UAV Design - Part II

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Lecture - 03
Lift and Drag For an Infinite Wing

Welcome back. In our previous lecture, we discussed about axial momentum theory, where the velocity is constrained in a particular, constrained to a single axis.

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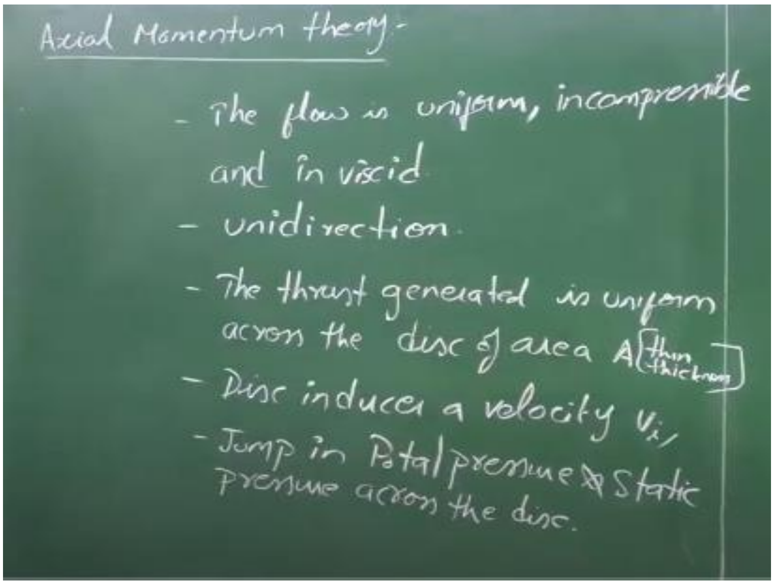

So what we discussed is, so we talked about axial momentum theory. So where the flow is assumed to be uniform, incompressible and invicid. Flow is also unidirectional where the velocity has only one component from left to right, right. And then we also assumed that the thrust generated is uniform or equally distributed throughout the disc, across the disc of area A, right.

So because of this disc induces velocity V i to the flow and due to which there is a jump in total pressure and the static pressure across the disc. So we unidirectional and then this thrust is generated by a disc of very thin what you call thickness, right.

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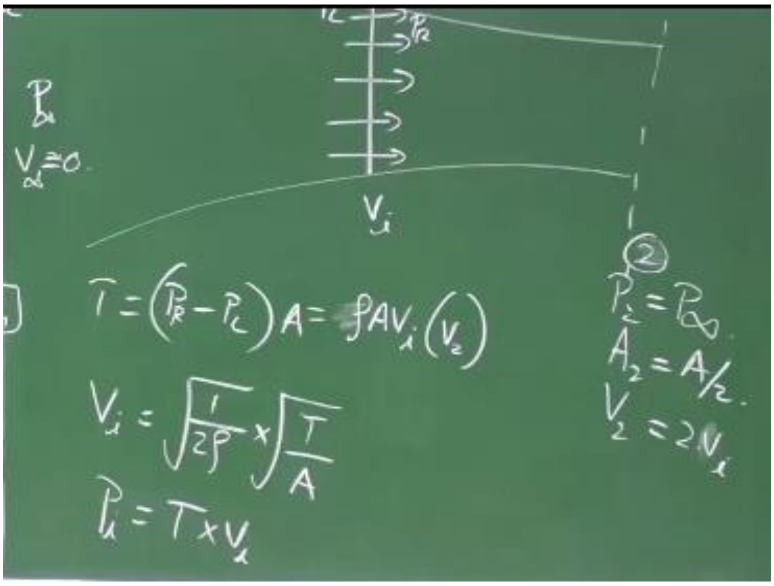

So with this assumptions we witnessed, so at a location say at a location 2 where the pressure in the downstream is equals to atmospheric pressure. So we have the cross sectional area of the stream to use figured out to be half the cross section area of this disc, half the area of this disc. And then the velocity at this particular location is equal to twice the velocity induced by the disc.

So let V i be the velocity induced by the disc where P L is a pressure to the left of the disc and P R is a pressure to the right of the disc and we are talking about static pressure here. And then P infinity be the pressure far ahead of this disc where V infinity is close to 0 here right. Okay and we also figured out the thrust generated is can be calculated.

Or can be estimated by means of the pressure generated, right pressure difference generated by the disc or imparted by the disc across the cross section, disc of cross section area A which is equals to mass flow rate times V i times. So V 2, right. So from here we related V i is equals to 1 upon root over 2 rho times root over T by A where T by A is known as thrust loading.

So V i induced velocity depends upon this thrust loading factor T by A, right. And also we witnessed the power induced is equals to thrust times thrust generated times or thrust imparted on the fluid times the corresponding velocity imparted to the fluid V i, right.

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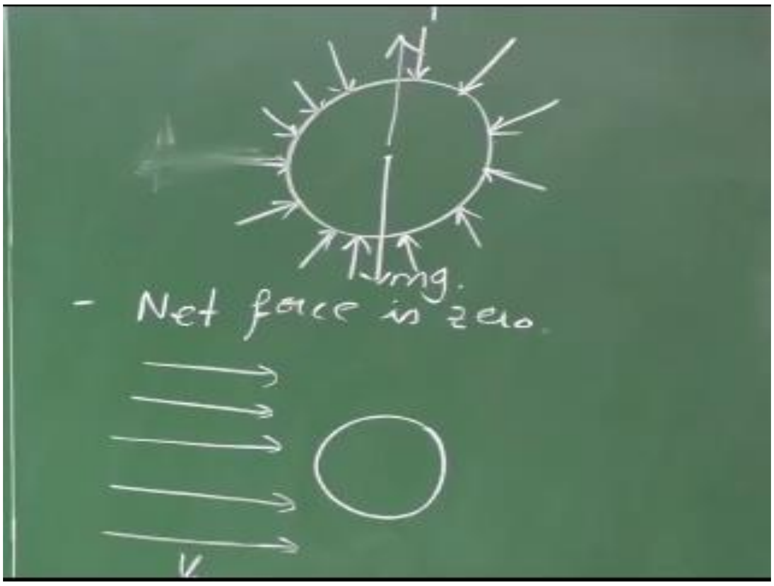

So now let us look at the circular cylinder. So it is the side view of the circular cylinder, right. So when you place this circular cylinder in the atmosphere so what do you think are the forces acting on it? So it is surrounded by the gas right, atmosphere here, which exerts equal pressure in all directions. Is it not? So the pressure exerted by the atmosphere on this cylinder is equal in all directions.

