AE2111-II Aircraft Group Homework assignment – Regular Session

2019 / 2020

You are required to work on the current homework assignment in a group of 5 students. You will have to assemble and hand in a single group report that presents the outcome of your combined efforts that answer the posed problems. This report will be checked and graded with a single group grade, which will be the grade that every individual team-member will receive for this part of the course assessment.

In order to give you an impression of what a typical design engineer's job looks like, you are to work together on this assignment in a "design team". Imagine that you would be working at the preliminary design department of some famous aircraft building company. Also, assume that an effective team effort will usually result in a better design than just your own individual brilliance . The presented homework assignment is quite extensive and you are allowed and even encouraged to divide work amongst each other to contribute to the final report.

Assessment will be based on the report that you hand in as a group. This means that your grade for this project is not only influenced by your own individual effort, but also by the effort of your teammates. If a team member has contributed to a certain solution in your report, then it will be assumed that all team members support this solution, even if they haven't worked on the problem themselves. It is therefore important that you, next to working on your own specific problem, also make sure that the results of your team members make sense, before agreeing to the final report.

As you are required to keep track of your peers' progress on the assignment effort, it will be useful to monitor what they are doing. You are free to work out the details of your collaboration by yourself, but you are suggested to have (at least) a "Final Report Review Meeting" where everyone is assembled and make sure that each one agrees to the final version of the report to be handed in.

Hand-in deadline: Monday, October 21st , 2019, 12:00h CEST

Important notes on reporting:

1. Write a concise and clear document in which you describe your solutions to the assignment, following all the requested tasks reported in the *Task description*. Stick to the point. Try to be **clear and complete** while also **minimizing the amount of text**. Try to answer all questions like you would for a **written exam.**

   - Focus on the problem solutions. There is no need for an introduction, summary, conclusion, etc.;
   - Be sure to include all used **equations** and the **numeric values** that you substitute in them;
   - Do **NOT** include any Appendix;
   - Do **NOT** include any piece of Matlab code or any Excel calculation sheets, because they will be ignored.

2. The deliverable of your tutorial work shall be a report delivered as an electronic file (PDF format). The file name of your report shall be in the form *"AE2111Group XX_Aircraft Tutorial"*. Example: for group 12, the file name shall be *"AE2111Group 12_Aircraft Tutorial"*.

3. Deliver your final report by uploading it in the assignment submission folder "Aircraft tutorial report" of your group on Brightspace; only in the case of an upload problem occurring, you can send it to the e-mail address: F.Oliviero@tudelft.nl.

4. On the **front page** of your report, you will clearly indicate the following:
   - Group number; Names of all group members; Student-numbers of all group members; Delivery date.
   - Leave some space for teacher's comments and evaluation.

5. You will number the pages of the report. **<u>The report has a limit of 12 pages.</u>**

6. **Do NOT hide** important **numerical results** or values that are read from figures and plots, by placing them inside large bodies of text. Use a separate line or a table for presenting such data.

7. **Justify** all your assumptions and design decisions.

8. **Always show your calculation steps**. In any case, always indicate first the used equations in a purely symbolic format and subsequently show by a visible substitution the numeric values that you fill in for each variable, e.g.; $L = ½ * ρ * V_2 * S * C_L = ½ *1.225*100^2*25*0.6 = 184$ kN.

9. If you use values obtained from **simulation codes,** such as JAVAFOIL, you will **provide evidence** in your report by including <u>readable</u> **screenshots.**

10. When the application of some design method requires the use of reference plots (for example, a DATCOM method), you **will copy ALL the used reference plots in your report** and you **will always graphically indicate the selected point** by means of a clear dot or two intersecting lines. It is OK to do that also **with a pen**, after the report has been printed.

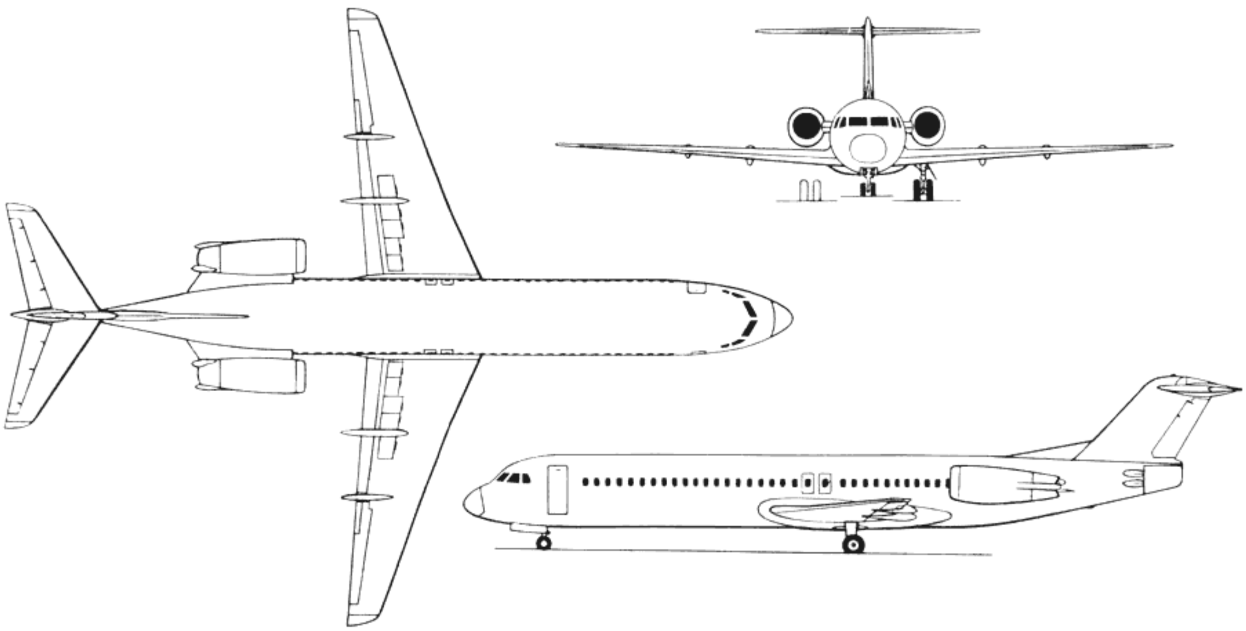
11. Do not forget **units**, and when generating your plots do not forget to **label the axes**. Also, plots of aerodynamic analysis results should include a reference of the **Re and M** numbers under consideration.

