Building a Glider

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1 HOW AN AIRPLANE FLY

In general the phisics of aerodinamics in flighing is quite complicated. But basicaly we can come down to 4 main forces that are present in the airplane flight.

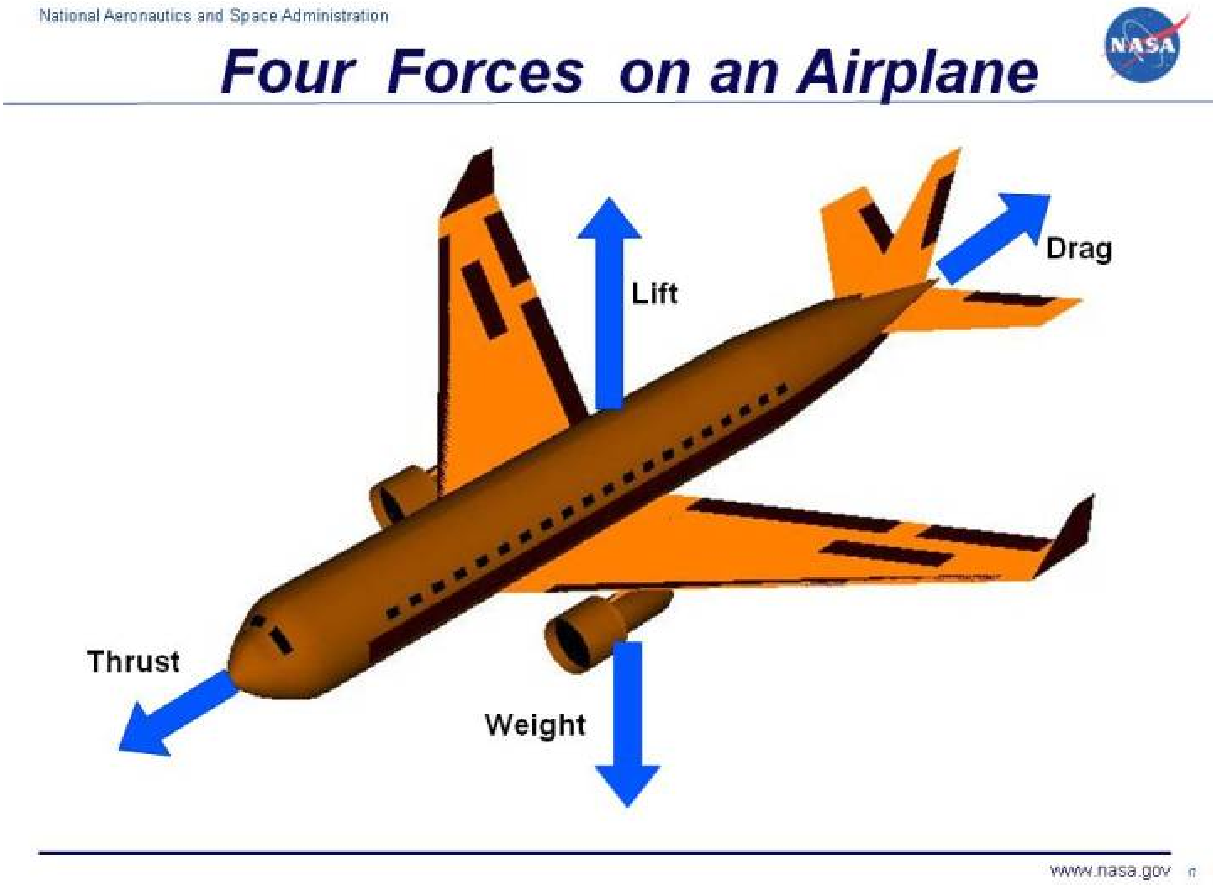

Figure 1.1: Forces on an Airplane(NASA 2018a)

As we know, if an airplane stays in motion during the flight the 1st Newton's law applies. So the weight, lift, drag and thrust must cancel each other out since the net force must be 0.

$$\Sigma\vec{F} = \vec{F_W} + \vec{F_L} + \vec{F_D} + \vec{F_T} = 0 \tag{1.1}$$

As Newton described:

> Every object persists in its state of rest or uniform motion - in a straight line unless it is compelled to change that state by forces impressed on it.

