Introduction To Flight
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Lecture 05.8
Tutorial on Airfoils

So after seeing this video you will be able to then attempt the tutorial that we have given you. So even if you know how to do it please pay attention to the video do not do the tutorial till I give you the go ahead.

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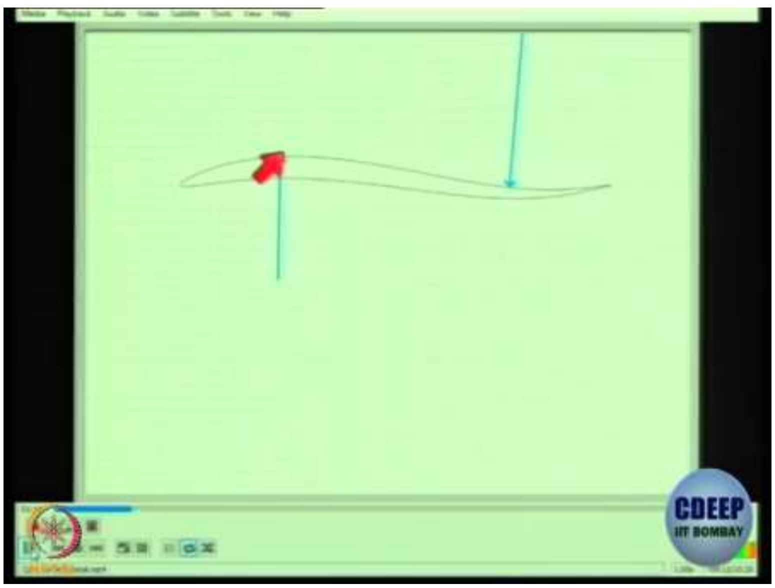

Video: So, finish it aerofoil, in fact this aerofoil shape is called a Reflexed Aerofoil and it does have some particular uses to help choose the pitching moment of a wing, this modern reflexes probably little bit more than its impact just I put this my change just to make it really clear away the curvature was behaving but this is quite a bit of reflex here. So probably little exaggerated for comment on situation but again we just stay in that for the purposes of showing in how that is type of airfoil behaves.

Okay, so let us start up by putting up some radius of curvature vectors in here. So here is on the upper surface the radius of curvature on the front half of the airfoil but at the back half the radius of curvature flips and comes in above. So like we have done now a few times that means in this region here you can expect the pressure to be lower than P infinity, right so that there is a net force inwards or the other ways we have seen that pressure increases as I move out along ways. If it increases P infinity is out here, so P here is going to be lower so P is lower than P infinity then the Cp in that region should be less than zero. In the opposite happens here the pressure increase towards the aerofoil along the radius direction always along the direction so here Cp is going to be greater than 0 since the pressure will be greater than P infinity there.

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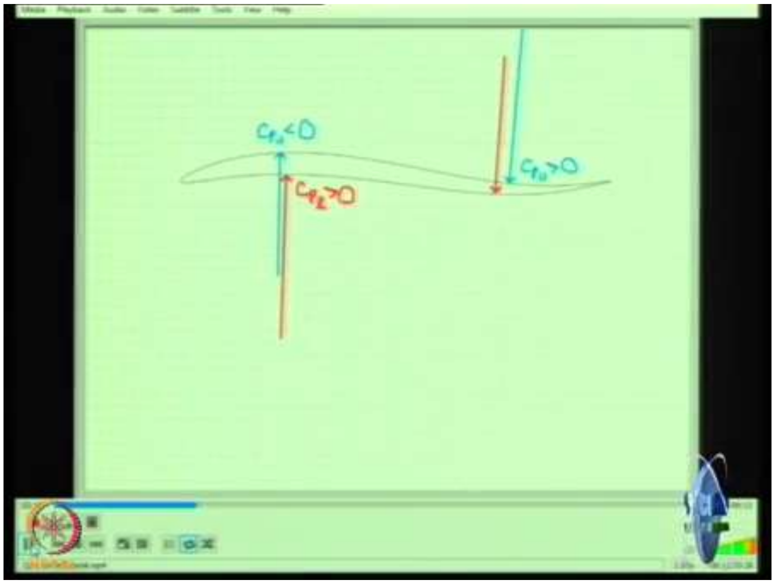

