Aeronautical Engineer for a Day

[Click here for an instructional video to support the task]

Introduction

Aeronautical Engineers works on essential parameters required to design an aircraft wing to produce sufficient lift force to keep the aircraft on air. Are you interested in knowing more about the key flight principles and how to generate enough lift force to keep the aircraft flying? Or may be consider a career in aeronautical or airspace industry? Then be an Aeronautical Engineer for a Day to get insight into the engineering challenges associated with designing an aircraft wing.

Background

For a wing to support the flight of an object, it must produce lift equal to its weight. Most wings used in flight are of a special teardrop shape called aerofoil. This shape is needed to help generate lift. Lift is a force that is produced by the dynamic effect of the air acting on an aerofoil, it acts perpendicular to the flight path through the Centre of Lift (CL) and perpendicular to the lateral axis. The centre of lift is a location along the chord of an aerofoil at which all lift forces produced by the aerofoil are considered concentrated. The figure below shows the flow distribution around an aerofoil.

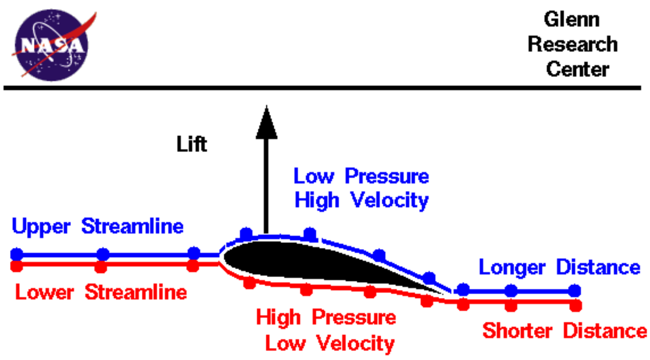


Figure 1: Aerofoil flow distribution

Normally, air moves along smoothly in streams, but airflow is disturbed when a wing moves through it, and the air divides and flows around the wing. The upper surface of the wing has more curvature (aerofoil shape), *i.e.*, more distance for molecules to travel than the lower surface. The air moving across the top of the wing goes faster than the air travelling under the bottom. Since it's moving faster, the air on top of the wing has less air pressure on the wing than the air below the wing. In other words, air below the wing pushes on the wing more than air above the wing as shown in the above figure.

This difference in pressure combines with the lift from the angle of attack to give even more lift as shown in figure 2. The shape of the aerofoil is different for different aircraft. It is designed to give the best trade-off between lift and drag for each aircraft. On many aeroplanes, the bottom of the wing will curve downwards slightly instead of being flat.

On other aircrafts, such as gliders, it will curve upwards. On a stunt plane, which is just as likely to fly upside down as it is to fly the right way up, the curve on the bottom of the wing will be the same as it is on the top.

Listed below are a few design tips concerning aerofoils:

1. The angle of attack of a wing is used to help generate more lift. Increasing the angle of attack results in a greater acceleration of airflow, leading to lower air pressures above the wing by Bernoulli's principle.
2. Greater speed results in an increase in lift. Indeed, slow moving wings provide very little lift. Large aeroplanes get around this fact by increasing their angle of attack using flaps to change the curvature of the wing.
3. Aerofoils with larger cross-sections suffer greater drag than those of thin aerofoils. Therefore, a fighter-jet's aerofoil is typically thinner in profile than that of a Cessna aircraft.

