RENEWABLE ENERGY SOURCES IN AVIATION

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EXECUTIVE SUMMARY

The following report focuses on our research into using renewable energy sources as an alternative in aircraft operations. The traditional engine and fuel system is outlined to show the criteria that must be considered when changing to a renewable energy source. The environmental factors associated with traditional fuels like kerosene are also included to emphasize the importance of current projects involving renewable fuels. Lastly the report's main focus is on current feasible projects in the field that deal with renewable energy such as using solar and wind energy and/or hydrogen fuels in aircrafts.

The limiting factors that influence the fuel performance are the composition and quality of the fuel. Fuel composition effects range from the weight of the aircraft to organization set regulations to variations in flying conditions. Distribution considerations such as tank settings and filtration systems are used in preserving fuel quality by limiting contamination.

Hydrogen is a renewable resource, and is focused on because of its abundance in the environment. It can be used in fuel cell setting or as a jet fuel. The main benefit is the absence of emissions associated with this renewable fuel source. The drawbacks are the lower mass to heat ratio associated with hydrogen compared to the kerosene values. Safety considerations are a big advantage in hydrogen processes, as it is less volatile than kerosene and is therefore less dangerous in a varying environment.

Other energy sources that can be used in the airline industry are solar and wind energy. Solar is clean source of energy that uses solar panel technology and limits waste product. Lacking a fuel, it is safer but it has additional drawbacks such as having a lower fuel efficiency and a higher fuel cost. Wind is a source of energy that uses the elements. The report considers blimps as a wind mode of transport. Although blimps are slower than normal aircrafts, they use less propelling energy and rely on wind to provide the rest.

1 Introduction

On September 20, 2006 our group submitted a proposal to research the field of renewable and greener fuel systems for future aircraft. Soon after we received approval for this topic and began researching what has been done and what is being done to lower emissions and to find cleaner air transportation. Our proposed study included the following activities:

1. research what is already being done to find cleaner fuel sources
2. determine the pros and cons of each planned development
3. investigate which methods are realistic and which methods are unrealistic
4. write a report that outlines and delivers our findings, including which projects we think should go forward and which should be canceled.

This report represents the final assessment of the research gathered by the group over the duration of project period. The information gathered here covers all four of the group's targeted goals, and presents a final conclusion as to what we believe is the best renewable energy source for aviation.

2 Traditional Fuels

2.1 Background

Aircraft fuels have evolved over time from aviation gasoline fuels that were used to power piston engines to the kerosene fuels currently used to power gas turbine jet engines. (Bisio & Boots, 1997, p.151)

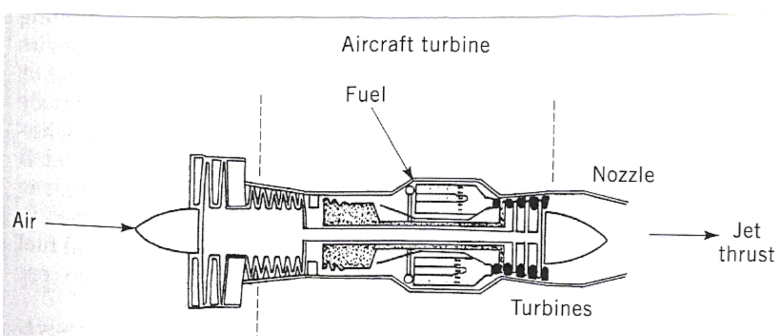

Figure 1: Schematic of jet turbine engine

Source: Bisio & Boots, 1997, p.151

Within a jet engine the driving power is produced in the following way:

1. Air flows through the air ducts and is compressed
2. Fuel is burned in the compressed air
3. Hot gasses expand through the turbine, and energy is extracted to power the compressor and provide shaft driving power
4. The residual exhaust exits the nozzle and provides forward thrust

2.2 Fuel Performance factors

Performance of the fuel is determined based on the quality of fuel and factors that limit the quality of fuel**.** Kerosene, a paraffinic fuel, is a preferred fuel source because it has a large mass to heat ratio of 45MJ/kg (Bisio, Boots, 1997, p.157). Turbines must be able to handle a range of motion of fuel and air from idle to full takeoff power. Stability of the fuel has also made kerosene a good fuel. Since aviation fuels are exposed to a range of thermal environments, deposits sometimes form during fuel injection and can cause blockage of the fuel nozzle and/or distort fuel spray patterns thereby impeding performance. Contaminants can also affect performance such as water and other extraneous materials that may be introduced into the system during fuel transportation. The principle means of removing these contaminants is by maintaining a good tank setting and filtration system. Low temperatures also affect performance, causing water saturation in fuel that can lead to ice formation in fuels which blocks filters and or leads to metal corrosion. Agents that lower fuel freezing points and filter heaters are used to maintain an efficient flow of fuel.