Okay, on the lower surface we have a radius of curvature in the front half that looks like that and on the back half looks like that so I am doing same things here this means that the pressure in this region has to be greater than P infinity, right P increases along that direction so Cp is positive here and over here we going to have opposite right. Cp being negative here, because the pressure has to increase in this direction so the high pressure is P infinity and low pressure will be on the surface.

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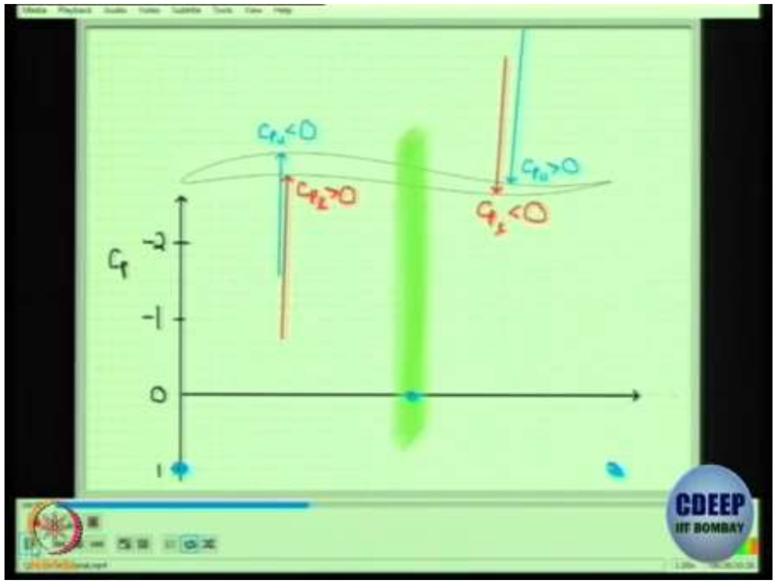

Okay so that is the basic behavior, now it is trying to do some sketches of the Cp here. So put an axis together here with usual negative Cp is up on the top, 1 is the Stagnation Point Cp and that is the highest Cp that we will ever have so in terms of positive value. So we have stagnation point here at the leading edge and in general for an Inviscid Flow we will have a stagnation point here. We will talk more about some in details at the stagnation point here or not at the trailing edge just we go along but for now expecting area stagnation point under an inviscid flow back here.

Okay, so those two points I have drawn in, now somewhere in the middle of the aerofoil here we will going to have all this sign for the curve, where Cp is going from negative to positive on the upper surface and on the lower surface vice-versa. We do not know exactly where that is going expected to be happen where that radius of curvature flips roughly. They do not have to be switch signs on the exactly the same spot upper and lower surface. That is not true, but in the general vicinity I would move it to expect that to be a case.

So I have drawn this green sort of fuzzy area to say I do not know exactly where it is going to be but somewhere in this vicinity in terms of x the Cp is going to cross through 0 on both side. I am just going to pick a spot here and say that where the Cp’s are going to cross through 0 and I am going to used that to help connect my dots.

Okay, so now next what I am going to do, now it gets little bit more hand wavy, we are knowing that the positive and negative values I am going to have pick some values here so I am going to stuck by picking the value on the lower surface and the back half here, why do I pick that one? Well, no particular reason really, one is that P is lower the higher pressures are little bit more bounded in that we now they cannot get about one where is the negative Cp values can go on you know for any value really. Pressing compressible exceptional breakdown probably some point but, it anyway so you know I just have to less pick from here, so I am just going to pick this. This is completely arbitrary.