And the corresponding force or the net force due to this will be 0, is it not? Because pressure acts in all directions and the net force is 0. So if I want to lift the cylinder up, right, the force that I need to overcome is weight of the cylinder mg, is it not? I need to produce a force which will overcome the weight of this object here right. So we have surrounding atmosphere and then it exerts some static pressure on this.

But which is equal in all directions. So the total force exerted from the top or from any direction because of this atmospheric pressure is canceled from the opposite part on this cylinder. So we do not get any useful lift or say, I try to constrain myself using the word lift for the time being. So useful force that will lift this body from the atmosphere under static condition, right.

So let us look at what happens when we place this circular cylinder in a flow. In other words, we now know we can generate a thrust from this disc, right? So if I attach the disc rigidly to this let us say maybe at some other location which will drag this body along with that disc right because there is thrust. So it will try to move forward and so this disc somehow we have attached sorry this circular cylinder we somehow attached to this disc right.

So it starts moving forward. Now when it is moving forward we know so the flow will also the atmosphere will also move or the air will also move in the opposite direction with the equal velocity. That means, it is equivalent to see if I have a disc like this. So say this is the V infinity. If the disc is moving with V infinity, I have flow opposite to it at the same velocity V infinity right.

Assume that it is circular, okay. Fine. Now what happens in an ideal flow? So what is an ideal flow? It is a flow of fluids in which the viscous forces are neglected, right. So viscosity is nothing but fluid friction, is it not? So when an object is trying to move in a fluid, the fluid try to resist its motion, right. So that is nothing but viscosity is nothing but fluid friction.

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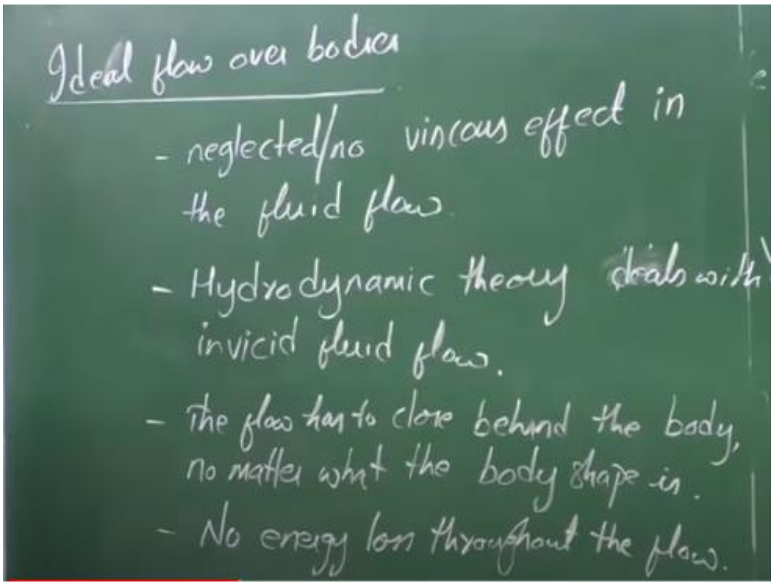

So ideal flow, let us consider ideal flow over bodies, right. So if I see the main aim of looking at the flow around this object is whether this flow can create any pressure difference here. So which can generate lift here or say which can generate a force that acts against weight of this body, right. That is the whole area. So for that we are trying to first look at what is an, what is the ideal flow.

What happens when there is an ideal flow across this cylinder, right? So the ideal flow means what? We have neglected or say no viscous effect in the fluid flow right with no viscous effect in the fluid flow right. So the study that talks about this is known as hydrodynamic theory. Theory talks about this invicid flows, deals with invicid fluid flow.

So the important prediction, one of the important prediction of this hydrodynamic theory is that so when there is flow across an object, so the flow has to close behind the object, right no matter what the shape of the object is, okay. So we will look into that.

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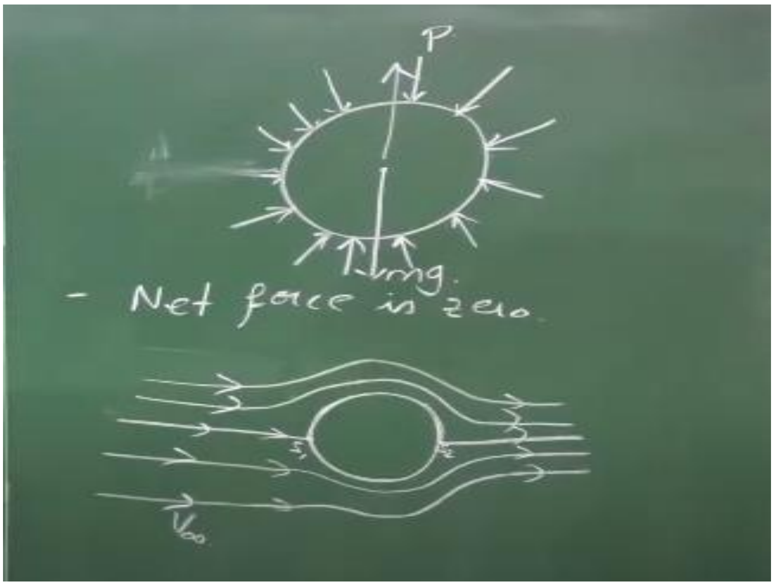

So this is my one of the stagnation point. So more or less tries to achieve the same profile. So more or less tries to achieve the same profile, right. So more or less tries to achieve the same profile as the profile of the flow which is ahead of this object, right. So even the profile behind the object is more or less same as profile ahead of the object.