12. Do not struggle more than necessary with Excel for your plots. Hand drawings are most welcome, as far as they are **to scale and, preferably drawn on graph paper**. You can also finalize and retouch some digital plots by hand, after the report has been printed (for example to add the nonlinear parts of the lift curves).

13. **Ignoring these notes will not be appreciated in the checking of your work**

Fokker F100

The Fokker 100 is a medium-sized, twin-turbofan jet airliner from Fokker, the largest such aircraft built by the company. Despite of the closed program due the company bankruptcy in 1996, the aircraft has been worldwide appreciated for its flight performance. The wing planform, that is reported in Figure 1, can be reduced to a simple trapezoid with no kink.



Credits: Phil Vabre - http://www.airliners.net/photo/Alliance-Airlines/Fokker-100-(F-28-0100)/1562447/L/

The following characteristics can be considered for this aircraft:

MTOW	*43090 kg*
OEW	*24593 kg*
W_{fuel}	*8832 kg*
b	*28.08 m*
S	*93.5m²*
$\Lambda_{c/4}$	*17.45 deg*
λ	*0.235*
Airfoil:	*Assume **NACA 64(1)-212** (6 digits series) everywhere, perpendicular to overall LE-line*
High-lift devices:	*Inboard edge 0.10 b/2; outboard edge 0.64 b/2*
Aileron:	*Inboard edge 0.65 b/2*
$V_{approach}$	*128 knt*
$h_{approach}$	*0 ft*
V_{cruise}	*414 knt*
h_{cruise}	*35000 ft*

Your group is asked to report on the following 4 tasks:

1. Airfoil analysis (max. of 2 points out of 10)

Compute the wing mean aerodynamic chord (MAC) and its span-wise location. Compute the wing Reynolds number based on MAC at both cruise flight and take-off conditions. Analyse the airfoil at the computed Reynolds, using one of the available airfoil analysis tools (it is recommended to use Javafoil).

a. Plot the considered airfoil geometry and describe the main software settings used to compute the aerodynamic characteristics (e.g. number of points, trailing edge gap, etc…).

Then for both the conditions:

b. Determine the airfoil C_{dmin}, C_{lmax}, $C_{l\alpha}$, α_0,α_s and report their value on a table.

c. Show them graphically plotting both the lift curve and the drag polar. Don't forget to display the relevant effects of Reynolds in the plot.

d. Discuss the validity of the results finding possible reference in literature.

2. HLD design (max. of 2 points out of 10)

Considering the landing conditions (80 % of the fuel is burned at this condition) at sea level, calculate the requested lift coefficient. Consequently, verify if the requested condition can be achieved by means of a **fowler flap** whose the limits are reported in Table 1. You can select suitable values of both the flap chord c_f/c and the deflection angle.

Discuss qualitatively if the condition is met or which possible modification (if any) to the HLD system are necessary.

3. Roll characteristics (max. of 3 points out of 10)

The outboard part of the wing is equipped with ailerons that have an aileron-chord-to-chord ratio $c_a/c=0.25$. Verify if the ailerons system satisfies the requirement on roll rate of the adequate aircraft category.

Assuming that the airfoil characteristics are the same ones calculated at question 1, then:

a. Calculate the value of both the aileron control derivative and the roll damping coefficient and provide evidence of the calculation steps. Remember that you can reduce the wing as a simple trapezoid.

b. Calculate the roll rate at the most demanding condition and compare with the requirements.

c. Discuss qualitatively if the rolling requirement is met or which modifications (if any) to the aileron system are necessary.

4. Calculation of the wing weight and design iteration (max. of 3 points out of 10)

Compute the Weight of the Wing using the *Torenbeek model* provided in the Eq. (1), where all the quantities are expressed in SI units.

Consequently, due to a redefinition of the aircraft operating requirements, it is asked to your group that the new ultimate load factor is incremented by 12 % with respect the initial one.

Re-compute again the Wing Weight due to this modification and, assuming that the Empty Operative Weight is composed by the sum of Wing Weight and a second term that is kept constant, compute the new converged MTOW of the aircraft. Note that an iterative calculation has to be implemented in order to guarantee the converge of the MTOW since the Ww affects the MTOW and MTOW affects Ww (through the ZFW term in Eq. 1). Include a graph that shows the evolution of the MTOW at each iteration.

$$Ww=\left(k_w b_s^{0.75}\left(1+\sqrt{\frac{b_{ref}}{b_s}}\right)n_{ult}^{0.55}\left(\frac{b_s/t_r}{ZFW/S}\right)^{0.30}\right)ZFW \qquad \text{Eq. (1)}$$

$$k_w=6.67\times10^{-3} \qquad b_{ref}=1.905m \qquad b_s=b/\cos\Lambda_{0.5c} \qquad t_r=C_r\left(\frac{t}{c}\right) \qquad n_{ult}=1.5\,n_{\max}$$