Delft University of Technology / Faculty of Aerospace Engineering		
Project	: AE2100 System Design - Essay	curriculum year : 2nd
Date	: 15 January 2013	10.00 – 12.00 hr
Remark: Please mention your name and ALL YOUR INITIALS on your work. If you use more than one set of papers, fill out the heading on each set and **also include your group number next to the TUDelft logo.**		

Aircraft: The impact of alternative jet fuels

In the near future standard aviation kerosene made from crude oil will become scarcer. This will result in higher fuel prices for airlines. Therefore they will start looking for alternatives. Gas turbine engines can run on a multitude of fuels but airlines don't like that. What they would like to see are so-called "drop-in" fuels. These type of fuels are much like kerosene and can be used without modifying the aircraft. One of these fuels is a synthetically produced kerosene. Via the so-called Fischer-Tropsch process one can convert virtually any type of material holding carbon atoms into a liquid fuel. The most likely candidates for this are coal, natural gas and biomass. These fuels are called coal-to-liquid (CTL), gas-to-liquid (GTL) or biomass-to-liquid (BTL) fuels respectively. Slowly but steadily production facilities for these synthetically made types of fuels are becoming operational. So over the coming years more and more of these fuels will be blended with standard kerosene. Regulations have already been approved for the use of blends containing up to 50% of synthetic fuel. For the time being the blend percentages in the order of 1 to 5% will be realistic.

New fuels also offer new possibilities in design. Your challenge is to investigate what the effect on your design will be when your aircraft changes completely to a synthetically made kerosene. The characteristics of synthetic kerosene are such that the energy density is 3% higher than that of standard Jet A-1 kerosene. The energy density is the amount of joules per kg. A higher energy density means that the same amount of energy can be carried by a smaller amount of kilos fuel mass.

Taking the higher energy density into account you are required to assess the changes in the wing design, focussing on :

- The effect on aircraft overall sizing and layout
- The effect on the wing layout
- The effect on the wing aerodynamics
- The effect on the wing structure and wing sub systems
- Will the percentage that the fuel weight is of the maximum take-off weight increase or decrease with the new fuel type? Why ?

The mission of your aircraft (transporting a certain payload over a certain range in a certain amount of time) must stay the same.

Assume that the density of the new fuel (in terms of kg/m^3) is the same as for the original kerosene

- The effect on aircraft overall sizing and layout

The number of passengers doesn't change, so the fuselage will generally be unaffected. (+0.5)

The same amount of energy can be delivered by less fuel, so the weight of it is lower. With constant payload and the weight of the fuel being lower the MTOW will decrease. The OEW can also decrease (see next point) (+1)

Less take-off weight means less lift required. Less lift generally means less drag (induced drag scales with C_L^2), which in its turn requires less thrust (+1). This can imply smaller engines (again less weight) or at the least less fuel.(+.5)

- The effect on the wing layout

To stay close to the design point, W/S needs to be constant.(+.5) With lower MTOW the S, so the wing area, goes down. This gives 2 possibilities with respect to the aspect ratio A of the wing.

1) With constant aspect ratio the wing span goes down. This will lead to a lower OEW and a better maneuverability of the aircraft.(+1) Note that the fuel still needs to fit into the wing.(+.5)
2) With constant span the aspect ratio goes up. This has a positive effect on the drag performance of the wing since the induced drag scales with 1/A. Also the induced angle of attack will be smaller which makes the wing lift performance come closer to the original airfoil performance.(+1)

Since the stall speed is proportional to W/S it does not change. Since W/S and the cruise Mach number do not change, the design lift coefficient does not change.(+.5) This also means that the wing airfoil can be the same.(+.5). If the Mach number and the airfoil do not change than the sweep angle remains the same.(+.5)

Taper can be the same since this partly is chosen to accommodate the fuel.(+.5) .

- The effect on the wing aerodynamics

So generally the wing plan form can stay the same. Also the type of lift devices doesn't change since the landing and take-off speeds will not change (+1). The percentage of the lift devices area of the total wing will not change (+.5).

- The effect on the wing structure and wing sub systems

The required lift will be smaller (less weight) so the bending moments will be smaller (+.5), so the stresses will decrease. The wing will become smaller (option 1), so the wing box will be smaller. In itself this may leave the structure unaffected. (+.5) However a smaller wing will have

the centre of pressure of the entire wing closer to the fuselage which will again bring the stresses down (+.5). This may lead to thinner or less stiffeners, spars etc. .(+.5). This will bring the wing weight down even more
The landing gear can be made smaller since the landing weight is smaller, so shock absorbers and struts can be downsized (+1)

- Will the percentage that the fuel weight is of the maximum take-off weight increase or decrease with the new fuel type? Why ?

A higher energy density means that the same amount of energy can be carried by a smaller amount of kilos fuel mass. 3% doesn't seem that much but you must consider that in aviation every kilo matters. Next to that there will be a snow ball effect. One kilo less fuel means less maximum take-off weight. Less take-off weight means less lift required. Less lift required means less drag. Less drag means less thrust required. Less thrust means less fuel, etc., etc.... Next to that there is a second compounding effect. Less mass will lead to a lighter aircraft. A lighter aircraft can be made smaller. A smaller aircraft will be a lighter aircraft, etc., etc… These two compounding effects can be quite significant.

This would result in the fuel weight going down to a lesser extent than the aircraft weight. Which means that (with the total weight going down significantly) the ratio of fuel over MTOW goes up! (+1)

Note:

In the grading generally 0.5 points can be awarded when smart remarks are being made next to the ones shown above, however if significantly wrong comments are given also points can be subtracted.