So in this so this one of the important predictions of the theory is the flow has to close behind the body no matter what the shape of the body or the body shape is right. So it also claims that no energy loss throughout the flow right. So but in reality for real fluid flows, there is definitely some viscosity right to some degree, is it not? And due to viscosity what happens is the fluid particles try to stick to the surface of the body.

In other words, so the velocity of the fluid particles on the body surface is equals to zero. So this is contradicting the ideal flow theory right where the ideal flow theory predicts that the fluid velocity on the body will be equal to the flow velocity or even more than that, right. So what is that?

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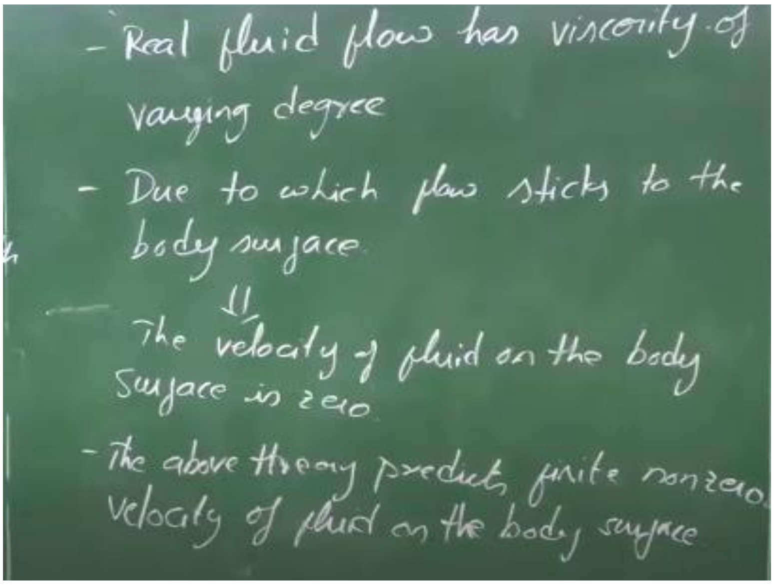

So but real fluid flow has viscosity right to some degree or of varying degree. And also due to which so in other words what we can say from here, so the velocity of fluid on the body surface will be zero right. So this is in contradiction to ideal flow theory which predicts that the velocity on the body surface can be or more than, can be equal to or more than the free stream velocity right.

So but the theory or the aforementioned theory predicts finite nonzero velocity and the velocity of the fluid on the body surface, yeah? Okay. In fact this theory considers the body surface or the boundary of the object as a part of the flow itself. So if you look at this particular streamline this is known as stagnation streamline, where, so the body itself forms the stagnation.

On the body there is a there are two stagnation points here s 1 and s 2 and this itself forms this particular stagnation streamline here, right. So these two points s 1 and s 2 the pressure is zero here. Sorry the velocity of the fluid particle is zero at this two points s 1 and s 2, right. Okay.

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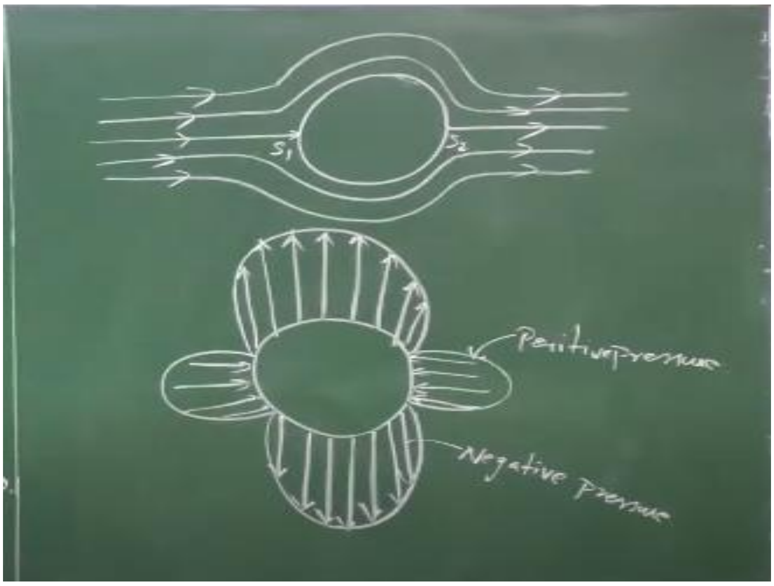

So according to this theory so we have finite flow we have finite velocity of the flow on the object, right. So which can be more than the free stream velocity as well right. So in this particular case, the object boundary of this object or the surface of the object itself is a part of the flow, which is a stagnate, which forms the stagnation stream line of this flow, right.

Let s 1 be the stagnation point which is on the front part of this body and let s 2 be the second stagnation point which is on the rear part of this body, right. So now along the stagnation streamline the flow initially which is at rest try to accelerate right and it reach certain velocity and then drop backs to zero velocity at s 2, right. And then yeah, so let us look at what is the pressure distribution because of this flow.

That is what we are most interested in, is it not? So because of the stagnation points we have positive pressure, right. And as the flow accelerates the static pressure decreases, let us call it as negative pressure, because we are not adding any energy in this entire part. So we have a total pressure P naught here right, which is completely the static pressure at the stagnation point.

As the flow accelerates the stagnation, the dynamic pressure increases and the static pressure drops down, right. This is the representation of static pressure here. So right and the flow and then again drops back to zero velocity after reaching certain velocity it will again drop back to the zero velocity at s 2, right. So at s 1 and s 2 we have stagnation points where it is total static pressure, right.

And here on the surface and below the surface there is certain velocity for the flow according to this theory. So because of which there is a drop in the static pressure because the total pressure still has to be same here right. So there is a drop in static pressure. That drop in static pressure let us call compared to the ambient conditions, right. So let us call it a negative pressure here.

We will discuss about this negative pressure in detail, very soon. Negative pressure and we have positive pressure. So on both sides we have positive pressure and on the top and bottom we have negative pressure.

