UAV Design - Part II
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Lecture - 04
Lift and Drag for an Infinite Wing (contd.)

Welcome back. In our previous lecture we discussed about boundary layer and then the concepts about hydrodynamic theory and also we looked at how the flow separation happens because of the adverse pressure gradient right. Now let us look at how lift is generated, right?

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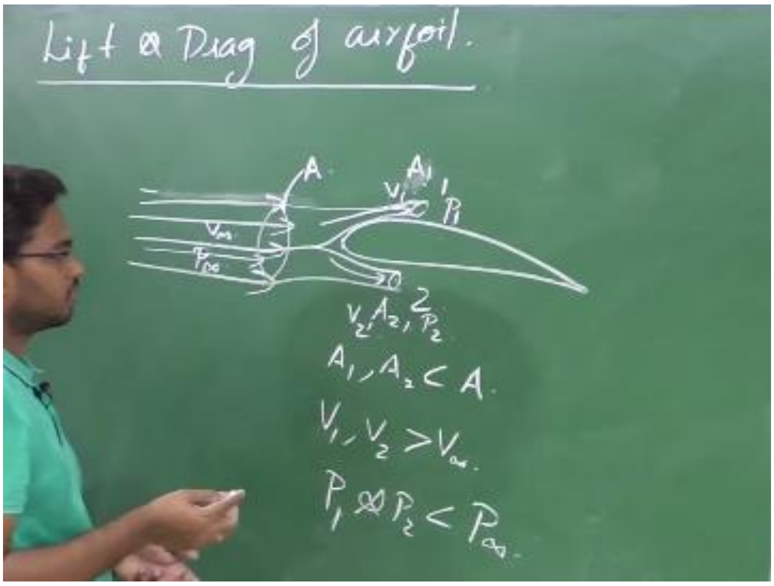

What is lift? We will define what is lift and drag right of a airfoil okay. So now let us consider an airfoil, which is a cross section of the wing as most of you are aware, right. So let us place this airfoil in the flow which means the airflow with the free stream velocity of V infinity, which means the airfoil is also moving at a velocity V infinity here right. Let us assume that this flow happens in a stream tube, right. Okay.

So now let us say this stream tube as soon as it encounters this aerofoil, right leading edge of this aerofoil, we will talk about that what is leading edge, let us say it encounters the aerofoil. What happens is this parent stream tube will get splitted into two daughter stream tubes. So there are many other explanations how the lift is generated. So this is one that I believe is more realistic, right.

So let us say the initial cross section area of the stream tube to be A and on the top surface let 1 be on the top of this aerorfoil which is the top surface and let 2 be the portion of this aerofoil which is on the bottom side of this surface right. So let us call it as yeah. And then the corresponding area here is say A or you can say A 1 and A 2, right.

So here what happens is since, so because of the presence of this body, the flow gets splitted, split across splitted across this and then which results in a reduction in cross section area in the flow above and below the airfoil right. So again this flow happens again in the stream tubes. We call them as daughter stream tubes here. So A 1 and A 2 are less than area of the parent stream tube, right.

Since the area is reduced, what happens is the flow tries to accelerate on the top and bottom surface here, right. That means you will have velocity V 1 and V 2 right and V 1 and V 2 are greater than V infinity, can be. Is it not? So which results in a drop in the pressure right according to Bernoulli’s theorem, right. What happens is, so let us say P 1 be the pressure at this point and P 2 be the pressure on the bottom side of this aerofoil, static pressure on the bottom side is, side of this airfoil.

So P 1 and P 2 less than the pressure in the free stream velocity V infinity, right. Okay, static pressure in the free yeah, in the free stream. Now can we observe something here? So there is a drop in pressure. So there is an increase in velocity on either side of this airfoil and at the same time, there is drop in pressure here right. So when this drop in pressure if P 1 and P 2 are equal, then there is no there is no pressure difference, is it not?

So which means there is no net force in this vertical plane. If there is a difference in P 1 and P 2, say P 1 is less than P 2, which means there is a differential pressure in the vertical plane and there will be a force like the pressure because of the static pressure on the bottom will try to push this aerofoil up right.

So equivalent to the area times of pressure, static pressure acting there and the difference of this pressure will give you pressure times the area will give you the corresponding force, right. Am I correct or not? So that means, when we have a pressure difference we can create the force called yeah, a force a force here force due to aerodynamics. Am I correct? Now again, this is from pressure contribution.

So we also witnessed that while discussing boundary layer theory concepts, initial concepts of this boundary layer theory, so we talked about viscous flows right. So what is viscosity doing here? It is trying to stop this body moving in this fluid. Am I correct or not, which means it is trying to so if say when we represent V infinity in this direction, which means the body is moving in the opposite direction right.

So the obstruction will be, because of viscosity what will be the direction of obstructing force? Opposite to the motion, right.