I know it has to be in this vicinity somewhere because the pressure in this region should go positive, Cp should go positive so I am picking the dot, do not make anything out of it beyond I am picking the dot, so nothing more than that and just saying it is positive.

Okay. And I am going to now also just pick a dot for the upper to lower surface Cp which will be negative in this region again do not know what it would be? I am just picking something at this point. Okay so this is even more arbitrary than this beyond it been above this line, that is only thing I really know for sure and it is same thing here it is below but less than the Cpl 1.

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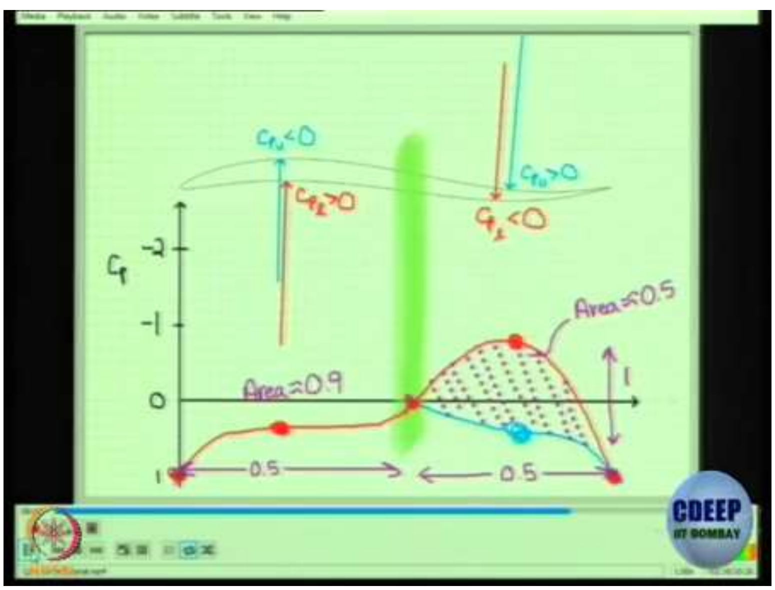

Okay, so with those two dots I picked, I can draw the Cp distribution for the lower surface and then the upper surface will go through this stagnation point as well since that would be at the this part and I am going to draw Cp crossing through 0 also for the lower surface through the same spots, so again an arbitrary choice on that one it could cross through 0 somewhere else but should be somewhere in this vicinity. Okay, now I am going to put in the lower surface Cp the rest of it okay and sketching couple of dots here so the Cp in this region picking again similar to this it is just got to be somewhere between 0 and 1.

I really do not know what it is? so I am just picking this value, so just to summarize very arbitrary beyond it pinning like positive very arbitrary beyond being positive, very arbitrary beyond being negative. Okay location here is arbitrary, these are not really arbitrary these are going to be stagnation points.

Okay, now the last part is less arbitrary because once I nailed this down I need to produce the Lift Coefficient that that I given you so I said Cl of 0.4, and the Cl would be the area under curve but I have to be little careful because this part here is actually going to be negative lift if you will this is first going to act downwards it is because the pressure now on the lower surface is less than the pressure on the upper surface. So this actually subtracts off lifts, so whatever I have over here it is going to have supplement and go beyond what it might otherwise still because it got to produce, it is got to overcome this negative contribution to the lift.

So I need to calculate some areas here, so this area here this is our rough number here so this is roughly about from the half chord let us call that 0.5 and this height here let us called height about 1, so the area here is something like about 0.5. Okay so that means the area over here is going to have to be 0.9, so that this area subtracts from that produces an area of 0.4 in total which is the lift coefficient, that what I needed? So I needed the area here to be about 0.9 okay and then x distance here is about that half of chord so that means that in order to produce area of 0.9 I need to go up from roughly about here since this is about average Cp on the lower surface that I picked so I need to go up at distance of 1.8 so that 1.8 times this 0.5 equals my 0.9 so that blue dots there is about 1.8 ok.