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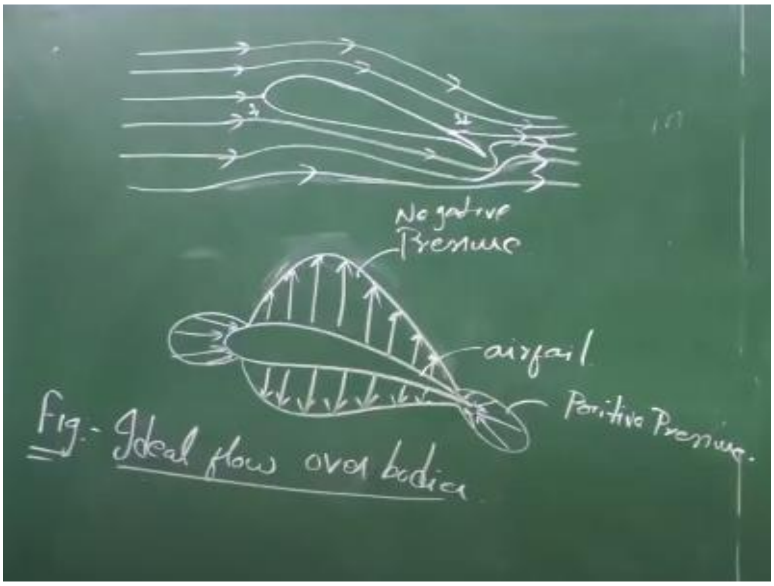

Similarly, let us look at ideal flow around a streamline body, right. Okay. So you have the initial stagnation point and the boundary itself forms the stagnation streamline, right. Let s 2 be the stagnation point, second stagnation point behind to this flow, right. Okay. So since according to this theory, the flow cannot separate from this body it has to close. It will try to curl around this particular trailing edge and then closes the flow right.

So you have two stagnation points again here in s 1 and s 2. If you look at the pressure distribution here, so similar to that we have positive pressure near the stagnation point right and then negative pressure on top and bottom sides of this airfoil. So this particular streamlined object is known as airfoil, right. So let us say this is our airfoil and this is negative pressure and this is positive pressure, okay.

So what we are talking about this is ideal flow or typical ideal flow over bodies, right. So this is what this figure is going to is talking about. So we have a bluff body and we have a streamlined body here. So this is how a typical pressure distribution is okay. Let us look at the velocity distribution here.

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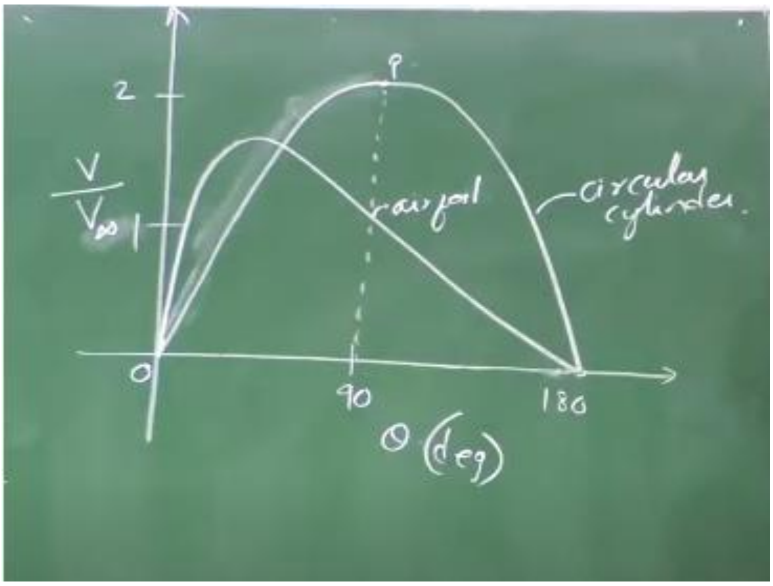

So V upon V infinity, say V infinity be the local velocity or say V be the local velocity and V infinity be the free stream velocity here right. So let theta represents a location here. So 0 corresponds to stagnation point 1 and say 180 degrees corresponds to stagnation point 2 right. So for a circular cylinder a typical variation is something like this right. And for an airfoil so this corresponds to circular cylinder, right.

And this corresponds to the airfoil, okay. So if you can observe for a circular cylinder at maximum thickness point say P, this corresponds to the maximum thickness point right. So with respect with respect to flow, so the maximum thickness point is at 90 degrees is it not? Theta 90 degrees so this is theta is in okay degree. So this is the maximum thickness point for the flow.

So at this flow it is almost the local velocity is almost twice that of the free stream velocity if you can observe, according to ideal hydrostatic theory which is ideal flow theory we are talking about. So according to it the free stream velocity at this maximum thickness point is about twice the sorry the local velocity is twice the free stream velocity right.

So but will it happen in reality? But what happens in reality? As we mentioned earlier, so real flows have some viscosity right. So the flow which is close to the surface of the object will experience a lot of retardation due to viscosity and then it comes to rest on the body surface. Am I correct or not?

So within certain distance, so the within certain distance from the surface of the body, the flow will try to reach the free stream velocity within very short distance right from zero to the free stream. Zero because it has fluid friction, right. So it will stick to the surface and on the surface the velocity is zero for the fluid flow and then it will reach the free stream velocity within small distance from the surface.

Let us say if you take a perpendicular distance to the surface. So within a small perpendicular distance from the surface it will try to reach to the free stream velocity at that particular location. So this small thickness in which the velocity reaches from zero to the free stream velocity, close to the free stream velocity is called boundary layer, right. Okay. So we will see why we are talking about boundary layer at the same time right.

So because we are dealing with not ideal fluids right. So we are talking about air flow, flow of air around the body, around the streamline body to be frank. So we need to know how this air which is a real fluid behaves on this particular object right at different conditions. So that is what we are trying to do. So from there how to and how to get the lift right how lift is generated, which is our main aim right.

We know how thrust is generated right now. And now we would like to know how lift is generated. By the way, when we are talking about the thrust generation, we are talking about reaction from the air, is it not? So the disc is rotating and which in our case it is a propeller. So the propeller is rotating which is pushing air behind and then air is pushing this propeller forward, is it not?