2.3 Environmental factors

Burning fossil fuels, such as kerosene, produces many types of emissions that harm the environment. These emissions include the following (NASA, 2006):

- Carbon dioxide (CO_2): a greenhouse gas that is contributing to global warming.
- Water vapor: also a greenhouse gas.
- Nitrogen oxides (NO_x): a major contributor in the formation of ground level o-zone (Raypak, n.d.).

- Sulfur dioxide (SO_2): the main cause of acid rain (Environment Canada, 2003)
- other emissions such as soot and unburned hydrocarbons

Reducing these types of emissions is the main motivation for investigating the use of alternative fuel sources to power aircraft.

3 Hydrogen as a Jet Fuel

3.1 Background

The first renewable fuel we considered was Hydrogen (H_2). Hydrogen is the most abundant element on the planet. It makes up seventy-five percent of the environment, and is typically found in compounds with other elements (Kushnir, 2001). However, to be used as a fuel, hydrogen must be in the form of H_2, which is an odorless and colorless gas at standard conditions. The best ways of generating H_2 are by producing it from water (using renewably generated electricity) and producing it from *biomass* (plant matter). Once in the form of H_2, hydrogen can be used either as a traditional jet fuel in a jet engine, or as a fuel in a fuel cell.

3.2 Benefits

Hydrogen is suitable as a jet fuel because it will co-exist with oxygen until there is an external input of energy (Kushnir, 2001). At this point combustion takes place. This reaction gives off only heat, water vapor, and nitrous oxides. The main benefit of using hydrogen is that there are no other emissions.

However, the emission of water vapor is not as harmless as one would think. Water is a dominant greenhouse gas, and is especially problematic at high altitudes (Imperial College Centre for Energy Policy and Technology*, 2003, p.23). This is a problem because hydrogen fuel would produce almost three times the water emissions per mass, compared to kerosene. But since hydrogen fuel would eliminate all the carbon dioxide emissions of kerosene, it is generally agreed that combined greenhouse emissions would be much lower with hydrogen fuel.

The nitrous oxides given off from any combustion reaction depend only on the duration and temperature of the combustion process (ICCEPT, 2003, p.24). There are

* Will be referred to as ICCEPT in future citations

methods that can take advantage of hydrogen's combustion properties to reduce nitrous oxide emissions in hydrogen burning engines. It has already been shown that very low NO_x emissions are possible in practical LH_2 engines.

3.3 Drawbacks

There are some drawbacks to hydrogen. First, liquid hydrogen has a lower volumetric energy density than kerosene (ICCEPT, 2003, p.24). This means that the fuel tanks would need to be around 4 times bigger, which will require considerable modifications to airframe design. The flip-side of this point is that liquid hydrogen actually has a higher (mass) energy density than kerosene, which will allow for greater payloads to be carried.

It is worth noting that the environmental benefits of using hydrogen only exist if the hydrogen is obtained by an environmentally friendly process. Two methods of doing this are producing it from water (using renewably generated electricity) and producing it from biomass.

3.4 Safety

With regards to safety, overall hydrogen fuel is deemed as safe as kerosene (Kushnir, 2001). However, hydrogen does have some unique safety concerns, which include the following:

- a wide explosive range (% concentrations able to explode in air)
- a low ignition energy
- rapid diffusion (compared to petroleum-based fuels)

These concerns would require certain alterations to airplane design, which include the following:

- the use of hydrogen detectors
- active ventilation systems
- a spark-less environment

3.5 Decision

Hydrogen is an abundant, safe, and environmentally clean fuel source. The largest benefit of using hydrogen fuel is the reduction in the types of emissions and their impact on the environment. Moreover, switching to hydrogen will require some modifications to airplane design. Overall, hydrogen would be a realistic substitute for kerosene for the long-term future (ICCEPT, 2003, p.25).

4 Solar Power

4.1 Background

The sun has been used by humanity as a tool since the beginning of time, and is the source of another renewable fuel source. Solar power is a completely free fuel source that has no dangerous or hazardous green house emissions; it also does not require large or bulky fuel tanks. Solar power technology is still evolving, and new developments are made every day, but it is still an inefficient and expensive technology. Tests and prototypes have been built and solar aircraft have been used for practical purposes such as communication relays and weather mapping.

