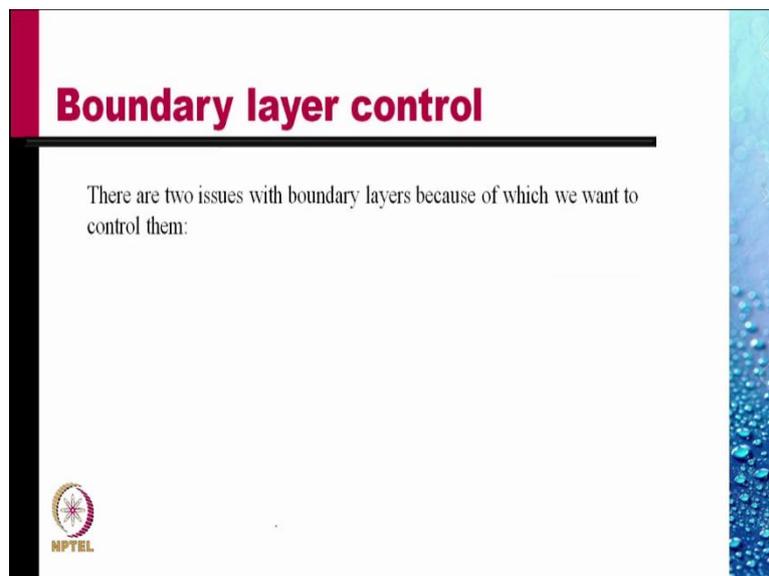
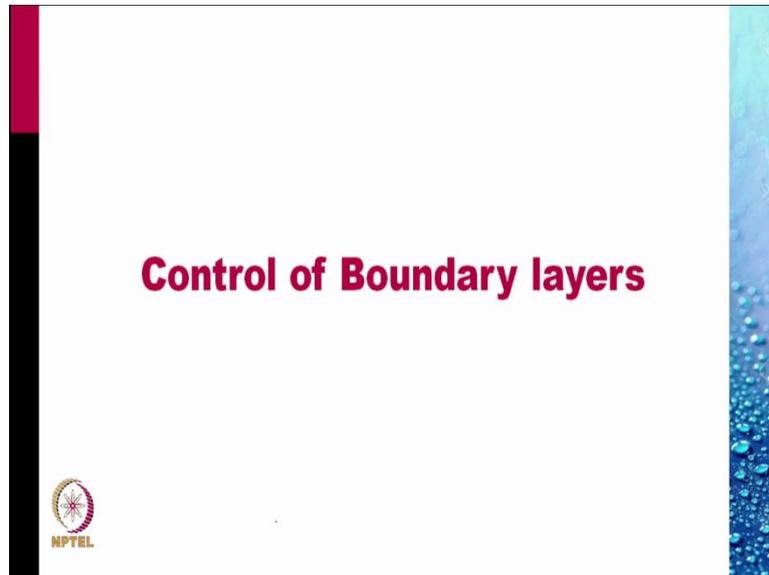


Fluid Mechanics & its Applications
Professor. Vijay Gupta
Indian Institute of Technology, Delhi
Lecture - 31A
Control of Boundary Layers