So this is producing this particular phenomenon is producing certain thrust right. So similarly, if there is a so that is in fact creating a pressure difference across the disc, right. That is what we witnessed. And why we have to depend upon air to generate thrust? Because that is the only medium on which we can apply force right, we can get reaction from.

For example, if you are talking about car, your car wheels are connected to the engine by means of some drives, right? Gearbox and then there is shaft axle and then there is shaft right. So you have certain linkage that that is connect the types of your car is connected with your engine right. So what happens is when there is power to this engine when the engine starts generating the power it will start rotating the shaft right and which in turn rotates the wheels right.

So the wheels because of the friction on the ground gets a reaction force right. Am I correct or not? So on the ground it is opposite direction it is backward, but on the tire the friction acts in the forward direction which is taking you forward right. So friction helps your car to move forward. If you put an ice in between beneath it, your tire will start slipping, you will not be able to move forward right.

So the car is moving forward because with the help of friction. That means you are getting reaction from the friction, due to friction sorry. Reaction from the ground due to friction, right. So the, your car is still in atmosphere, but you are using the, you are using reaction from the ground, is it not? Right? But when you are off the ground, the only medium which can give you the reaction force is air, right?

So that means we need that is the reason why we are depending on air for the for generation of thrust, right. Similarly, we have to depend on air. Of course, we know that for generation of lift, is it not? So if you want to know how this air behaves in reality on this, then we need to talk a bit about this boundary layer theory as well right.

So that will help us to understand why there is a flow separation or when you talk about the airfoil see this streamlined body is known as airfoil. So when we talk about the characteristics of airfoil, we will be using this flow separation concept right. So in order to understand what is flow separation, how it happens, we first need to talk about boundary layer. So this lecture maybe bit with bit more aerodynamics right.

So maybe boring to some of you, but still there is no shortcut. We have to go through this lecture, right.

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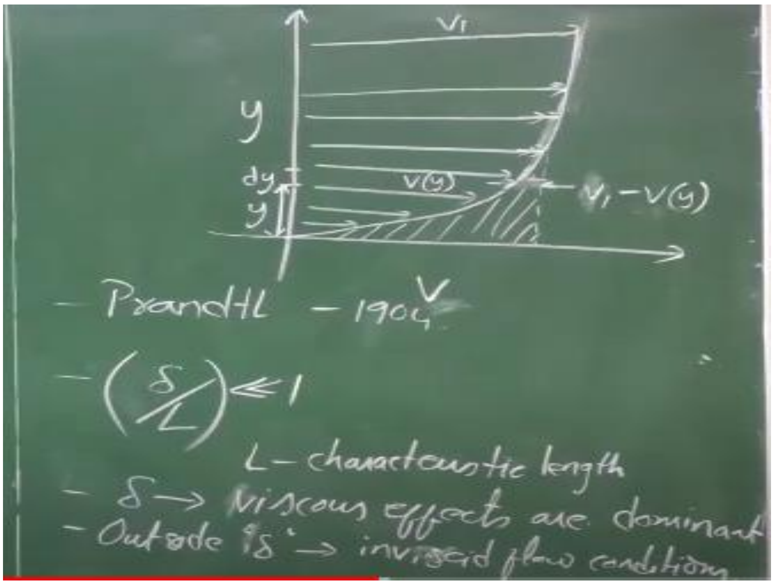

So let us say y be the perpendicular distance to the surface, right. And then say V infinity is the V is the corresponding velocity. Let us say V 1 be the local velocity here, okay. So on the body when y is 0 which is on the body, the velocity of the fluid is 0 and it slowly increases to the free stream velocity. This is almost close to that point we can say, okay. So this is almost close to that point.

So this is right, this is the loss. Okay, we will talk about this. But first let us look at this curve, right. So the velocity gradually, see this talks about the magnitude of velocity. Let us say if I have an object like this, right. So at this particular say point say this is my tangent to the surface and this is my normal to the surface right. So along this normal let us say there is flow here, right.

So this object is in flow, we place this object in flow. So at this particular point what is the corresponding magnitude of velocity? It is not that these arrows does not mean that the velocity at this particular point these arrows represent the magnitude of velocity at this particular at these different points, that is it, right. So arrows represents the magnitude at this particular point.

If you have so multiple those pitot tubes, let us say or say static tubes, multiple of the static tubes arranged in a stack, right. So if you have a vertical column and you have perpendicular to it, we have multiple ports and then use that particular frame with multiple ports to measure this particular velocity profile, right.

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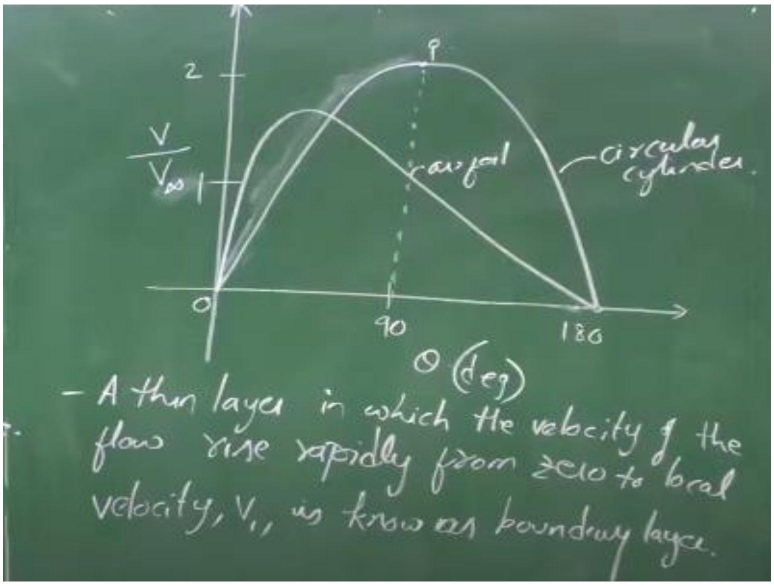

So a thin layer in which the velocity of the flow rise rapidly from zero to free stream or local velocity say V 1 is known as boundary layer, right. Okay. So Prandtl in the year 1904 proposed this theory right. So he postulated that the this delta is the thickness of the boundary layer is far less compared to or very small compared to the dimension, characteristic dimension of the object.

