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Aircraft Redesign Semester Homework

Organization of the design

The homework is carried out during the semester. The progress of the work is linked to the presentation of the material in the lecture "Aircraft Design" (FE). The main results of the homework must be available by 21.07.2024. In 6 interim meetings, the partial results are to be presented and discussed. The interim meetings are documented in a form[1]. For this purpose, the form must be brought along to the interim meetings.

Interim meetings (individual appointments):

1. Preliminary sizing
2. Fuselage
3. Wing / High-lift devices
4. Empennage I / Mass and center of gravity
5. Empennage II
6. Landing gear / Polar

The calculation of the DOC should be carried out independently.

The **scope of the design** is essentially the same as in the lecture notes (http://LectureNotes.AircraftDesign.org). Parameters are to be iterated. Additional work is created by the landing gear integration based on the literature available in the library. Further calculations (as discusses) may be required due to the aircraft specific design of the aircraft.

Steps

The work steps are based on Section 2 of the lecture notes.

Preparatory work

The requirements are taken over from the aircraft to be redesigned. The requirements serve as input values for sizing. Modification of these requirements is not permitted. The other parameters result from your own calculation. Where the design gives you freedom, parameters should be chosen based on the original aircraft. Requirements are:

[1] https://www.fzt.haw-hamburg.de/pers/Scholz/arbeiten/Laufzettel_fuer_studentische_Arbeiten.pdf

- Range at given payload
- Number of passengers
- Take-off field length
- Landing field length
- Certification according to CS-25 / FAR Part25 with resulting further requirements.

The requirements and other parameters of the redesign aircraft are to be listed in a table (Table 1). The three-view drawing of the aircraft should also be included in the text. Research: Library, Internet, Manufacturer. Identify dimensioning requirements.

Table 1: Parameters of the aircraft chosen as the model for the design

Parameter	Source 1	Source 2	Source 3	Selected reference value of the design
m_{MTO}				
S_W				
m_{OE}				
...				

Preliminary Sizing

Calculations for "Preliminary Sizing" (Step 5) to optimize the design regarding the DOC. Preliminary sizing should provide the following parameters:

- Approach speed
- Maximum take-off mass
- Operating empty mass
- Fuel mass
- Wing area
- Take-off thrust

If applicable: Proof of "Initial Cruise Altitude, ICA". Proof of the housing of the required fuel (density = 0.80 kg/l; equation 7.35). If the fuel cannot be accommodated in the wing, other usual areas for accommodation should be used and their volume estimated. The calculated, realistically chosen, estimated, or assumed values must also be listed:

- ratio of maximum landing mass and maximum take-off mass,
- maximum lift coefficient in landing configuration,
- maximum lift coefficient in take-off configuration,
- glide ratio in starting configuration (2nd segment),
- glide ratio in take-off configuration (take-off with the landing gear extended),

- glide ratio in cruising flight and verification of the selected glide ratio,
- lift coefficient in cruise flight.

Make use of PreSTo-Classic (http://PreSTo-Classic.ProfScholz.de) and check out SAS (http://SAS.ProfScholz.de).

Fuselage design

When designing cabin and fuselage you may want to use the Excel tool PreSTo-Cabin, http://PreSTo.ProfScholz.de. In addition to the standard cabin layout it should be possible to have also high density single-class seating – with more passengers than given in the requirements. As part of the fuselage design, the following documents must be prepared:

- scale drawing of a fuselage cross-section,
- scale drawing of a cabin layout (created in compliance with CS/FAR 25.813 and the arrangement of the doors and emergency exits - see below)
- scale drawing of a side view of the fuselage,
- a table with a summary of important hull dimensions:
  - number of seats per row (YC) (number of seats abreast)
  - number of aisles,
  - number of cabin crew members,
  - fuselage diameter,
  - fuselage length,
  - length of the cabin,
  - length of the bow section,
  - length of the stern section,
  - rear cone angle.

The following calculations must be carried out and evidence must be provided:

- Verification of the available transport volume.
- Checking the available cabin space.
- Proof of the number and distribution of doors and emergency exits (CS/FAR 25.807 in conjunction with FAA AC 25.807-1) in compliance with the arrangement of emergency slides (CS/FAR 25.810).
- Check the location of the "design waterline" (CS/FAR 25.801).

Wings and high-lift devices

Wing **design** according to script: Section 7 provides the data according to script: Section 2, Step 7:

- Choose a suitable airfoil, considering the lift coefficient already determined in cruising flight.
- Select the relative airfoil thickness and the sweep at the airfoil section of the average aerodynamic airfoil depth to match the cruising Mach number and the lift coefficient in cruising flight.
- Note that in the case of a double trapezoidal wing, parameters on the inner and outer wing differ.
- Determine: Tapering, dihedral angle, camber, incidence angle.
- Check the tank volume with the data now available.
- Define the geometry of the ailerons and spoilers (compared to existing aircraft).

The design of the **high-lift system** on the leading and trailing edges of the wings provides the required maximum lift coefficients during take-off and landing according to the script: Section 8:

- type of high lift system
- relative chord of the system c_F / c
- span extension of the system from η_i to η_o
- if necessary, area enlargement c' / c
- flap angle δ_f
- geometry of the slats.