4.2 Benefits

Solar aircraft require no fuel to be loaded on to the aircraft: its fuel comes from a completely renewable source that never needs to be refilled, the sun. As no fuel is added to the aircraft, there is no waste produced: no harmful green house gases are released into the atmosphere while it's flying, making it a completely clean source of fuel that passes even the strictest environmental regulations. The lack of fuel tanks allows the aircraft to be smaller and less bulky. This also makes the aircraft safer. No fuel means there are fewer flammable and possibly dangerous products on the aircraft [http://www.nasa.gov/centers/dryden/news/FactSheets/FS-034-DFRC.html].

Onboard back up batteries provide power in the dark allowing limited night time flight, and because solar energy powers electric motors, solar aircraft run more quietly than tradition jet or propeller combustion engines. Prototype solar aircraft have also set altitude records for non-rocket powered aircraft (http://www.nasa.gov...).

4.3 Drawbacks

Years of research and development into solar energy has not gotten the scientific community very far in the development of the size, cost and efficiency of solar devices. Solar panels and the technology to convert the energy it gathers into electric power are still large, bulky, expensive, and very inefficient. Test aircraft equipped with solar panels have long wings to accommodate the many solar panels needed to generate enough power to fly, and aircraft still doesn't generate enough power to take off, needed to boost its motors with energy from its backup batteries which it recharges while flying [http://www.nasa.gov...].

The solar panels that are placed on aircraft are not cheap as they have to be accurately manufactured and made of high quality materials to ensure that they are efficient and durable. These panels are also notoriously inefficient, turning less than 20 percent of the energy they absorb from the sun into electric power even the record setting Pathfinder-Plus solar aircraft, after years of research, achieved to a system that could only convert 19% of the energy absorbed to electric power on a good day [http://www.nasa.gov...].

Solar aircraft are also slow, with an average speed of around 20 miles per hour, carrying a small payload of around 100 pounds. Solar aircraft are restricted to day time operations and limited night operations if aided by onboard batteries. This capability is so limited that the aircraft is mostly used to descend the aircraft from its high altitude, with the possibility of gliding the aircraft until it can reach light which it can recharge from. Solar technology is not ready to take the step to full sized aircraft that can reliable transport people or goods around the world [http://www.nasa.gov...].

4.4 Decision

Although the technology has been proven and there are practical uses for solar power in the aerospace industry, we believe that a full sized completely solar powered aircraft capable of transporting people or goods is not a reasonable expectation for the next few years. It is, however, possible that in the near future there may be enough progression in the field of solar efficiency to make an aircraft that is solar powered.

5 Blimps and Lighter than Air Vehicles

5.1 Background

Blimps have been used for many years and in most cases outdate traditional aircraft, the question is, is there still a viable commercial market for them. Blimps lie in a unique place in modern transportation, they are cheaper and more fuel efficient than regular air transportation, but are also slower. Blimps are faster and easier than boat or truck transport, but they also come with a higher price tag. Blimps overall are also less reliable and more susceptible to weather.

5.2 Benefits

Imagine an aircraft that can carry large loads across an ocean using less fuel and at a cheaper price than regular aircraft, and yet still faster than by ship. Blimps and airships develop most or all of their lift from gases that are lighter-than-air so it does not need high powered motors propelling wings at high speed through the air to generate lift. Therefore blimps can be powered by smaller engines that run on a fraction of the fuel used by regular airliners.

Although blimps are slower than traditional aircraft, they are still capable of moving faster than ships and because they don't encounter traffic and can move in a straight line instead of following winding roads they can deliver goods faster than trucks (Wise, Jeff. (2006)).

5.3 Drawbacks

Airships are not as safe as regular aircraft. Some gases that are lighter than air are explosive, leaks can be fatal as it's only a fabric like material covering the gas bags, and airships are more affected by wind, turbulence, and weather conditions than regular aircraft. Airships are slow. They move faster than boats or trucks, but it's a more expensive medium of transportation than either of those, and blimps have a smaller payload capacity than a ship, and there is really no intermediate product that needs to reach a market place slower than an aircraft can deliver it, but faster than a boat can, meaning that there may not be a market for a blimp cargo service to prosper from (Wise, Jeff. (2006)).

5.4 Decision

Blimps and lighter-than-air vehicles have been used for generations and there are still ongoing research and prototype projects, but it is hard to see any kind of blimp hybrid finding a commercially successful market. They are slower and less reliable than modern aircraft and more expensive than boat or truck transportation, making it a hard sell to the business world (Wise, Jeff. (2006)).

6 Conclusions

After much deliberation and research into the future of renewable energy sources in aviation it has been decided that hydrogen is the most realistic renewable energy source. Solar powered and lighter-than-air vehicles may be possible in the future, but any commercial use of them is dependant on possible technological advance that may or may not take place. Small commercial hydrogen aircraft are with in grasp at the time of writing, and further developments will only increase there usefulness towards making flight a more environmentally healthy task.

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