Assignment Description
AE4204 Knowledge based engineering

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Introduction

The chosen design challenge for this assignment is to model the preliminary design of the High Lift Devices (HLD) of a commercial transport aircraft according to the design procedure proposed by [1] and [2]. The developed KBE application will allow the user to explore different possible leading edge and trailing edge HLD types during the preliminary design of the wing and allow for parallel wing planform and HLD sizing. This application will be able to quickly size the HLD of a given wing geometry and a desired $C_{L_{max}}$ and will help select a wing geometry that will allow for a favourable design. By doing so, the tool will reduce the amount of required iterations of the wing geometry.
The application will require the user to input wing planform parameters, airfoil coordinates and a desied $C_{L_{max}}$. Using this, the application will determine the $C_{L_{max}}$ of the clean wing using two external analysis tools: X-foil and AVL. Subsequently the ΔC_L that needs to be provided by the HLDs will be determine and the HLDs will be sized using the design steps proposed by [1] and [2]. The User will be able to chose from multiple different HLD types and see which one is the most suitable for the aircraft that is being designed.
By using this application, the user will confirm whether the wing design in question is capable of achieving the required $C_{L_{max}}$ for Take-off and Landing with the use of common types of HLD and and will be left with a preliminary design of the system.

We believe that a KBE application is suitable for this particular design challenge, as during the initial phase of an aircraft design, many possible design options are explored. It is probable that a team designing a transport aircraft will go through several wing planform designs, and for each a HLD system will have to be sized. Since the preliminary design process of HLDs is well understood and consists of simple, repetitive calculations, it can easily be turned into a KBE application.

Rule based parametric model

The rule based parametric model at the core of our KBE application will consist of the sizing of the high lift devices (HLDs). These HLDs consist of leading and trailing edge devices, which each have their individual different options. We will consider the following options for the leading edge devices:

- Leading edge flap (nose flap) - [Figure 1]
- Krueger flap - [Figure 2]
- Leading edge slat - [Figure 3]

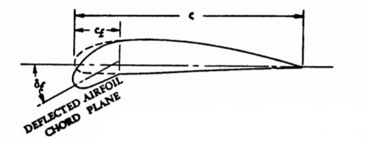

Figure 1: Leading edge flap (nose flap) geometry [2]

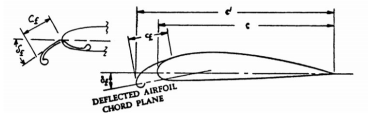

Figure 2: Krueger flap geometry [2]

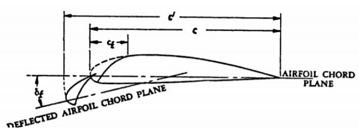

Figure 3: Leading edge slat geometry [2]

The following trailing edge devices are considered:

- Plain flap - [Figure 4]
- Split flap - [Figure 5]
- Single-slotted flap - [Figure 6]
- Double slotted flap - [Figure 7]
- Fowler flap - [Figure 8]

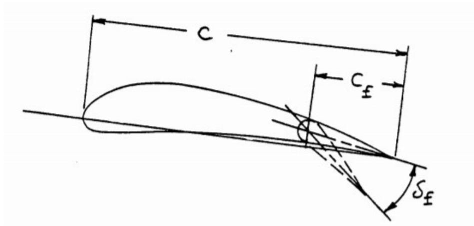

Figure 4: Plain flap geometry [2]

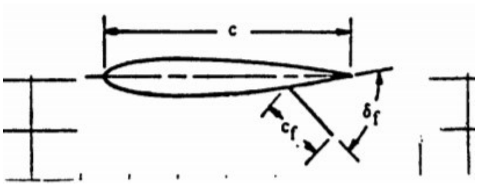

Figure 5: Split flap geometry [2]

