HOMEWORK 2

Have you heard about Horten brothers? Many people recognize them as the inventors of the modern flying wing. Walter and Reimar (these were their names) carried out most of their work in Germany until the end of the second war, but Reimar continued to research in Argentine, where he developed and tested numerous prototypes. From their work arose aerodynamic solutions for the effective flight of tailless aircrafts that have had a great impact on modern developments. As an example, Northrop's wings rely heavily on Hortens' ideas.

This homework deal with the **Horten wing Ho IV**, which was and advanced sailplane for its time. You can find the main geometric and aerodynamic data of the Ho IV wing in [1]. Before starting work, it is strongly recommended to read [2] and also visit https://www.mh-aerotools.de/airfoils/flywing1.htm, where the main aspects of tailless aerodynamics are described. In addition, pros and cons of the different pilot positions are discussed in http://www.nurflugel.com/Nurflugel/n_o_d/weird_07.htm (the Ho IV wing adopted a semi-proned pilot position).

Once familiar with the literature above, use the program LLWing (provided in class) to perform the following analyses assuming that the sailplane design condition is: **W/S = 20 kg/m^2, V = 100 km/h** and the **center of mass is x_{cg} = 1.3 m aft** the leading edge of the wing's root section. We will consider that the **cockpit is an ellipsoid having 2 m long and 0.6 m maximum diameter** whose major axis is slightly inclined upwards with respect to the root chord of the wing. Only contributions of the fuselage to the moment and parasitic drag will be accounted for in this work.

Part 1: Airfoil choice and fuselage estimates

1. Investigate modern reflex airfoils available in the literature (for example in https://www.mh-aerotools.de/airfoils/nf_1.htm) and select a new airfoil for the wing. We will use the same airfoil along the span, so check that your choice is suitable for both root and tip flight Reynolds number. In addition, the airfoil should have a thickness ratio t/c ≥ 0.1, high L/D ratio and slightly positive (low) free pitching moment. Use airfoil's experimental data to calculate the Cl-α curve and the angle of zero lift (αl_0). Using the experimental drag curves Cd-Cl, fit a regression line of Cd=f(Cl^2) to obtain Cd_0 and *k* for the root and tip sections. You can also use

calculation if experimental data found is not enough, but at least you must check a few points against experimental data. Briefly justify your choice of airfoil in the report.

2. Calculate the fuselage pitching moment coefficient as a function of the angle of attack (see M3_3 p. 6). In addition, estimate the fuselage parasitic drag using the method described in DATCOM 4.2.3.1 (provided in Atenea). The dimensionless coefficients must be referred to the dynamic pressure and the wing's planform area and mean aerodynamic chord.

Part 2: Preliminary wing calculations

This section lists some capabilities that should be added to the program LLWing in order to solve the Part 3 of the homework. Hence, each team will write additional code lines, functions or routines, that using the program's output data stored in *cl_local* and *force_coef* (see the users' notes), calculate the following:

1. Fuselage parasitic drag and pitching moment coefficients (as a function of α).
2. The wing's lift slope ($C_{L,\alpha}$) and angle of zero lift (α_{L0}).
3. The wing pitching moment's slope about the root chord's leading edge (dCM_{LE}/dC_L) and the free moment coefficient (C_{M0}). Also the position of the aerodynamic center.
4. The wing's basic and additional lift coefficient distributions.
5. The wing-body's drag curve using a parabolic model (CD_0 and k). The variation of the fuselage drag with the angle of attack can be neglected at this point.
6. The wing-body's CMcg-C_L curve.

For testing purposes, you can use the original wing parameters (e.g. from [1]), the aerodynamic data of the airfoil selected in Part 1 and a suitable set of angles of attack.

Note: Matlab's function *polyfit* could be useful for regression of the program outputs.

Part 3: Analysis

The sweep and washout of the wing will be determined first in this section. This would require testing different values in LLWing until **the output variables meet the design conditions** defined in the introduction. After that, some performance data of the wing will be calculated. The analyses to be carried out are the following:

1. Slightly adjust the original wing sweep to guarantee a stability margin (i.e. the distance between the wing's aerodynamic center and the center of mass) in the range of 10-20% (this distance is adimensionalized with the wing's mean

aerodynamic chord). You can obtain an initial guess for wing's sweep using the geometrical approach described in M3_2 p. 40.

2. Calculate the washout needed to trim the wing (i.e. to make the moment about the center of mass equal to zero) at the design flight C_L.
3. Calculate the wing's C_{Lmax} and stall speed (see M3_3 pp. 26) for the wing without flap using the additional and basic lift distributions. If necessary, slightly modify the washout to ensure a safe wing's stall, and check possible impact on the points 1 and 2 above.
4. Approximate the wing-body drag curve using a parabolic model (CD_0 and k) and calculate the curve L/D as a function of the flight speed.
5. Calculate the wing-body CMcg-CL curve for up and down flap deflections (e.g. -20 to 20 with an interval of 5 deg). Use a full-span trailing edge flap with cf/c=0.2. Use these curves and the drag data above to estimate the deflection required to trim the wing at maximum-range and minimum-descent-speed flight conditions.

Submission

This homework must be performed in **groups having 4-5 students**. The code lines wroten for solving the items in Part 2 should be included in an annex. The entire document (i.e. Parts 1, 2 and 3 above and appendix) cannot exceed **15 pages**. Report submission will be online (ATENEA) and the deadline is **January 24, 2022**. Late submissions will have a -10% penalization.

References

1. Gyorgyfalvy, D. (1960). Performance analysis of the Horten IV flying wing. MISSISSIPPI STATE UNIV MISSISSIPPI STATE DEPT OF AEROPHYSICS.
2. Kroo, I. (1994, April). Tailless aircraft design—recent experiences. In Symposium on Aerodynamics and Aeroacoustics (pp. 207-229). River Edge, NJ: World Scientific.