Chapter 5 Aerodynamics of Flight

Forces Acting on the Aircraft

The FAA "Pilot's Handbook of Aeronautical Knowledge" does an adequate job of describing level flight however it is important to understand the basic aerodynamic force that the that the lift and the drag which figure 5-1 shows. Note the thrust is equal to the drag in level flight.

forward component of weight. Some call this thrust however the classic definition of thrust:

"Thrust is a reaction force described quantitatively by Newton's second and third laws. When a system expels or accelerates mass in one direction, the accelerated mass will cause a force of equal magnitude but opposite direction on that system". With this definition of thrust this component of weight opposing drag would not be called thrust but it is presented here as thrust for your information.

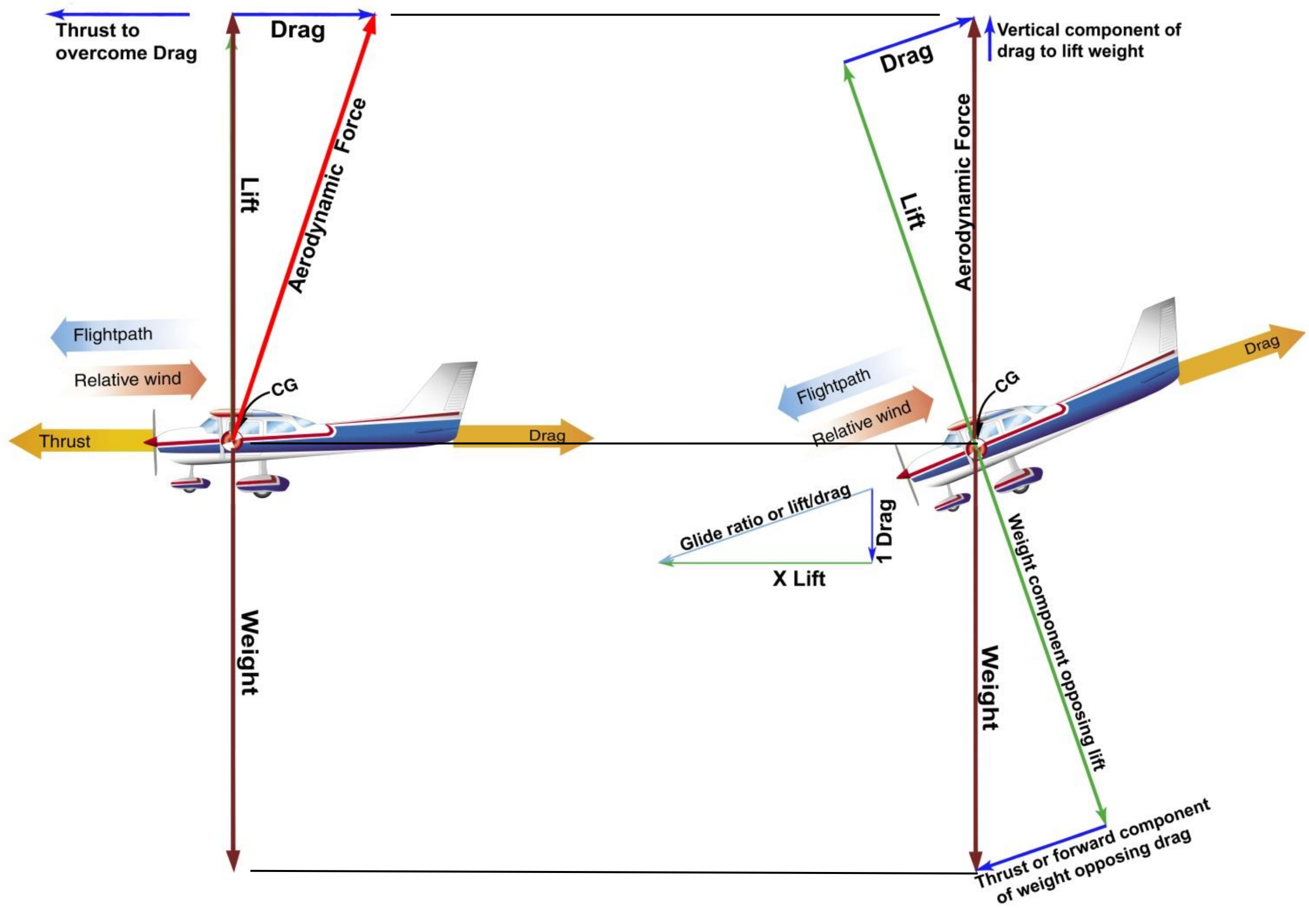

Figure 5-1 *Level flight and gliding flight.*

The next flight mode to understand is a glide with no thrust and the aircraft gliding down with no engine thrust like a glider. Here we need forces to lift the weight. Note the lift is perpendicular to the flight path and relative wind, as well as the drag parallel to the flight path and relative wind, but a portion of the drag is used to lift the weight with the vertical component of drag. So in a glide there is less lift needed because the drag helps to lift the weight.

The weight is broken into two components. The weight component to oppose lift, and the resultant

It should be noted that the FAA "Glider Flying Handbook" 8083-13A calls it thrust so either definition can be used.

The important concept is that the forward component of weight opposes drag and allows the aircraft to maintain speed in the forward direction.

It is easiest to understand is that the weight provides this forward component that opposes drag and allows the aircraft to glide forward.

Excess Thrust to Climb

Now let's look at the "excess thrust" which is required to climb. Again, we will compare this to the easiest to understand level flight.

Note that in a climb the the weight of the aircraft is the same as in level flight and in a glide. Now we have the thrust needed to overcome the drag plus the "excess thrust" needed to climb.

Basic Concepts for Thrust

- **Thrust at a constant airspeed** - changing thrust at a constant airspeed will change the vertical speed.
- **Thrust flying straight and level** - changing thrust flying straight and level will change the airspeed.