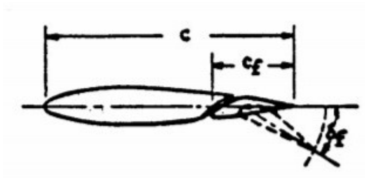

Figure 6: Single-slotted flap geometry [2]

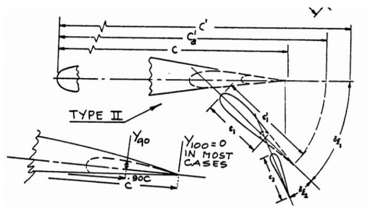

Figure 7: Double-slotted flap geometry [2]

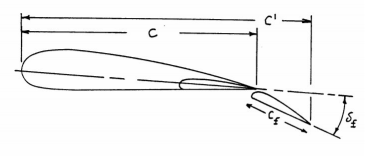

Figure 8: Fowler flap geometry [2]

These high lift devices will be sized using the methods of Roskam, as stated in his books preliminary airplane design [1] [2]. For these methods, the most important parameters are the sizes of the flaps and slats, the ΔC_L that the HLDs need to provide and the type of HLD that will be implemented. The type of HLD used on the aircraft can be specified by the user, if the user has a certain preference, or the application will consider all of the options and provide the user with different configurations as a result.
The ΔC_L that the HLDs will have to provide, will be determined using the user specified

maximum lift coefficient that the wing has to attain and the maximum lift coefficient that the clean wing can attain. This $C_{L_{max}}$ of the clean wing will be determined using AVL and XFOIL, using the user specified geometry.
The sizes of the flaps and slats will be determined by the user specified geometry of the clean wing. Figure 9 shows an example of the geometry of a wing. In this figure, the elevators and the fuselage are indicated, which for the spanwise limit for the size of the trailing edge devices. The locations of the spars are limiting for the chordwise size of the HLDs, which means that they will either be specified by the user, or multiple designs for different spar locations can be presented as a result of the application.

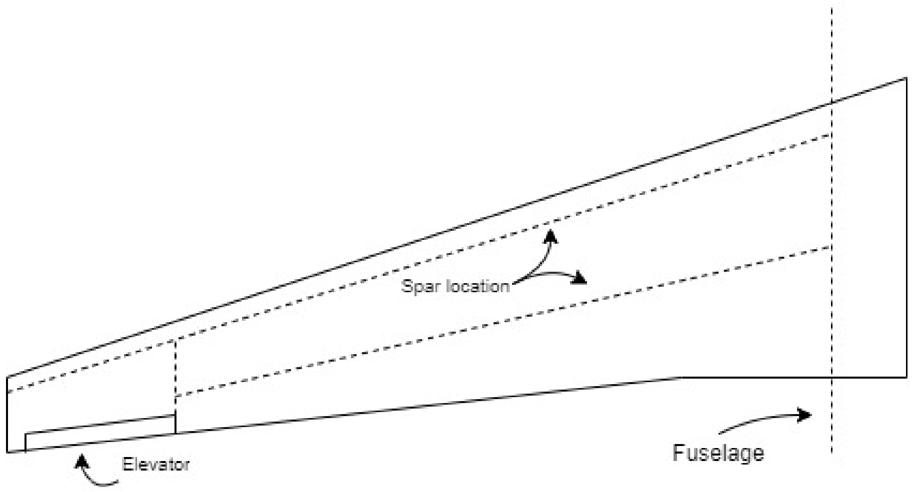

Figure 9: Example of a wing geometry

The first obvious condition where the application should return a message is when the resultant design does not meet the $C_{L_{max}}$ that the user specified beforehand. This message should state what the exact configuration is and by how much it did not reach the objective. Other messages or warnings should be given when the user specifies a geometry that is not feasible, for instance locating the front spar behind the rear spar. The program should recognise these flaws and should report what this issue is and not continue the calculations with this flawed information.