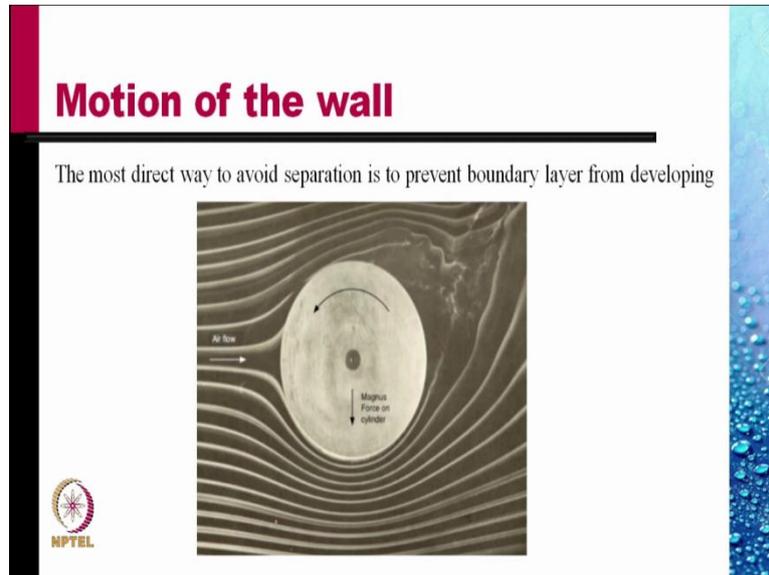
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Now, let us move to the last chapter on boundary layers, that is, the control of boundary layers. There are two issues with boundary layer because of which we want to control them. The two issues are, first, when a boundary layer does not separate as on a streamlined body, the turbulence within the boundary layer increases the skin friction drag. We have said, on a streamlined body the pressure drag is low, but the skin friction drag dominates, and its skin friction is more in turbulence than in laminar. So, we like to keep a boundary layer laminar on streamlined bodies.

We like laminar wings on aircraft to keep the flow laminar as far as possible, so that the skin friction drag, which is dominant in wings, is low. The second concern is that the on bluff bodies, as the boundary layers separates, pressure drag increases drastically. Therefore, we aim to suppress separation.

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How do we prevent separation? Separation occurs as the boundary layer grows. Within the boundary layer, the flow is slow. It does not have enough kinetic energy to overcome the adverse pressure gradient, and so, it reverses and separates from the wall. If we can prevent the boundary layer from growing, from developing, then it is possible that the boundary layer does not separate. This is what is happening in this case.

In the lower portion of the sphere or the cylinder, this surface is moving in the same direction as the flow. So, relative velocity between the flow and the ball reduces, and this decreases the growth of the boundary layer. So, the boundary layer separation is delayed. Quite reversed from what happens in the top, where the surface is moving into the flow, increasing the relative velocity, leading to an early separation.

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Acceleration of the boundary layer

Boundary layers separate because of the viscous action within the layer dissipates kinetic energy of the fluid, when the flow reverses, the boundary layer separates.

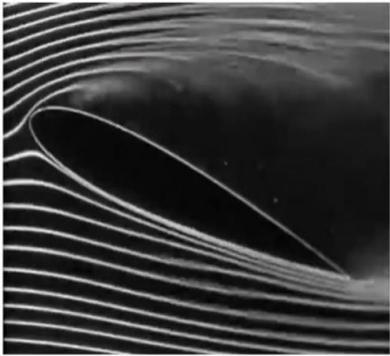
This suggests that if we could energize the flow within boundary layer, we could prevent or delay separation



Boundary layer separates because the viscous action within the layer dissipates kinetic energy of the fluid. When the flow reverses, the boundary layer separates. This suggests that if we could re-energize the flow within boundary layer, we could prevent or delay separation.

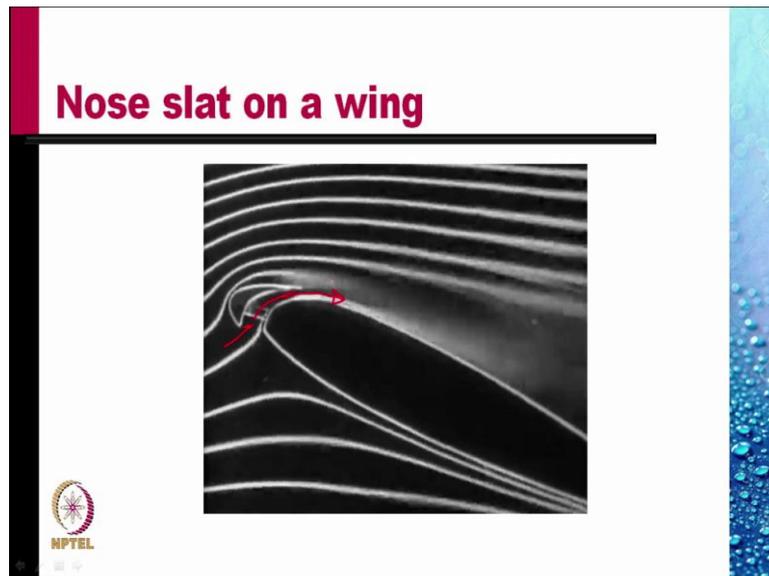
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Stall on an airfoil