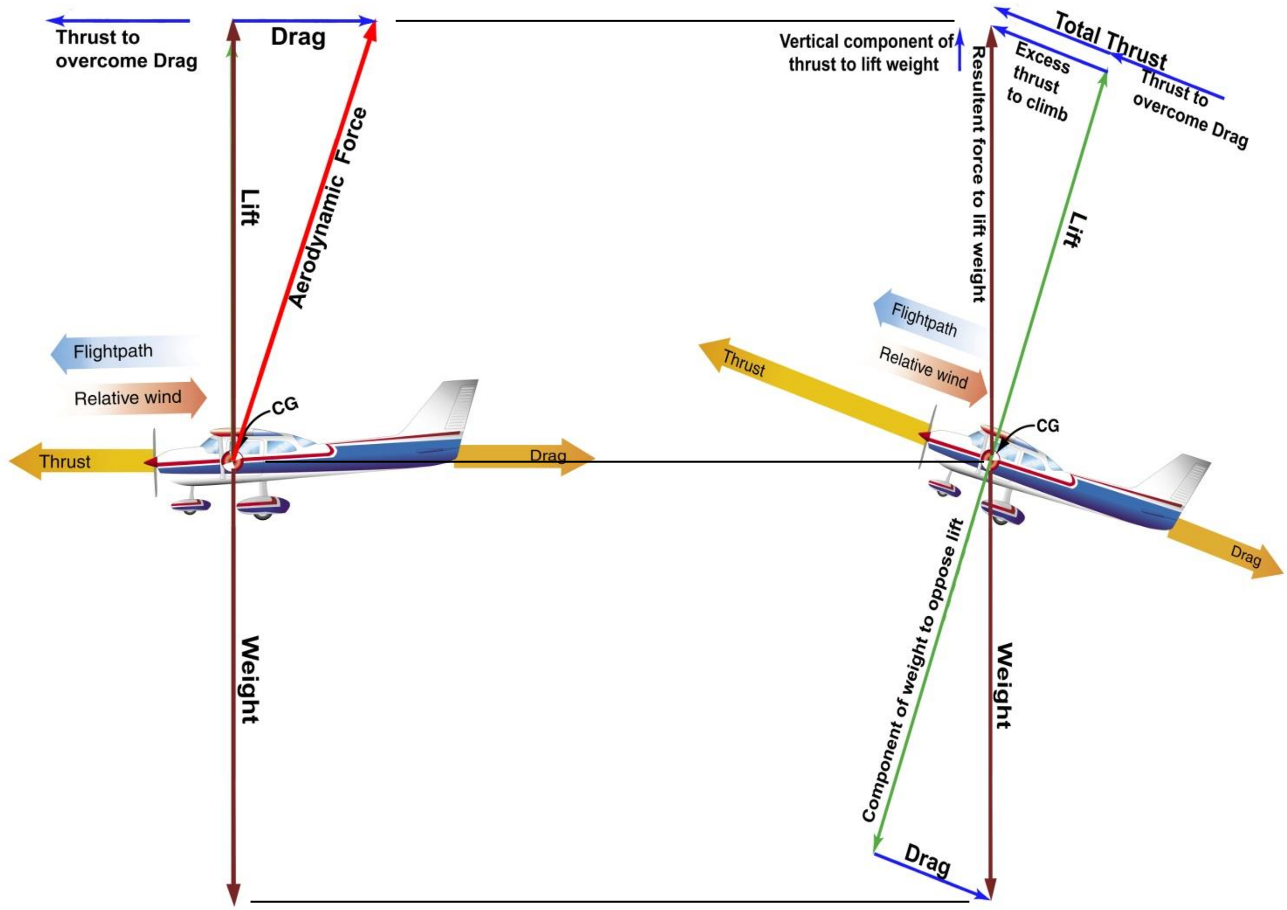

Figure 5-2 *Level flight and climbing flight.*

Note that in a climb the weight of the aircraft is the same as in level flight and in a glide. Now we have the thrust needed to overcome the drag plus the "excess thrust" needed to climb.

There is a big misunderstanding for many who think that extra lift is required to climb. This is a myth that is not true. Notice that the "excess thrust" above the thrust to overcome drag provides a vertical component of lift which allows the aircraft to climb.

As we can see in figure 5-2 there is less lift required to climb then in level flight.

Thrust Effects at High Pitch Angles

Aircraft at high pitch angles have interesting conditions relative to the equilibrium of forces because with the aircraft in a nose-high attitude. Most pilots are aware that an aircraft will stall, other conditions being equal, at a slower speed with the power on than with the power off. This is because the thrust has a horizontal and a vertical component where the vertical component provides some of the lift allowing the lift required for the wing to be less.

With less lift required from the wing, the stall speed decreases.

Induced Drag

Induced drag is the drag produced as a result of the lift. The FAA "Pilot's Handbook of Aeronautical Knowledge" does a good job of describing the wing tip vortices that cause induced drag.

The other important factor that is not explained well is the aerodynamic force "drag component" that contributes to induced drag. As shown in figure 5-3 below, we see that as the angle of attack increases and the force required to lift the lift remains constant, the aerodynamic force tilts back and the drag component increases significantly.

So at high angle of attack/slow speeds, the aerodynamic force PLUS the wing tip vorticies produce induced drag.

example ---- if your aircraft weights 1000 lbs loaded, your lift in straight and level flight is 1000 pounds.

What is your drag?- This is a little more difficult and there are a number of ways to do it but let's approach it so everyone can calculate/measure it. Therefore, we will use the lift over the drag method L/D commonly known as the glide ratio.
Measure your L/D. No matter how you do it there will be some type of error and here are a couple of ways to do it. First start with the manufacturers best glide speed as a baseline (or use 1.3 times your stall speed) to calculate your best glide speed.

Here are some options to measure/calculate your L/D. For each case it must be done in calm air with throttle at idle. Generally the higher and longer you measure the better measurement you will get. Here some ways on is how to measure/calculate your L/D (glide ratio):