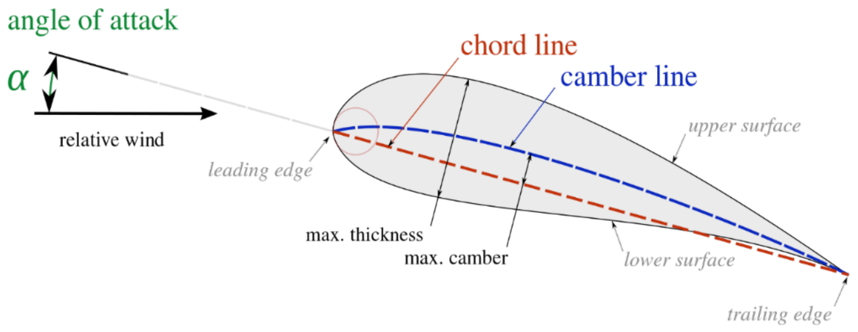


Figure 2: Aerofoil parameters

The Task

This task is comprised of two activities. Activity 1 helps you learn the relationship between lift force and angle of attack, and Activity 2 helps you to learn how to design an aerofoil for an existing aeroplane. Supporting video on how to progress with FoilSim can be accessed here.

Activity 1: Lift Relationships

The objective of this activity is to determine how lift is affected by varying parameters on FoilSim. This activity helps you understand the relationship between lift of an aerofoil. This relationship will be demonstrated experimentally on a wind tunnel.

Using FoilSim, set the following parameters as listed in Table 1 (do not forget to select metric, as shown in the figure) then follow the following steps:

1. What is the value of lift with these parameters?
2. Determine the Lift value for each of the prescribed Angle levels, in Table 2, while keeping the other values the same.
3. Using any tools or software such as Microsoft Excel, Google Sheets or Numbers App in iOS, graph the values for Angle and Lift. (Place the Angle on the *x*-axis and the Lift on the *y*-axis.)
4. What is the relationship between the Angle and the Lift?

Parameter	*Value*	*Unit*
Airspeed (V)	160	km/h
Altitude (h)	0	m
Angle (α)	0	Degrees
Thickness (t)	12.5	%
Camber	0	% Chord
Area (A)	1	m^2
Chord (c)	0.2	m
Span (b)	5	m

Table 1: Activity Parameters

5. Write an equation that will sum up this relationship.

Table 2: Lift vs angle of attack

Angle (degrees)	Lift (N)
0	
2	
4	
6	
8	
10	
12	
16	
20	

Activity 2: Wing Area Investigations

In this activity you will design an aerofoil using FoilSim for any of the airplanes of your choice listed in

, to sustain the conditions listed in Table 4. By the following steps you will find aerofoil characteristics, i.e., camber, thickness, chord, and span, to fly at the conditions listed in Table 4.

1. Choose one aeroplane from the list provided.
2. Calculate Maximum Take-off Weight in Newtons and complete.
3. Start the FoilSim program.
4. Set the conditions provided in Table 4.
5. FoilSim only accepts rectangular shape wing platforms. Vary chord and span length of the aerofoil and wing provided in
6. to achieve the required wing area provided for your selected airplane. For example, if the wing area is 12 m^2, you can choose chord = 2 m and span = 6 m, or chord = 3 m and span = 4 m, and so on. Search online for your aeroplane to get an idea of the existing dimensions of the wing and choose the chord and span wisely to be as close as possible to real model.
7. Enter the chord and span that you determined in step 4, in FoilSim.

   Hint 1: *Lift and Area are directly proportional. If the area is over 1000 m^2, then divide it by 10 and enter that number. When you get the lift, multiply it by 10 to get the real value!*

   Hint 2: *If you cannot choose exact numbers in FoilSim, round up the numbers until you are able to set them in the Tool.*
8. Change the camber and thickness until you can produce **50%** of Maximum Take-Off Weight.
9. Record the camber and thickness, Lift and Drag.
10. Try to optimise your design to reduce drag as much as possible, while still generating the same amount of lift, by only varying camber and thickness.
11. What happens when your aeroplane flies at 800 m altitudes? Does your design still work? If not, what do you need to change to ensure your design can work at both 0 and 800 m altitudes?

Table 3: List of airplanes and their maximum take-off mass and wing area for Activity 2. The maximum take-off mass is provided for your reference only.