The flow visualization pictures that follow are from a film by David C Hazen, produced in 1965 by the National Committee for Fluid Mechanics Films for National Science Foundation of USA





This is a wing or an aerofoil we saw which is stalling. The angle of attack is so large that the flow separates from the surface right near the nose on the upper surface. If we introduce a slat in that airfoil at the tip, then the pressure, increased pressure of air here, would force the air into it, and this air is released tangentially onto the upper surface. And as it is introduced there tangentially, this energizes the boundary layer and the separation decreases. Notice how the separation has decreased. This device of a nose slat has been used in many aircraft wings to increase the angle at which the wing stalls.

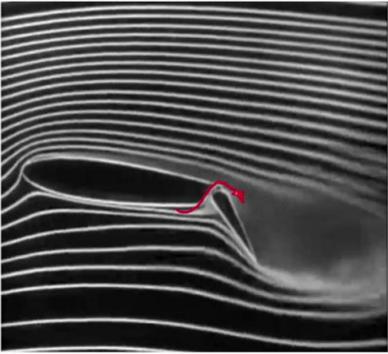
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This is an example of a nose slat. The air flowing from this salt over the wing reduces the separation and permits a larger stall angle giving high lift.

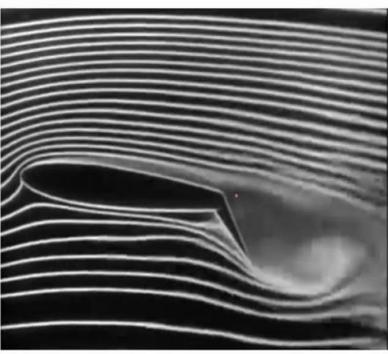
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Blowing on the flaps



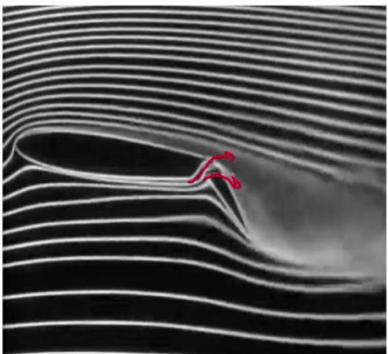
The image shows a flow visualization over a flap. The flow lines are represented by white streaks on a black background. A red line highlights a specific feature on the flap's surface. The NPTEL logo is visible in the bottom left corner.

Blowing on the flaps



The image shows a flow visualization over a flap. The flow lines are represented by white streaks on a black background. A red line highlights a specific feature on the flap's surface. The NPTEL logo is visible in the bottom left corner.

