and zero emissions of CO2. However, the combustion of the hydrogen still produces water and NOx. Due to the nature of hydrogen, having a lower density and the necessity of storing it at cryogenic temperatures, important changes in aircraft and airport design are necessary that require high investments. The idea is to lower necessary investments by using a minimum change derivative of the Airbus 320 instead of a new clean sheet design. Promising studies have been conducted before, regarding the feasibility of hydrogen as aircraft fuel. The Cryoplane Project was guided by Airbus Deutschland. The Green Freighter Project was led by HAW Hamburg, studying (among others) a new concept of a hydrogen-fueled freighter based on the ATR 72.

Task

Task of this Master Thesis is to study and analyze a hydrogen-fueled concept based on the A320. The hydrogen-fueled aircraft shall have the same requirements as the original kerosene-fueled aircraft. The subtasks are:

- Data collection and comparison: hydrogen and kerosene as aviation fuel.
- Discussion of the main aircraft design differences: hydrogen and kerosene versions.
- Study of various hydrogen tank configurations for the minimum change derivative.
- Analysis and comparison of hydrogen-fueled aircraft with OPerA.
- Use of OpenVSP for the presentation of the aircraft versions.

The report has to be written in English based on German or international standards on report writing.