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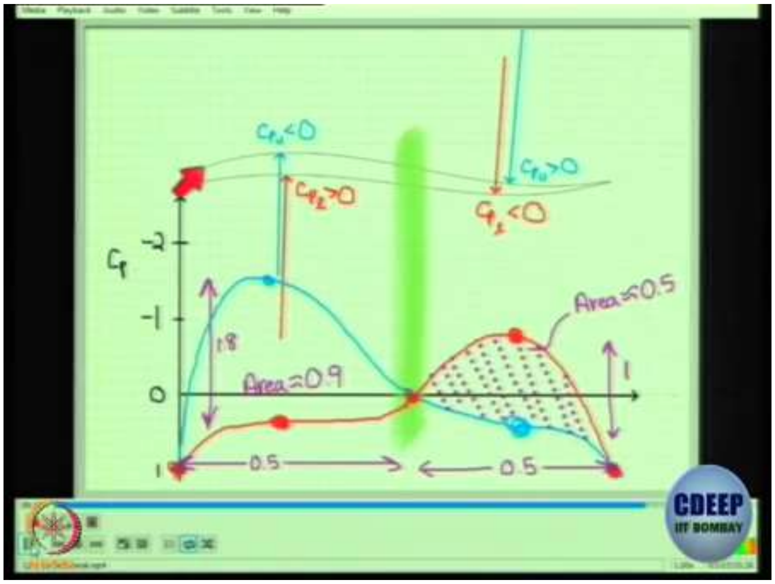

So now just connect the dots again like that and that is what we think Cp works like, so whatever things again just emphasizing what I pretty much know for sure well what I will know for sure? I know the stagnation point, the leading edge and know this one at trailing edge somewhere there going to cross through 0 we are expecting, the upper surface is going to have negative Cp on the front half and positive Cp on the back half we are expecting opposite on the lower surface except the Cl is 0.4 so that means I have the sum of the areas here making sure that this one I realizes in negative region and the difference between these two areas that my Cl will differ.

Okay so I actually simulated this using the X-Foil software in the incompressible potential mode and when you simulate that for Cl of 0.4, here is what is the Cp distribution looks like. So actually pretty similar what I just sketched, you know I overestimated the Cp value here means more negative than this, but if you if you foot back here, let me do that, in fact it is it is not bad it is certainly the right shape qualitatively and in fact this aerofoil does cross through 0 fairly close to each other, not exactly but very close, so generally the trends clearly the trends are right on. And a little bit of guess work actually did pretty well on the Cp but the trends right on. So again important part here is just how do you apply streamline curvature? How does this work? How does it relate the Cp distribution to the geometry and therefore the geometry to the lift?

Professor: Okay so before we go ahead; let us take doubt if anybody has about the arguments that were presented by this author in arriving at this distribution. And you noticed that the estimated curve by just reasoning and simple argument is not very bad as compared to the value predicted by software called X Foil. So we have to apply a similar reasoning today in trying to arrive at the Cp distribution. Now all of you do not have the same aerofoil just to inform you, those of you are experts in looking left and right and trying to copy from your friends, you may have the same one, but actually there are five aerofoils in the whole class so there are five different aerofoils and these five aerofoils we are now going to apply the same logic to arrive at the pressure distribution. So first of all are there any questions or doubts?

Student: Hello, why do we have stagnation point at trailing edge?

Professor: Why not? What is stagnation point?

Student: The like, the velocity becomes zero and the pressure is at its maximum.

Professor: Is it P infinity equal to P?

Student: No

Professor: So what it would be stagnation point when the value of U local velocity is equal to 0.

Student: Yes.

Professor: Okay, so this is a inviscid flow assumption, number 1. So in the inviscid flow assumption, we need to have a full pressure recovery, we are not looking at the losses due the viscous effects so in case of Unseparated Flow there has to be full pressure recovery at the trailing edge. So in the case of aerofoils, especially when we assume inviscid flow and unseparated flow, you will get Cp, you will get a full pressure recovery and therefore you will have a stagnation point at the leading edge and at the trailing edge, it is an assumption. So when you actually look at the aircraft wing, you may not get complete recovery, there will be little bit of loss, okay any other question. Yes.