Have a look at the Diederich Method for the calculation of lift distribution and maximum lift coefficient (http://Diederich.ProfScholz.de).

Empennage Design I

The **tail design** according to the script: Section 9 provides the data according to the script: Section 2, Step 9.

Mass and center of gravity

Run design step 10 according to script (see Section 2). Use Raymer's **Class I mass forecast** (Section 10) to get an initial overview of the masses. After that, work with the **Class II mass forecast** according to Torenbeek (Section 10) (or another source by arrangement). It is recommended to carry out the calculation with the help of a spreadsheet program.

Remember that an iteration will be required (script Section 10, p. 199). Perform the **inner and outer iteration** using steps 1 through 7 (see Section 10). Compare your initial takeoff mass m_{MTO} from preliminary sizing to the takeoff mass from the Class I mass forecast, the takeoff mass after the first run of the Class II mass forecast, and the takeoff mass after the iteration.
Calculate the **center of gravity** of the empty aircraft and shift the masses associated with the wing (wing group) so that the center of gravity of the empty aircraft is on the 25% lines of the mean aerodynamic chord (MAC). Set the area of focus.

Empennage Design II

The empennage design according to the script: Section 11. Result:

1. A required **horizontal stabilizer area** is calculated from the controllability of the aircraft in the "critical" flight condition and from requirements for longitudinal stability determined with the "V-diagram". If the horizontal stabilizer area calculated here under "Empennage II" deviates by more than 10% from the area already calculated under "Tail I", then iteration must be carried out (horizontal stabilizer mass, wing position, empennage lever arm). There is no need to calculate a loading diagram. However, it must be ensured that the center of gravity of the unloaded aircraft is "sensibly" located in the center of gravity area selected above according to the aircraft configuration (script: Fig. 10.11).
2. A required **vertical stabilizer area** is calculated from the controllability of the aircraft in the event of an engine failure during take-off. In addition, a required vertical stabilizer area must be calculated from stability requirements (if this area should be considerably larger than the vertical stabilizer surfaces calculated so far, please consult me).
3. After the iteration, adjust the remaining empennage and rudder parameters to the newly calculated areas.

Landing gear

Choose the **length of the landing gear legs**, considering:

- ground clearance: longitudinal ground clearance
- ground clearance: lateral ground clearance: Minimum 7.5°
- maximum height of the thresholds.
- longitudinal tip-over angle: Minimum: 15° (at the most unfavorable center of gravity)
- lateral tip-over angle: Maximum: 55° (at the most unfavorable center of gravity)

Select the **number of main landing gear legs** and the **number and arrangement of wheels** on each landing gear leg (according to the model). Calculation of an LCN value according to (old) literature (Roskam, Vol. IV, Section 2.3; Torenbeek, Section 10.2) to get a fundamental understanding and calculate the new ICAO Aircraft Classification Rating

(ACR) with the program ICAO-ACR 1.4[2]. The ACR/PCR-System will be effective November 2024. Choose the **tire diameter** according to the catalogue specifications or in comparison with other aircraft. Describe (roughly) the attachment of the landing gear to the aircraft structure, the direction(s) in which the landing gear will be retracted and the spaces in which the retracted landing gear will be housed.

Polar

Calculation of the zero-lift drag from the individual drag of the components. Estimation of the remaining drag elements. Calculation of the Oswald factor. See Appendix A and B of the lecture notes.

DOC

The DOCs are to be calculated as equivalent ton-km costs (script: Eq. 14.19, factors according to **AI 1989**) based on the DOC method according to **AEA 1989** (short- and long-haul aircraft). Estimation of the delivery price over the maximum take-off mass. Fuel price: US$ 1.00/kg. The flight distance on which the DOC calculation is based should be 50% of the range at maximum payload. See PreSTo-DOC from http://PreSTo.ProfScholz.de.

3D visualization

Using http://OpenVSP.ProfScholz.de, you can convert your design parameters into a 3D representation of your redesigned aircraft. With http://3d.profscholz.de it is possible to convert this into a 3D image within(!) your PDF of your report.

Required form of the finished document

The calculations and calculation results should be summarized in a clear form: equations, numerical values used, calculation results. It is not necessary to explain all the iteration steps. However, the general sequence of the iteration, thoughts and experiences must be documented by a required amount of text.

A collection of Excel pages is not acceptable. Please note the instructions for creating theoretical papers on the Internet:
http://WritingHints.ProfScholz.de see also:
http://buch.ProfScholz.de (with Word template for your homework).

[2] https://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/ICAO-ACR-14

Please note:

1. Before submitting your thesis, please make sure that this task has been completed in full and that all required parameters have been clearly stated (use tables for a clear presentation).
2. If sources other than the lecture notes are used, the sources must be cited. In this case, a list of references (http://ISO690.ProfScholz.de) must be provided with a correct identification of the source.
3. Please do the "Final Checks" (including checklist) from http://WritingHints.ProfScholz.de .
4. Please deliver you homework as PDF (if it contains the 3D image of your aircraft) otherwise as PDF/A.
5. Submit via e-mail with a link to a cloud storage. Do not attach your report to the e-mail (this would clog my mailbox).