Let us say, in this particular circular cylinder case we can consider the characteristic dimension as the diameter right. So in this particular case, we can consider some length which can join right the first point and the last point here right. So that can be the characteristic length here. So according to this according to him, this delta upon L is far less than 1 where L is the characteristic length, fine.

Now typically, so within this delta, so all the invicid viscous effects are, viscous effects are dominant, right. So we can say so these viscous effects are confined within this particular boundary layer, right. And also outside this boundary layer, we can deal with the same potential flow theory or the hydrodynamic theory, we can use the same principle.

So outside this boundary layer, the fluid flow behaves as if it is invicid, right. We can consider the conditions to be invicid, right. Yeah.

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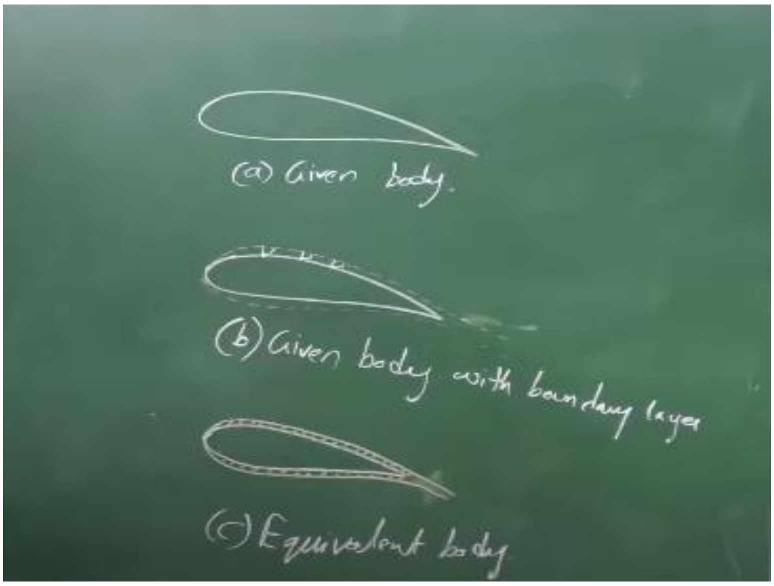

So now what happens actually, so when you have an aerofoil. So this is your given object, right. So say let us say this is your given body, right. And then there is flow. You have a boundary layer, right. Okay. So you have given body with boundary layer, right. So what is happening within boundary layer?

We know the velocity at any given point will raise from at any given point on this airfoil, will try to raise from zero to the free stream or the local velocity at that particular. So it is same as here same for here. So it may, it depends how the pressure is, right. So the velocity keep changing from zero to free stream velocity, right. And when you say zero velocity, what do you mean by that?

Are you not bringing the particle of mass m to rest at that particular point, is it not? So is it not is it nothing but you are accumulating mass, is it not? Am I correct or not? So the concept of equivalent bodies introduced in order to so what happens is, so we can actually replace this particular boundary layer with this body by means of a body of thickness delta star added to this particular given body right.

So we have the boundary of this given body and add a delta star thickness, which is which accounts for this boundary layer effect, right. So add that particular thickness and replace this body with that particular thickness then what you have is a potential flow solution or ideal flow solution, right. So all that viscous effects are now constrained within this delta star and then delta star is now become a part of this body itself, right.

So that is what we call it as equivalent body here, right. So how it is, okay. So according to Kutta condition, right the flow has to live parallel to this trailing edge, right. So you can read about that. So this so we can replace our given body by means of this equivalent body right and consider the flow is invicid. And you can figure out what is the corresponding pressure distribution as well as velocity distribution using ideal flow theory.

So what is this called as equivalent body, right? Fine. So according to this equivalent theory right, so what we are doing we are displacing this boundary layer or the surface of the boundary by means of an equivalent boundary layer thickness, right.

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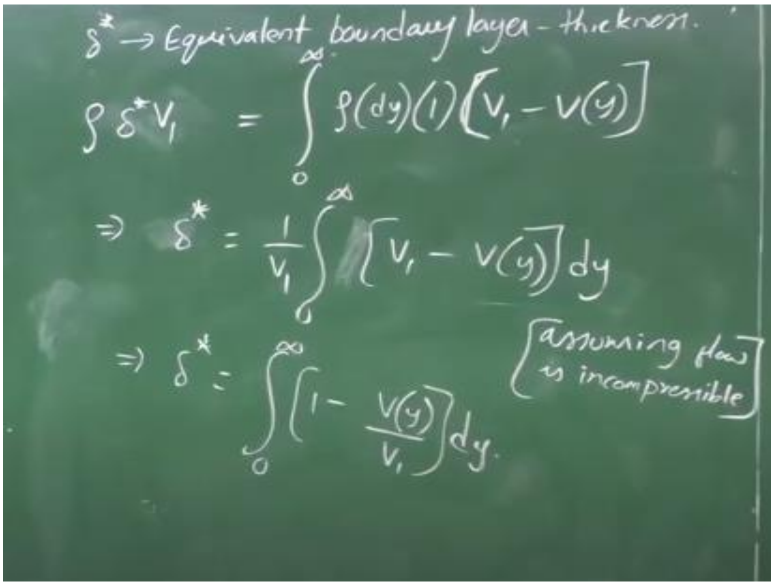

So let us say delta star represents the equivalent boundary layer thickness. Say this is my, this is my delta star. So let us say delta star represents equivalent boundary layer thickness. So why we are using this equivalent boundary layer thickness? So if the if we shift the flow by this particular delta star right, in delta star what is happening? So we are losing some mass flow, is it not?

Whatever the mass that is entering, if you consider a particular control volume, whatever the mass that is entering may not be leaving because it is being trapped in this particular boundary layer because of the retardation that the fluid element faces right is it not it? So the bottom most particle will face as the retardation, more retardation, is it not? Higher retardation compared to the others here.