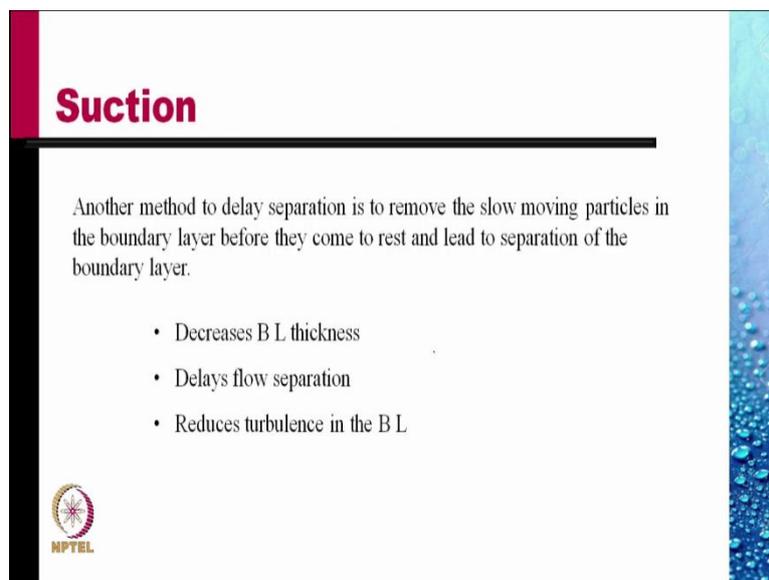
Blowing on the flaps



The image shows a flow visualization over a flap. The flow lines are represented by white streaks on a black background. A red line highlights a specific feature on the flap's surface. The NPTEL logo is visible in the bottom left corner.

To increase lift on the wings we sometimes use flaps which, though they introduce more drag, give more surface area for the lift to act. They effectively increase the chord of the wing, and therefore, give higher C_L maximum. But the flow tends to separate on this flow. So, if we can create an opening between the flap and the main wing, so that the flow from here is directed on to the upper surface of the flap, the separation is reduced. You notice the separation is reduced, and so this would increase the lift coefficient much more. We can have more than one slot. Here we have two slots, a slot here and a slot there, to give better control on the boundary layer.

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Suction

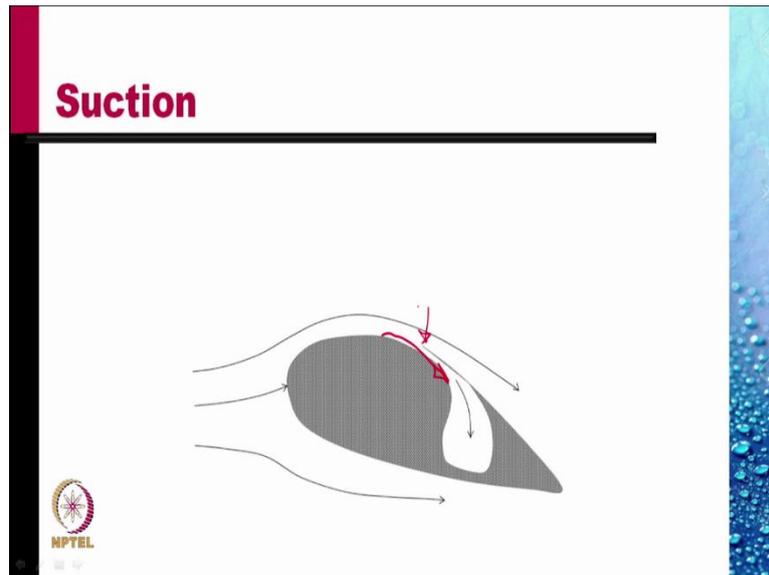
Another method to delay separation is to remove the slow moving particles in the boundary layer before they come to rest and lead to separation of the boundary layer.

- Decreases B L thickness
- Delays flow separation
- Reduces turbulence in the B L

 NPTEL

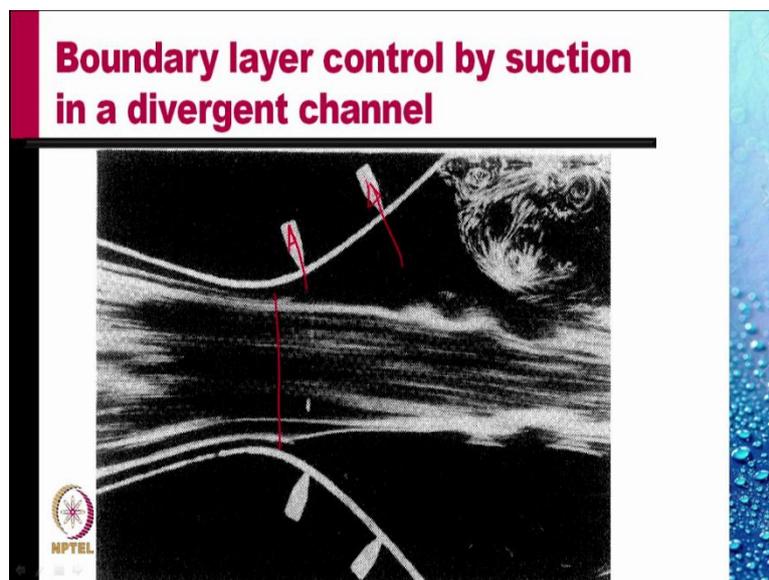
Another method to delay separation is to remove the slow moving particles in the boundary layer before they come to rest and lead to separation of the boundary layer. This decreases the boundary-layer thickness, delays the flow separation, and reduces turbulence in the boundary layer.