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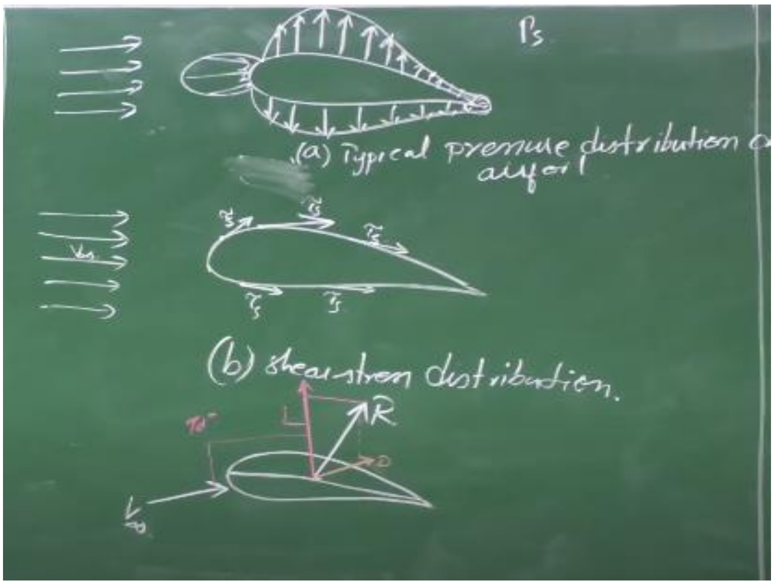

So due to viscosity let us say. So let us say, so viscosity is acting on the surface right. So there is a force acting on the surface which is a yeah, am I correct or not. So there is surface and there is a tangential force, what we can expect is a shear stress acting in the tangential direction on the surface, right. Let tau s represents this particular tangential stress called shear stress here, right. Fine?

So when you have flow due to viscosity you have shear stress and when you have flow you have pressure distribution, is it not? You have pressure distribution here. So this negative pressure is nothing but drop in pressure compared to the static pressure, surrounding static pressure, right. Let us assume there is no energy addition in this particular flow right.

So we have that our disk actuator disk attached to an aircraft near the fuselage, right. And let us assume the wings are far away from the influence of the free stream from this particular set, right the disk or the propeller and the engine there, right. Now this propeller is generating a thrust T, which is now rigidly attached to the aircraft.

Now the aircraft is being pulled by the, with the same force right and wings are rigidly attached to this aircraft and wings also experience the same velocity forward velocity. So in a fluid when there is forward velocity, you have equal and opposite flow moving with equal and opposite velocity, in the direction in the opposite direction of the velocity, is it not? Am I correct or not?

So that means, so the wing which is not under the influence of this propeller, ideally the pressure far ahead is static pressure which is atmospheric pressure. So when it start moving that means the static pressure, atmospheric pressure drops down and then your dynamic pressure increases to maintain the total pressure right, constant.

So when this happens right that means, in that particular stream tube compare to the ambient conditions, let us say if you consider an offset distance from that particular stream tube, you have static pressure conditions. Am I correct or not? So compared to that ambient conditions, the pressure inside that stream tube which is upstream is less. Am I correct or not?

And it is further less on the wings right. So because the velocity is increasing here, so the pressure ambient to this is static pressure, but this pressure here the static pressure, which is the atmospheric pressure there, but the static pressure inside this particular stream tube is far lesser, am I correct or not compared to static pressure. And when compared when we compare the pressure on the upper and bottom surface we have higher.

So this is for a typical airfoil right, so we have higher pressure drop on the top and lower pressure drop on the bottom part, right. So we will see why it is once we look at the nomenclature of this aerofoil and then we will get back to that right, why there is higher pressure drop on the top and lower pressure drop on the bottom. So there is pressure drop on either side, but there is a higher pressure drop on the top and low lower pressure drop on the bottom phase.

So that is why these arrows represent that negative pressure, that pressure drop compared to that is ambient conditions right, pressure in ambient conditions, okay. So you have these two are happening together right, is it not? So these two are happening together. And there is flow, there is viscosity, there is shear stress and there is static pressure right and there is certain pressure distribution.

So this talks about a typical pressure distribution on airfoil, right. So figure B talks about shear stress distribution, okay. So combining them what we have is a resultant aerodynamic force, is it not? So there, so this object is moving in the fluid right this airfoil is moving in the fluid and it experienced the pressure as well as shear stress distribution.

So and the result as a result of this aerodynamic right aerodynamics we have a resultant aerodynamic force, here okay. Let us say this is some reference line for the time being. So and say this is moving in this V infinity. What do you mean by this V infinity? We are representing this entire flow field by means of this particular vector here V infinity, which means the airfoil is actually moving in this direction.