So that is why it will come to rest soon compared to the other particles or particles in the above layers in that particular boundary layer. So what we can say is say at a particular location say this is my y right. Say consider a small element dy here right. So where V y is the corresponding velocity at that particular location, got it? And then what is this difference?

So this particular difference will be V 1 - V(y). V(y) is the velocity at that particular location. So mass flow rate or V 1 – V y represents this particular loss in mass flow rate, mass flow is it not? So this mass flow is equals to the loss in mass flow. This talks about the loss in mass flow. So the actual mass flow should be what rho A V 1 ideally it should be.

But because of this, so in this particular strip what you have is rho A V y where A is the cross section here let us say, if you have unit depth no unit depth into this, what you have is the area of cross section of this thin strip will be let us say if you extrude this strip outside right you have this dy let us say this depth be unit right. So dy times 1 will be the corresponding cross section through which it is the mass flow is happening.

So that is rho A dy, A is nothing but d sorry rho times dy times 1 times V y will be the corresponding mass flow through that particular strip in the boundary layer, right. And then what will be the loss of the mass flow it is like rho A ideally when there is no for a invicid flow, the velocity on the surface will also be equal to the velocity V 1 here, right is it not? So in that case the total mass flow should be rho V 1 right minus now you have yeah.

So across this strip it should be rho dy times one times V 1 right. So the same strip is now, in the same strip because of this boundary layer we have what rho A, A is nothing but dy times 1 times V y, V at that particular location, is it not? So subtracting these two what you have is the mass flow that is lost, this particular thing. So the mass flow that is lost is rho corresponding cross section area is dy times unit depth times what is the velocity?

This is the loss in velocity. Am I correct or not? So this if you integrate it from 0 to infinity, right. So at a location when V y becomes V or 0.99 times of V 1 right. So this particular integral will not have any meaning. So you can say zero to some value where dy value where this velocity becomes velocity local velocity become velocity at that particular y location becomes local velocity, close to local velocity, right.

So this must be equal to, so again coming back to this equivalent body. So what is the concept here? So we are replacing, so in a invicid flow let us say, now we want to find a way how to get the solution, right? Am I correct or not? How to figure out so coming back to this equivalent body what we have is delta star just to replace the given body right so that the flow solution becomes invicid flow solution right, is it not? Okay.

So that means, so whatever the mass flow rate that was lost must be compensated by this delta star, am I correct or not? So let us say the mass flow rate compensated by this is, delta is the thickness right, thickness and unit depth will give you the corresponding cross section area times the density here times the corresponding velocity will be V 1 because for a invicid solution even the velocity in the boundary layer will be same.

If you use the equivalent boundary layer concept the velocity in that boundary layer should also be same. Let us say, yeah, so here this must be the delta star okay. So this is your delta star that y and then unit depth if you extrude it out, unit depth. So delta star times one is the area, corresponding area, density times area times the corresponding velocity.

The concept is it should help for a invicid flow it should it will be equivalent right. It will be equal to V 1. So what we have is delta star is equals to 1 upon V 1 times zero to infinity rho times. So let us say, if you consider invicid sorry, incompressible flow. So I am taking density out what I can have is V 1 – V(y) at a given location times dy assuming flow is incompressible, okay.

This is what we are going to have. So you can further take it in saying 1 – V(y) upon local velocity times dy, right. So you can look at the detailed derivation. This is just like it is a one dimensional thing that we have used. You can look at the detailed derivation for this, okay.

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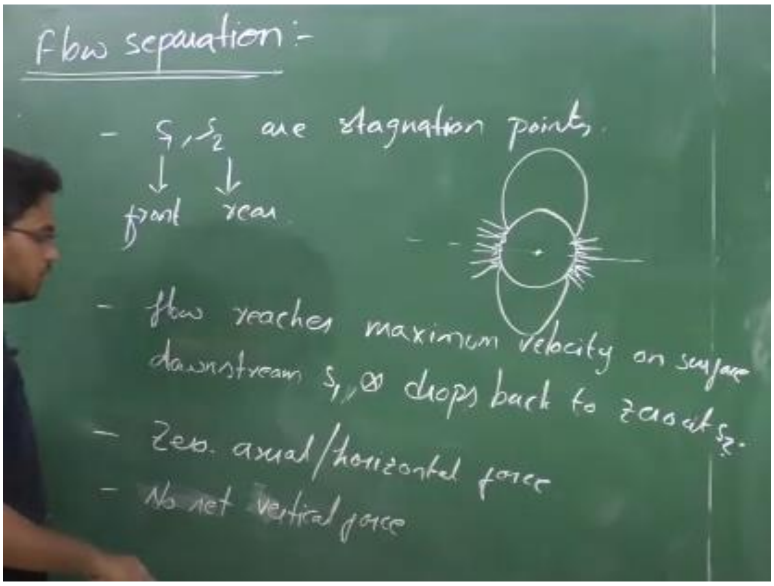

Let us talk about flow separation. Since we know what is boundary layer and equivalent boundary layer concepts of boundary layer and equivalent boundary layer, we now try to use them for our concept of flow separation, right. Okay, so according to ideal flow theory, what it predicts? So according to this we have one stagnation s 1 and s 2 are stagnation points right?

Which is on the front and on the rear sides right, rear side of the object. Is it not? So according to this, so there is and then the flow tries to flow reaches some maximum velocity on the surface, right. Maximum velocity on surface downstream s 1 right and drops back zero at s 2. Am I correct or not? So due to which there is pressure in the front and pressure in the back pause to pressure acting in the front and back, right.

So these the force generated or the net force generated by this by the pressure acting on the front and the rear side of this object of this cylinder will be canceled out is it not? So there is and similarly, there is a stagnation point in the rear end of this object. So this force in the front end and the rear end will get cancelled. Force because of this pressure acting right at this stagnation points will cancel out.