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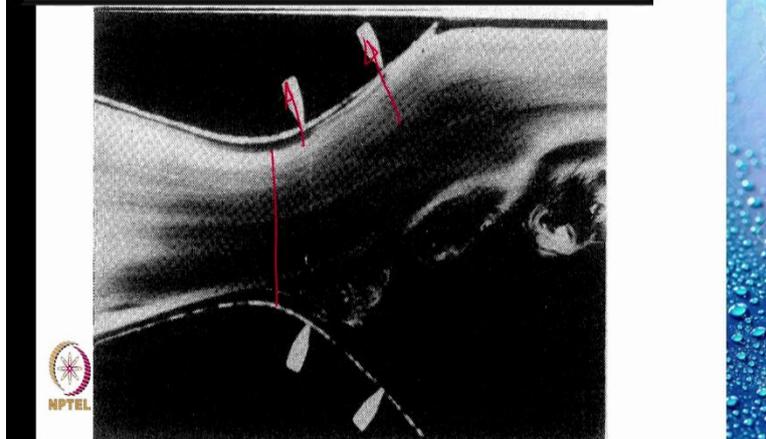


So, within the wing we have a sink where we suck the air. This. So slow moving boundary layer is sucked into there, and the flow, main flow, comes down and it is more energetic. So, the separation is delayed.

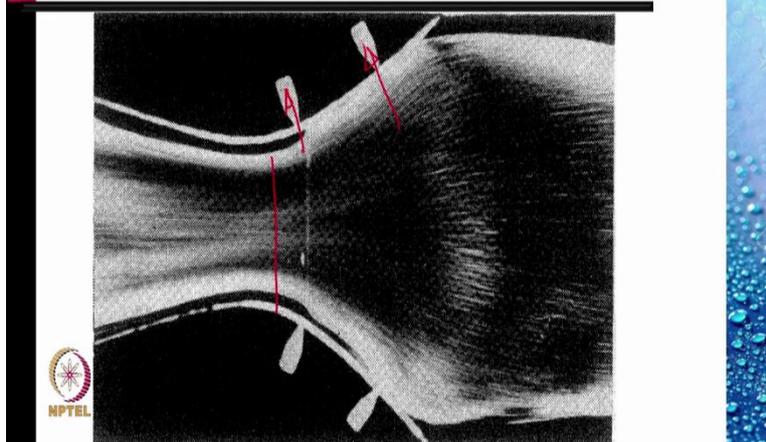
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Boundary layer control by suction in a divergent channel