1.1 Weight

Weight is a force that is always directed toward the center of the earth. The magnitude of the weight depends on the mass of all the airplane parts, plus the amount of fuel, plus any payload on board (people, baggage, freight, etc.). The weight is distributed throughout the airplane. But we can often think of it as collected and acting through a single point called the center of gravity. In flight, the airplane rotates about the center of gravity(NASA 2018a).

Flying encompasses two major problems; overcoming the weight of an object by some opposing force, and controlling the object in flight. Both of these problems are related to the object's weight and the location of the center of gravity. During a flight, an airplane's weight constantly changes as the aircraft consumes fuel. The distribution of the weight and the center of gravity also changes. So the pilot must constantly adjust the controls to keep the airplane balanced, or trimmed.

1.2 Lift

To overcome the weight force, airplanes generate an opposing force called lift. Lift is generated by the motion of the airplane through the air and is an aerodynamic force. "Aero" stands for the air, and "dynamic" denotes motion. Lift is directed perpendicular to the flight direction. The magnitude of the lift depends on several factors including the shape, size, and velocity of the aircraft. As with weight, each part of the aircraft contributes to the aircraft lift force. Most of the lift is generated by the wings. Aircraft lift acts through a single point called the center of pressure. The center of pressure is defined just like the center of gravity, but using the pressure distribution around the body instead of the weight distribution.

The distribution of lift around the aircraft is important for solving the control problem. Aerodynamic surfaces are used to control the aircraft in roll, pitch, and yaw(NASA 2018a).

1.3 Drag

As the airplane moves through the air, there is another aerodynamic force present. The air resists the motion of the aircraft and the resistance force is called drag. Drag is directed along and opposed to the flight direction. Like lift, there are many factors that affect the magnitude of the drag force including the shape of the aircraft, the "stickiness" of the air, and the velocity of the aircraft. Like lift, we collect all of the individual components' drags and combine them into a single aircraft drag magnitude. And like lift, drag acts through the aircraft center of pressure(NASA 2018a).

1.4 Thrust

To overcome drag, airplanes use a propulsion system to generate a force called thrust. The direction of the thrust force depends on how the engines are attached to the aircraft. In the figure shown above, two turbine engines are located under the wings, parallel to the body, with thrust acting along the body centerline. On some aircraft, such as the Harrier, the thrust direction can be varied to help the airplane take off in a very short distance. The magnitude of the thrust depends on many factors associated with the propulsion system including the type of engine, the number of engines, and the throttle setting(NASA 2018a).

1.5 Short Video Tutorial…

Figure 1.2: How do Airplanes Fly.

2 HOW WINGS CREATE LIFT

"Lift is FORCE generated by TURNING a moving fluid" (NASA 2018b). Meaning that the relative direction of moving air in front of the wing is different from the moving air after the wing.