Student: My name is Raghu, sir my question is that like we have seen here that on the back side of aerofoil the net force is downward due to the pressure, and on the front side of the aerofoil the net force is upward lift, so it will create a pitching moment and it will increase angle of attack, so will it not create stall in the aerofoil?

Professor: See, it will create a pitching moment no doubt about it, now whether that pitching moment will be large enough to overcome the inertia of the aerofoil. To actually create an alpha increase we do not know. Right, moreover if you look at an aerofoil analysis, it is a 2D flow. So in a wind tunnel for example, we assume that aerofoil section goes across the wall from this wall to this wall so it is constraint, not allow to rotate.

So, yes there can be pitching there will be in every aerofoil in general there will be some kind of a pitching moment because in this case of course there will be a huge pitching moment because clearly front part and the rear part are having loads in the different direction okay, but pitching the moment may not lead to increase in the angle as you are expecting it may not if the whole wing is constraint it may not, but it also can be. So in a freely moving aerofoil in an aerofoil in free space what will happen is the pitching moment will make it attain a position where the net moment is 0 and that could be beyond Alpha stall and hence the aircraft can stall.

Student: And sir,

Professor: Yes.

Student: At the trailing edge we are not getting Cp equals to one the reason is; we have viscous flow or something else.

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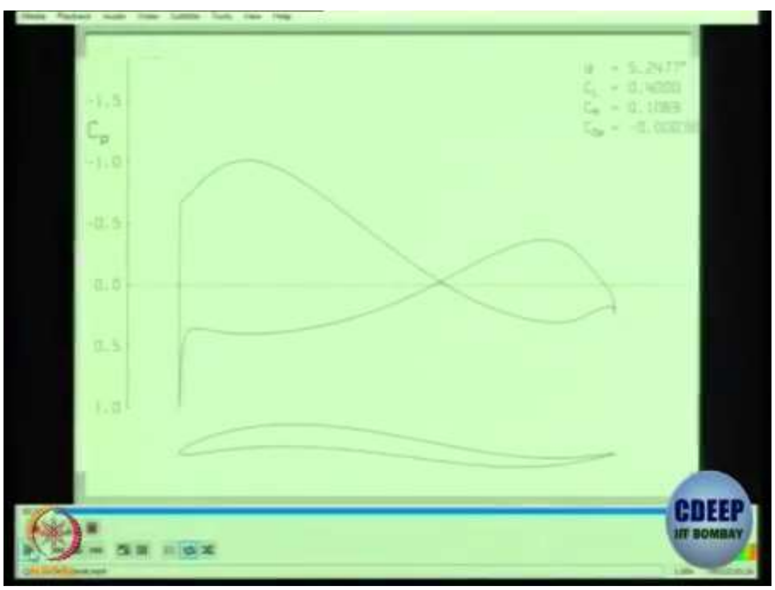

Professor: No, if you are looking this particular CFD analysis you are not getting it recovered but in the theoretical calculation which was shown by the author, he assumed full pressure recovery, it is an assumption so it is an assumption that they will be full pressure recovery or there is no way of knowing how much it will be, when you reason out by just physics, it is very difficult to know how much it will be, so he assumed that there will be a full recovery ok. Yes any more questions, yes.

Student: Sir the maxima or minima in the Cp graph does it correspond to the camber maximum camber in the aerofoil or?

Professor: I think it does if you look at the aerofoil it does, the peaks in the front portion and the rear portion are appearing at the places where the camber is maximum so it will be. By simple argument camber leads to acceleration of flow and therefore, there will be more suctions at maximum camber location. Yes but the thickness distribution can also alter that slightly, so you cannot say it only camber it is camber plus thickness, both of them play a role.