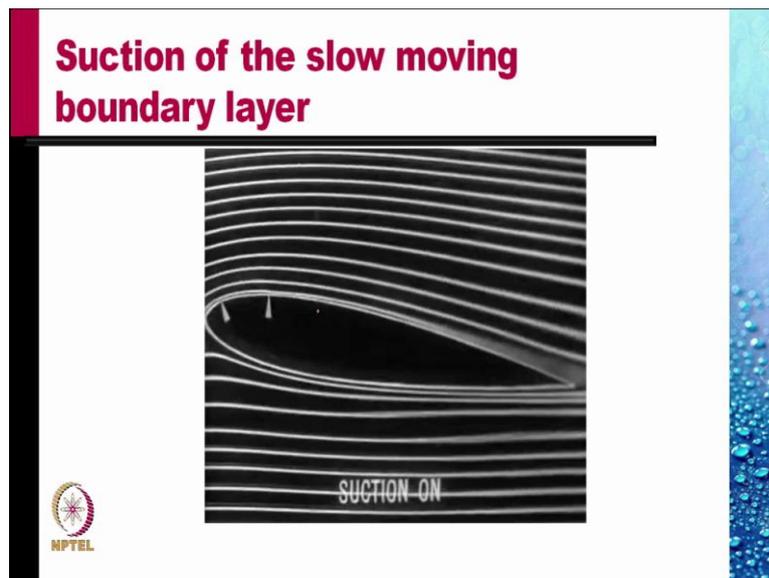
Boundary layer control by suction in a divergent channel



We start with a channel flow, in this case, water is flowing in a converging diverging channel with a large angle divergent section. Because of the adverse pressure gradient required in the diverging portion, the flow separates as a jet here. Now, if we can remove the fluid from here, the slow, the stagnant fluid from here, we can make the boundary layer attach itself. We turn the suction on, and the boundary layer got attached.

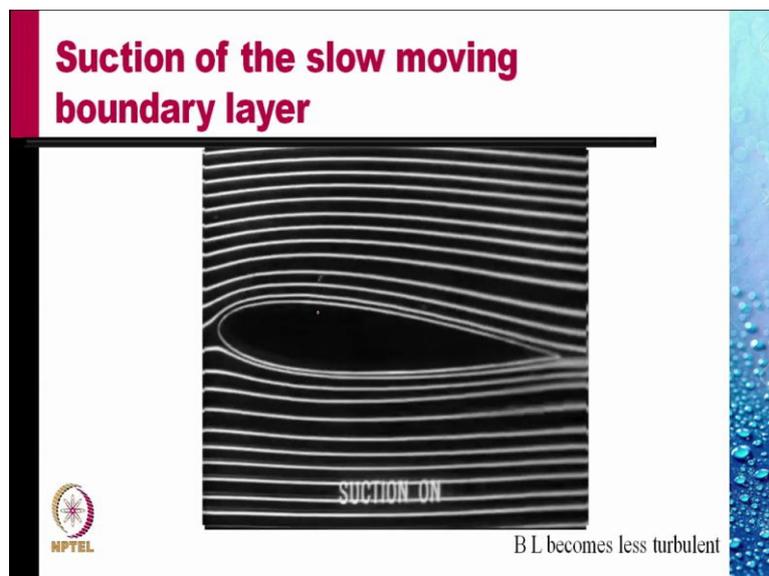
We could do this on the other side also. We turn it on the both sides. And now, we have made the boundary layer, we have made the channel flow full. Of course, we have to spend energy in sucking off the boundary layer, but that is a small fraction of the energy that we save when we reduce the losses in the diverging portion.

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Same thing is shown here. In this airfoil I have a boundary layer which is developing here. As you see, the boundary layer has become turbulent, because of the haziness that we see there. Now, we turn on the suction at the two points which are marked with the arrows at and near the nose. And as we turn the suction on, we see that the turbulence has decreased. See again, this is without the suction. This is with the suction. The turbulence has decreased. As the turbulence decreases on the streamline body, the drag comes down.