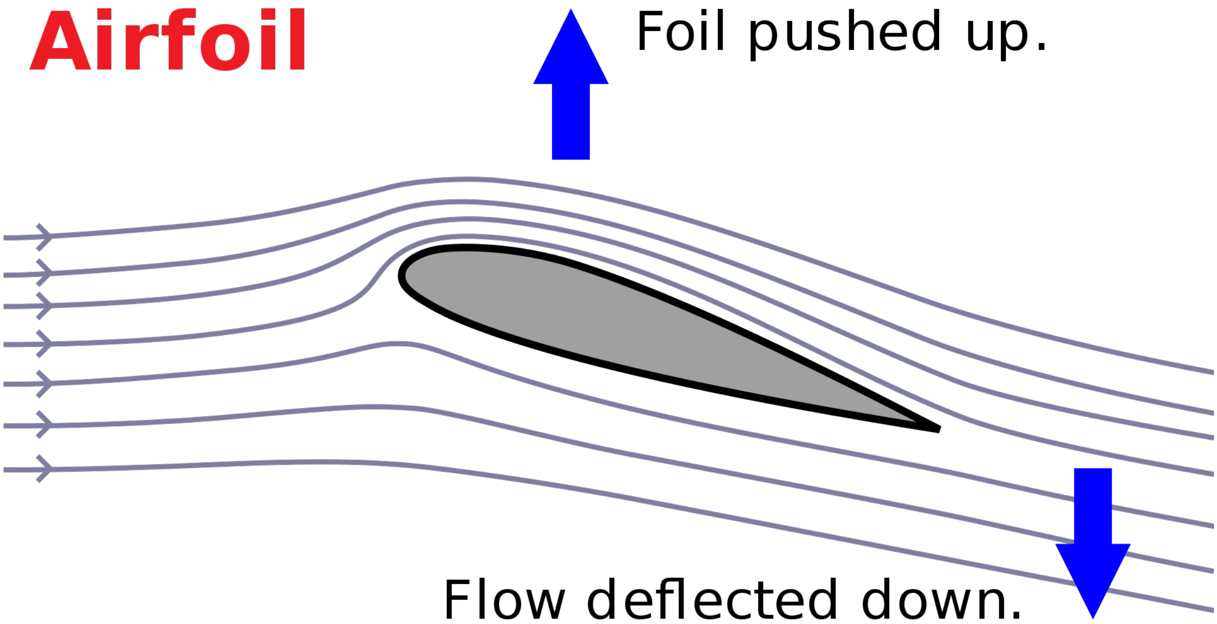

Figure 2.1: Deflection of air mass movement caused by wing (Wikipedia Contributors 2020).

In other words wing producing the force on air mass and causing the air to change the direction of relative movement. From 3rd Newton's law… :

> When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

… we know that the same force is applied in opposite direction.

Applying the 2nd Newtons law:

> In an inertial frame of reference, the vector sum of the forces F on an object is equal to the mass m of that object multiplied by the acceleration a of the object:

$$F = ma \tag{2.1}$$

Since the acceleration a is the change of velocity in time (regardless if the change is in scale or direction):

$$a = \frac{\vec{v}}{t} \tag{2.2}$$

… we get the lift force mainly by the changing the airflow direction.

How much air mass (m) will be deflected in certain time by the wing is depended on several factors: air density (ρ), wing airfoil shape (included in C_L), wing area (A), wing angle (included in C_L) and wing speed (v). Thus we end up with eq. 2.3:

$$F_{LIFT} = \frac{1}{2}\rho C_L A v^2 \tag{2.3}$$

More about the lift you can learn here:

Figure 2.2: Video on: How wings create lift.

2.1 Angle Of Attack

- Angle of attack also gain to direction change of moving air mass
- Increasing an ANGLE of ATTACK…
  - air flow cannot follow the top wing surface
  - airflow will separate of the wing -> stalling

2.2 Bernoulli principal

In a lot of resources you will find that the lift is generated by the Bernoulli effect. It is true that the change the velocity of fluid will cause the difference in pressure:

$$\Delta P = \frac{1}{2}\rho\Delta v^2 \tag{2.4}$$

It is a fact that the air flow under the wing is slowed down and airflow over the wing is speeded up. Thus we can find high pressure under the wing and low pressure on the upper surface of the wing. BUT THE LIFT FROM THAT PHENOMENON IS MINIMAL.

However this phenomena can not be overlooked. Since we have two different air masses with different pressures meeting at the end of the wing the vortex of air mass is produced which causing the **induced drag** (presented in fig. 3.1) which is our next issue to discuss.

3 DRAG

- How to to reduce drag?

3.1 Parasite drag

Drag caused by any aircraft surface that deflects or interferes with the smooth airflow around the airplane. - Surface finish

3.2 Induced drag

Drag that is the consequence of developing lift with a finite-span wing. It can be represented by a vector that results from the difference between total and vertical lift.