That means it will result in zero net axial force right or net axial horizontal force. There is no net horizontal force zero. I am trying not to use this words drag and lift for the time being. We will soon define them and then we can start using them, right. So till then let me talk in terms of axial force and then vertical force here okay. So zero axial or horizontal I should say horizontal force here, right.

And then zero, similarly, you have negative pressure on the top and negative pressure on the bottom, right. So the because of which this negative force because of this new pressure cancels out and there is no force or net zero net vertical force, right. So let us look at an analogy in order to understand what happens in reality for this flow, right. So this is again from the ideal flow which we just discussed.

We will talk about this in detail or say we will talk about the actual flow once we look at this analogy.

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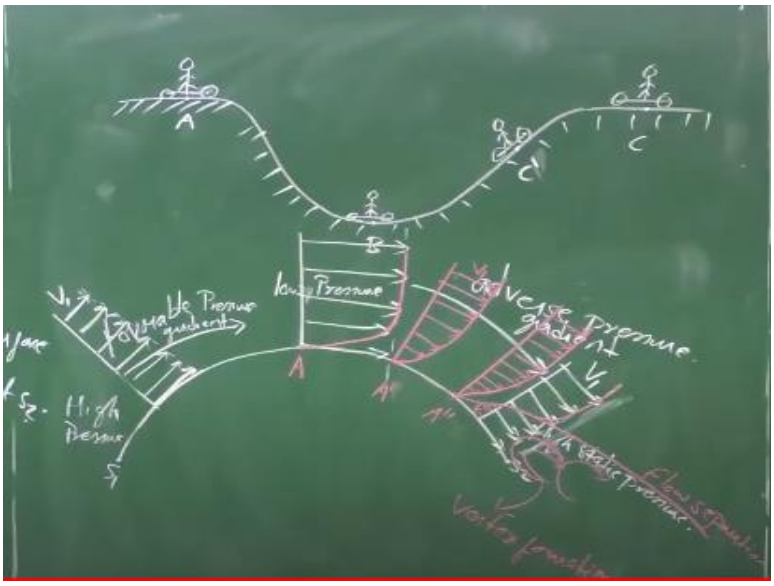

So let us consider a road which is flat on the top and then there is a slope down and you need to climb the slope up and then there is a flat road which is almost at the same height right of this initial road, which is here, okay. Now, let us say if I am on this skating board, right. Let us say I am on the skating board. So let us say this is point A, which is a height h, right.

So it possess some potential energy definitely. And now as you go down the slope right, so my potential energy is converted to maximum kinetic energy at point B right. And then ideally, I should reach point C attaining same potential energy, which is at point A, right. This is when there are no losses. But when there is loss, see of course there is friction here friction generates heat and there is loss in energy.

So you may not be able to reach point C what you desired, but practically you may end up reaching point C prime here, right. Is it not? So the desired point is C, you may end up reaching C prime because of the loss in energy. So similar thing happens in real flows as well, right. So let us look at that. So this is my s 1 and this is my s 2. That is what we have right, is it not for this circular cylinder.

Now say see at s 1 you have high static pressure, is it not? High pressure and according to ideal fluid flow, where there is no viscosity, you achieved a maximum velocity here, right, which is so that means when you have maximum velocity what you have is low pressure, low static pressure here. Am I correct or not? And then there is some again high static pressure.

And there is no loss of energy in this entire process for this ideal flows right. So what happens we know how gas flows, how a fluid flow. When do you a fluid flow? So from high pressure to low pressure, when there is a pressure difference from high pressure to low pressure, the fluid flow happens, is it not? So such a condition is a favorable condition for us, is it not?

So what we have is pressure gradient. Gradient is changed, right? It is a slope. We have a favorable pressure gradient right when reaching from s 1 to this particular point P, right. Is it not? So in invicid flow what happens say this is my local velocity. So what I have is same local velocity perpendicular to the surface starting from the body. Am I correct or not?

Say this is my local velocity V 1 at this particular location. Is it not? And here I am reaching almost twice that of the free stream velocity two times V infinity here, right. So and then what is happening so we have high pressure here and we have low pressure because of which the fluid retards, is it not?

It is an adverse condition flow. So you are trying to, the fluid here is trying to push itself from low pressure to high pressure right which is a adverse pressure condition for us which is known as adverse. So this particular direction is adverse pressure gradient. Am I correct or not? So again from the ideal fluid flow, so close to this it is zero and then ahead of this the velocity reduces compared to the velocity at points P and this velocity will be equal to the local velocity at that particular location.

Am I correct? So but for real fluids real flow what happens is right, this is how the velocity profile will, am I correct or not? Right. So the fluid elements so let us say this is my point A here, right. So let us look at what is A prime right what happens at A prime. So if I draw a perpendicular to the surface here at A prime right.

So the fluid element which is having certain velocity here because of the adverse pressure conditions and also because of the fluid friction, it will try to retard, is it not? It will the velocity profile will completely change compared to that of what is A. So the fluid maybe something like this, right. So say that V 1 is the local velocity at that particular location. Am I correct or not?

So let us move ahead and then go to this point A double prime which is here and see what happens now. Now say the innermost particle which is on the surface because of this adverse pressure it is opposing right. This pressure is opposing it opposing the flow. So it will retard this molecules to rest. Am I correct or not. So that means, the pressure profile here be completely different where the molecules in this boundary layer can may almost reach the.

So the molecules on the surface definitely is at zero, velocity is zero. And in the boundary layer as well it has come to rest almost to the rest. Now if you move ahead, what happens here is there can be a reverse flow happening, right. Because, so the molecules now these molecules are at rest these fluid molecules here fluid or the fluid element. So there will be a reverse flow from high pressure to the low pressure present here.

And then there is something called flow separation. So the flow tries to separate from this surface. This is called flow separation right and what you end up seeing is a vertex formation here. We have is vortex formation, right. So this under the adverse pressure conditions there will be a flow separation from the surface. So when there is flow separation, the pressure distribution on the body will altogether get redistributed right. It will change.

The pressure distribution completely changes compared to the attached flow condition, right. So we will use this flow separation concept very regularly in the coming lectures right to at least while discussing the characteristics of aerofoil, right. So thank you.