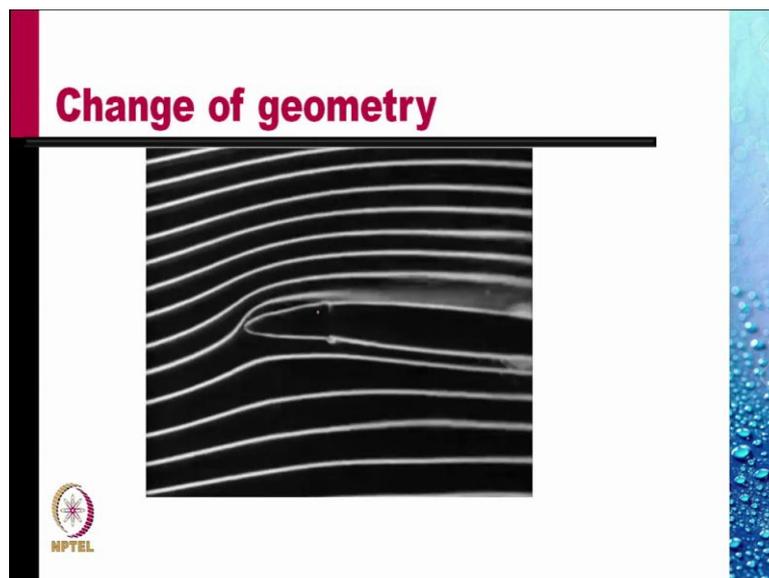
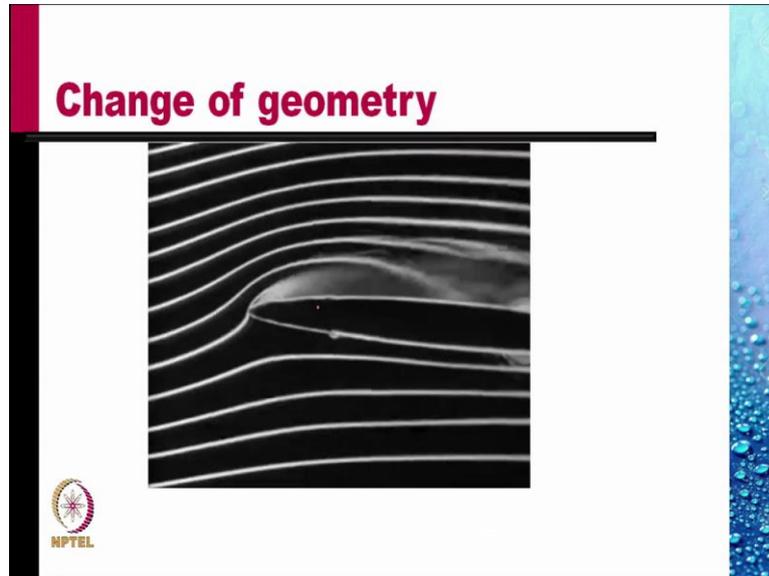
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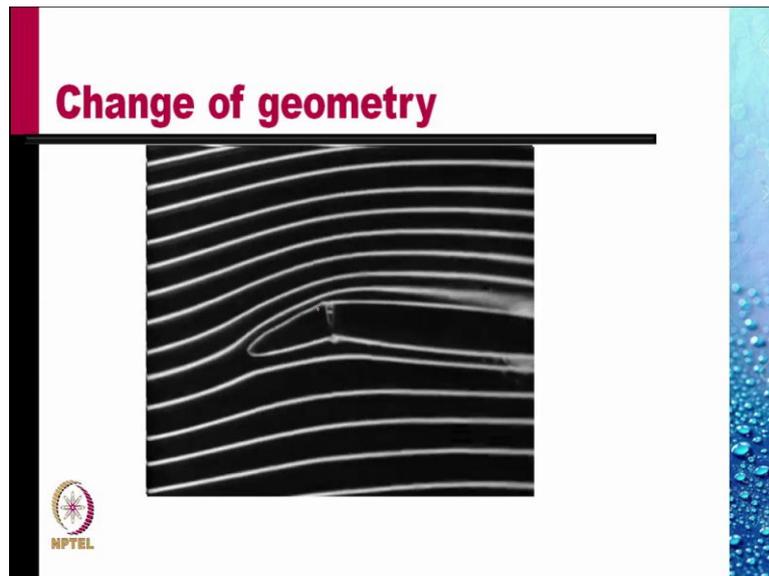


Here we have an aerofoil which is stalled. Now, we apply suction through the upper surface at various points, and as we turn on the suction, the flow becomes attached on the upper surface as well reducing the drag drastically and increasing the lift. Also, again we would see in this

case, the boundary layer becomes less turbulent when the suction is turned on, on the upper surface.