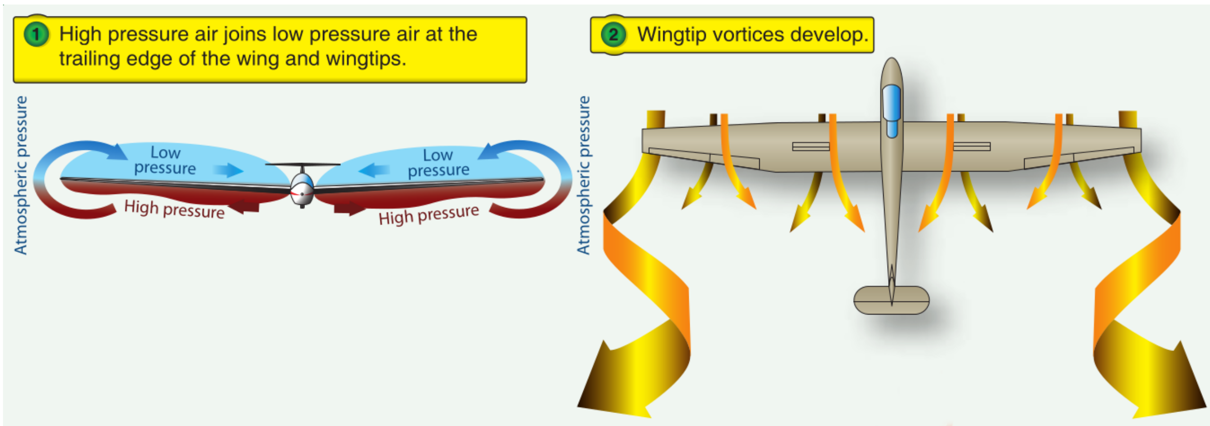

Figure 3.1: Induced drag caused by air pressure difference (United States 2013).

- Difference in pressure
  - higher aspect ratio of the wing area

3.3 Stability

3.3.1 Longitudinal stability

3.3.2 Lateral stability

4 Experimentation

- Identify your problem?
- Which basic phisical principals apply to your problem?
- Which factors will you change?
- Which factors will you try to stay fixed?
- What you have learned?

4.1 Lift

4.1.1 Wing Area

4.1.2 Thickness of profile

4.1.3 Aspect Ratio

4.1.4 Angle of attack

4.2 Drag

4.2.1 Induced drag

4.2.2 Parasite drag

4.3 Stability

4.3.1 Longitudinal

4.3.2 Lateral (rolling)

5 RULE OF THUMB BUILDING INSTRUCTIONS

5.1 Main Wing

A quick tutorial can be found at that video (https://www.youtube.com/watch?v=h_RzXO5u3M0).

5.1.1 Area of the wing

Calculate area of the wing according to eq. 2.3. Assuming that your glider will travel at speed $v = 4..8m/s$ and will have mass of cca. $m_{glider} = 200..300g$.

5.1.2 Aspect ratio of wing area

The aspect ratio of the wing area for the glider models (homemade) are far from the values of the real gliders. Thus mainly for the practical reasons we choose the aspect ratio between 6..12 values.

5.1.3 Airfoil shape

Symetrical profile:

- Ceter of Lift is at 25% the cord lenght of the wing
- not changing if AOA change

Profile (CLAR Y):

- Center of Lift is changing from 20% (AOA=+10°) to 40% (AOA= -10°).
- Center of GRAVITY should be at $\frac{1}{3}$ of chord lenght.
- thickness of the airfoil shape should be cca. 12% of the chord length and is located at 31% of the cord length.

5.1.4 More instructions on wing build

- Cut the material from depron sheet

- Nice taping technique is described in this video (https://youtu.be/PbyVGfB1oCg?t=639)

- Join two half's of the wing (if needed)
  Video(https://youtu.be/40lgBxxLxyk?t=88)
- Fold the sheets to get airfoil shape
  Video(https://youtu.be/40lgBxxLxyk?t=192)
- Glue the spacers to get right thickness of the wing
  Video(https://youtu.be/40lgBxxLxyk?t=224)
- Glue the end wing panel upwards - to increase stability
  Video(https://youtu.be/40lgBxxLxyk?t=537)
- Reinforce back edge of the wing
  Video(https://youtu.be/40lgBxxLxyk?t=634)

5.2 Fuselage

Basically you will do square tube from a depron sheet. Much like this guy in the video(https://www.youtube.com/watch?v

The 1°..2° degrees of negative angle on horizontal stabilizer are desired, which can be achieved by several options:
- the angle of back of the fuselage or - gluing it with some support…

Area of horizontal stabilizer should be cca. 20% - 30% of the main wing area.

Area of the vertical stabilizer should be cca 33% of horizontal stabilizer.

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