Airplane	Maximum Take-off Mass (tonnes)	Wing Area (m^2)
Boeing 737-800	**70.5**	**147.2**
Boeing 737 Max	**63.7**	**127**
Airbus A320	**68**	**122.6**
Embraer 195	**50.8**	**92.53**
Cessna 172	**1.1**	**16.17**
Bonanza G36	**1.73**	**16.82**

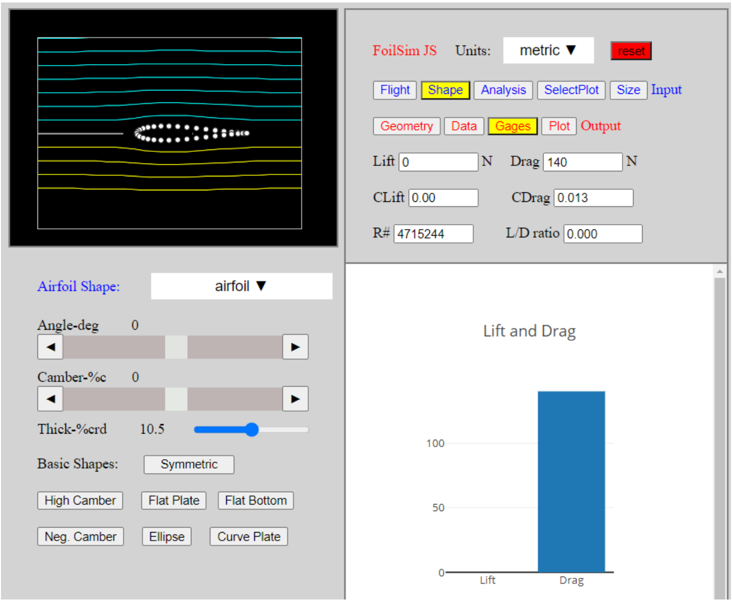
Table 4: Suggested conditions for Activity 2

Parameter	Value	Unit
Altitude	0	m
Angle	5	Degrees
Airspeed	160	km/h

Appendix 1: Information About FoilSim

FoilSim is an interactive simulation software package that examines the airflow around various shapes of aerofoils. As you change parameters such as airspeed, altitude, angle of attack, thickness and curvature of the aerofoil, and size of the wing area, the software calculates the lift. The package was created at the NASA Glenn Research Centre.

FoilSim is a Java applet program that executes within the internet browser. It is accessible using [this link](). You can also download the program using [this link]() to run off-line. Shown beside is a screen shot from the program's controls and displays. You may change the values of the variables by using the slider or the input boxes.



There are a variety of choices which you must make regarding the analysis and the display of results by using a push button or a drop menu. The push buttons occur in groups, and the chosen option is shown as a yellow "lighted" button. The current values of the design variables are presented to you in boxes. For most input variables you can use the slider located next to the input value. Click on the slider bar, hold down and drag the slider bar to change values, or you can click on the arrows at either end of the slider. At any time, to return to the original default conditions, click the red Reset button at the upper right of the program.

The program screen is divided into four main parts:

On the top left side of the screen is the View Window. The view window includes a graphic of the aerofoil that you are designing and several buttons which control the graphic. On the upper right side of the screen is the Control Panel. The control panel holds several push buttons which control the input and output to be displayed. You can choose either Imperial Units or Metric Units by using the drop-down menu at the top. Input choices have blue letters, and the selected input panel appears at the lower left. Output choices have red letters, and the output panel appears at the lower right. You will always see the computed lift, drag, Reynold's number and lift to drag ratio. You can display lift and drag as numerical values or as dimensionless coefficients. Details of the input and output variables are given below.

On the lower right side of the screen is the Output Window. The output can be presented as graphs of aerofoil performance, a probe which you can move through the flow field, lift, and drag gages, or printed numerical values of certain parameters. You select the type of output displayed by using the push buttons labelled "Output:" on the upper right panel. On the lower left side of the screen is the Input Window. Various input panels are displayed in this window. You select the input panel by using the push buttons labelled "Input:" on the upper right panel.

For additional information on the graphics details, the input, and the output variables refer to [this link]().