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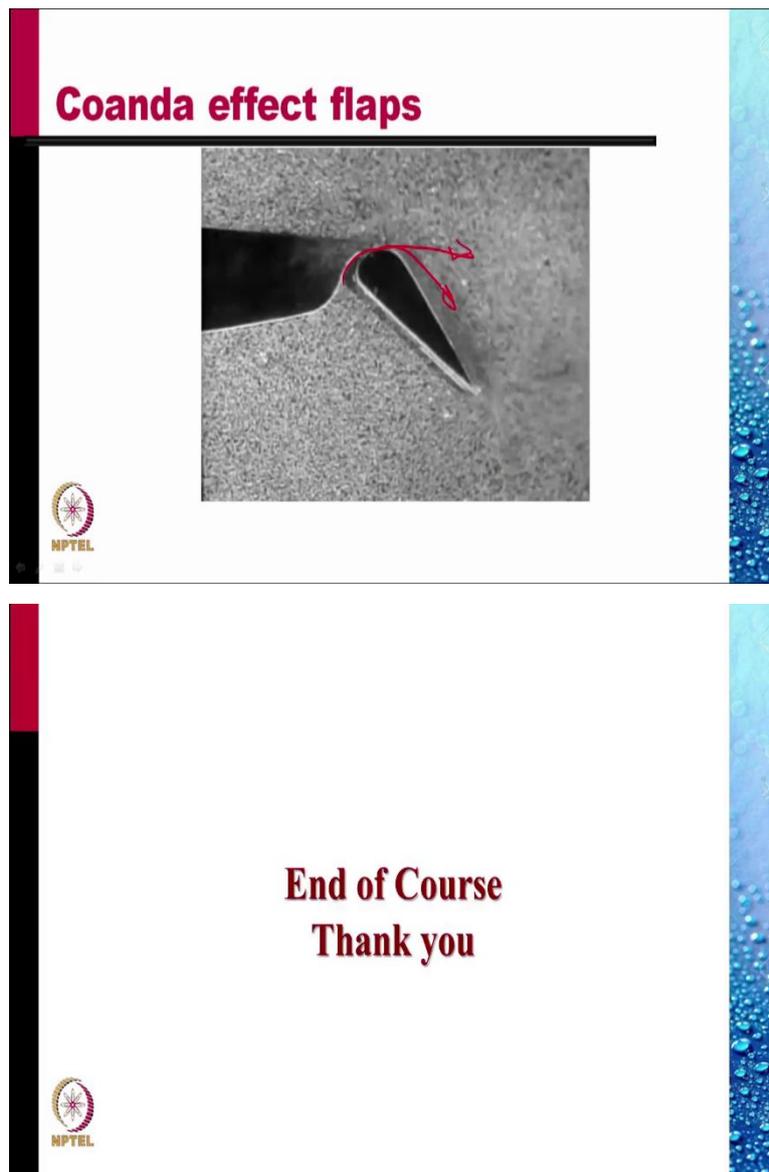
Change the geometry: This wing is stalling, is causing separation at the upper surface because of the angle of attack. If I change the geometry, I make the nose droop a little, I see the separation is suppressed. I droop more, separation is suppressed more. More. Aircraft wings have been designed with these geometries.

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These are vortex generators, near the flaps on the wing which create vortices, and these vortices energize the flow, and make the boundary layer turbulent. So, that separation over the flaps are delayed, and we get more lift.

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The another kind of boundary layer separation suppression device is what are called the Coanda effect flaps. Coanda effect is the effect when the flow, instead of going straight, follows the contour of a body. So, here we will see that in this the flow passing through this which is going down like this, and if we bring them closer together, then the flow goes along this line. The flow follows the contour of the flap and so the separation is delayed.

Thank you very much.