Though it is oriented in a particular fashion, but still it is moving downward, right. Let us say if there is an arrow in this direction that means the object is moving in this particular direction, right. Now a component of this resultant aerodynamic force, which is acting perpendicular to this V infinity right say is called lift, right. So we have a component from this resultant aerodynamic force which is acting perpendicular to V infinity.

So V infinity and lift makes an angle 90 degrees here. And a component of this resultant aerodynamic force acting parallel to V infinity or along V infinity is your drag, right? So now we have defined what is lift and drag.

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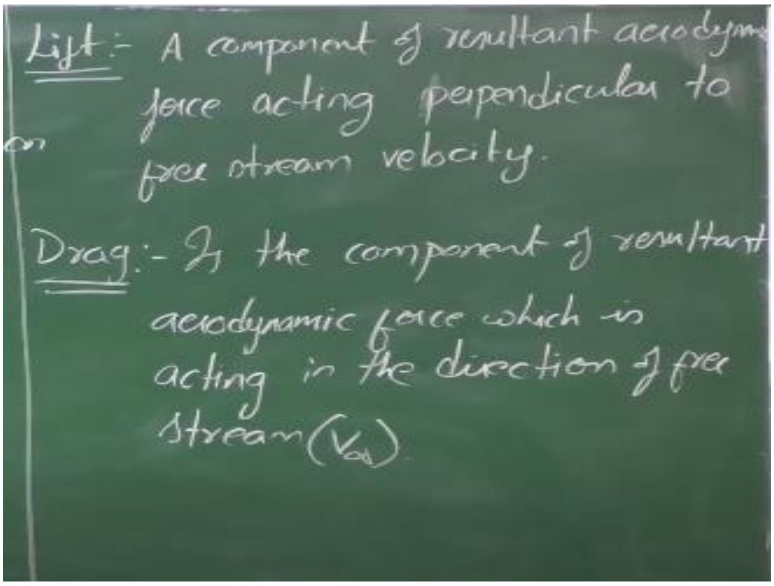

So lift is a component of resultant aerodynamic force acting perpendicular to free stream, okay. So and drag is a component of resultant aerodynamic force which is acting in the direction of free stream, which is direction of V infinity here right, is it not? So we know now drag is in this negative direction of the motion, am I correct or not?

So when we represent V infinity in this direction, which means the object is moving in this direction and we know drag is acting in a negative direction or along V infinity which is the negative direction of motion. So that means drag retards the motion of this object in the fluid here, right. So let us now quickly look at what is the nomenclature of this airfoil, right.

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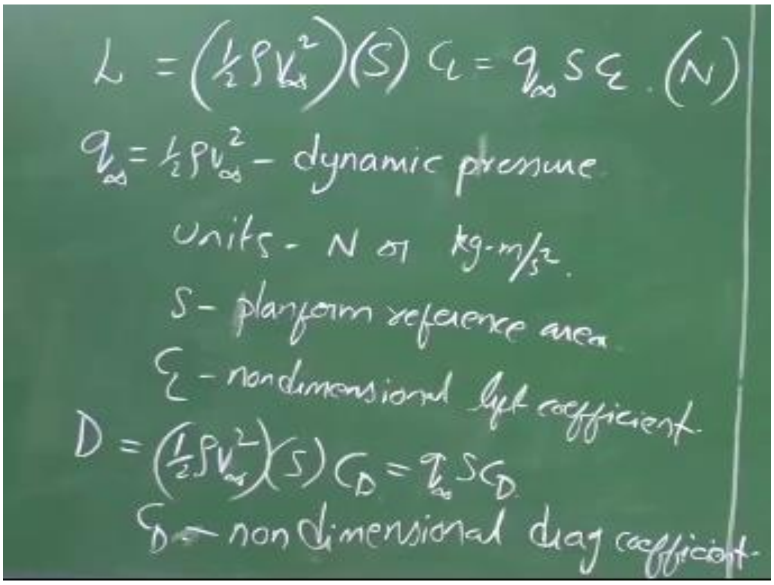

And then the lift here, lift here is defined as, is represented by L and is defined as the dynamic pressure times half rho V square dynamic pressure times the reference area, which in general is a wing planform area right times the non-dimensional lift quotient called C L here, right. So where half rho V square is known as dynamic pressure as you are aware.

And is so q infinity, it is represented by q infinity. What you can say is, so q infinity S time C L here right and the units of lift is Newtons here, right. So units are Newtons or what kg meter per second square, okay. And then S is the reference area, planform reference area that is contributing towards lift here, right? And then C L is a non-dimensional lift coefficient.

We will see what C L depends upon, right. As we progress we will talk about that. Similarly, drag is defined as half rho V square dynamic pressure times the reference area times C D. C D is a non-dimensional drag coefficient, right. So you have S and this which is q infinity times S C D where C D is equals to C D is the non-dimensional drag coefficient. Okay, thank you.