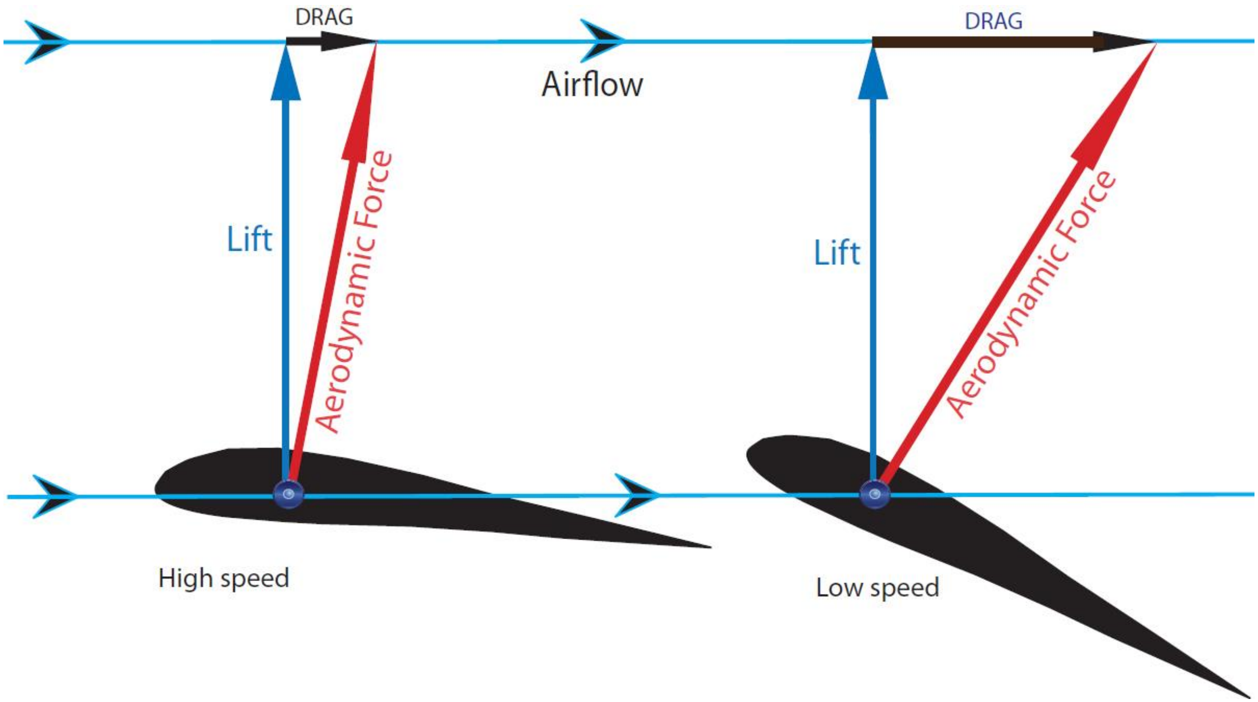

Figure 5-3 *Induced drag of an airfoil at low and high angles of attack.*

Lift/Drag Ratio

Understanding the Lift/Drag Numbers for Your Aircraft
So let's look what lift, drag, L/D and thrust numbers are and how you get them. First we will provide a method for you to measure/calculate the lift and drag of your aircraft

What is your Lift? – this is pretty easy. In straight and level flight your lift equals your weight. For

1. Use a modern electronic device such as a GPS or EFIS and it will calculate your glide slope or L/D as one of its functions. This provides a direct reading. Let's just say it averages out to be 9.

2. Measure your groundspeed with a GPS and your vertical speed with an accurate vertical speed indicator. Convert to

common units and put the horizontal speed over the vertical and you have the L/D ratio. Let's say you are reading 500 foot per minute vertical speed and your ground speed is 50 MPH. Convert to common units 500FPM * .0114= 5.7 MPH . Glide ratio is 50/5.7 = 8.77 so lets say l/d = 9 to keep it simple. Note that http://www.engineeringtoolbox.com/velocity-units-converter-d_1035.html can be used to convert to whatever units you want.

3. Start at a known point AGL say 4000 feet and glide a distance, lets say it is 7 statute miles over level ground. Convert to common units 7 statute miles * 5280 = 36,960 feet. Horizontal over vertical 36,960/4000 is 9.24 so let's say 9 to keep it simple.

4. Use the manufacturers claimed L/D ratio which is typically less than actual.

Now you have your Lift, you have your L/D, now calculate your drag. Let's use 1000 lbs lift with a glide ratio of 9. Glide ratio L/D = 9 = 1000/Drag or 1000/9 = 111 pounds of drag. There you go. For this condition you have about 111 pounds of drag. Yes there is a little thrust from the prop but not much.

So in summary at 50 MPH speed your lift and weight is 1000 pounds, your L/D is 9 and your drag is 111 pounds. We can take this one step further and figure your thrust at 50 MPH in level flight. Thrust equals drag in straight and level flight so your thrust is 111 pounds in straight and level flight once you know your L/D and your weight.

Here we have looked at some practical numbers to help you understand lift, drag, weight and thrust.

High Speed Flight

Starting at High Speed Flight the rest of the chapter can be ignored.