Internal analysis capabilities

The actual design process as proposed by [1] and [2], will be coded within ParaPy. This will be a series of empirical equations that will compute the required dimensions of the system based on the required ΔC_L and the wing design defined by the user. This will include equations taken directly from the book as well as polynomial interpolations of any required graphs. This analysis module will provide all the dimensions necessary to build the geometry of the HLD system.

Use external analysis modules

Our application will make use of two external analysis modules, AVL and XFOIL. These two tools will be used to determine the $C_{L_{max}}$ of the clean wing, which will be needed to calculated the $\Delta C_{L_{max}}$ that the HLDs need to provide. To find the $C_{L_{max}}$ of the clean wing, the point at which the wing stalls needs to be calculated. unfortunately, AVL can not do this. Therefore, we will first use XFOIL to calculated the $C_{L_{max}}$ of the airfoil, after which that value will be used to determine the $C_{L_{max}}$ of the clean wing using AVL. This is done by looking at the C_L distribution along the span of the wing, which AVL can provide. If one of these C_L values on the wing is higher than the $C_{L_{max}}$ of the airfoil, we can assume that that region is stalled. The application will thus vary the angle of attack of the wing in AVL until none of the sectional C_L values exceeds the $C_{L_{max}}$ of the airfoil.

Input data handling capabilities

The user specified input parameters are summarised in Table 1. They consist of wing geometry parameters which will fully determine the geometry of the clean wing and of HLD parameters which will give the user the option to select the type of HLDs and the available space for their placement. Finally, the deflection angle of both the Trailing edge and leading edge HLD will also be inputs so that the user will be able to visualize the different settings of the HLDs. All of these parameters will be editable through the GUI, except for the airfoil coordinates, which will be supplied in a text file. Multiple airfoil data files can be inserted in to the designated folder and switched between by specifying the name of the file in the GUI. It will however not be possible to define different airfoil along the wing as this would make determining the $C_{L_{max}}$ much more complicated and time intensive. All parameters will be given some default value allowing the user to open the application and supply all the parameters within it. If the user already has a geometry file for AVL or prefers to work with a file instead of separate parameters, the user also has the choice to insert this file in the application, after which he still has the ability to edit specific parameters.

Output data reporting capabilities

The output of the KBE application will be the geometry of wing with the designed HLDs. This will have an option to be exported in an STEP file so that the user can use it for further analysis, for example it can be imported into CATIA and used as a base for constructing a structural model of the system. Further the key dimensions that were obtained from the design process such as HLD surface area, deflection angle, chord ratio etc., that will be used to construct the geometry of the HLD will be also written to a PDF. This file will also contain a render of the design and several cross sectional drawings of the chord of the wing with the HLDs at different locations. All input parameters will also be stated in this file in order to keep the results traceable.

Table 1: Input parameters for the KBE application.

Wing geometry			
Wing span	b	m	editable
Root chord	c_r	m	editable
Kink chord	c_k	m	editable
Tip chord	c_t	m	editable
Leading edge sweep	Λ	deg	editable
Dihedral	Γ	deg	editable
Incidence	i	deg	editable
Front spar position	x_{FS}/c	-	editable
Rear spar position	x_{RS}/c	-	editable
Airfoil name		string	editable
Airfoil coordinates		-	text file
HLD parameters			
TE HLD type		string	editable
LE HLD type		string	editable
Fuselage limit	y_{min}	m	editable
Elevator limit	y_{max}	m	editable
TE HLD deflection	δ_{TE}	deg	editable
LE HLD deflection	δ_{LE}	deg	editable

Bibliography

[1] Dr. Jan Roskam. *Airplane Design - Part II: Preliminary Configuration Design and Integration of the Propulsion System.* Roskam Aviation and Engineering, 1985.

[2] Dr. Jan Roskam. *Airplane Design - Part VI: Preliminary Calculation of Aerodynamic, Thrust and Power Characteristics.* Roskam Aviation and Engineering, 1987.