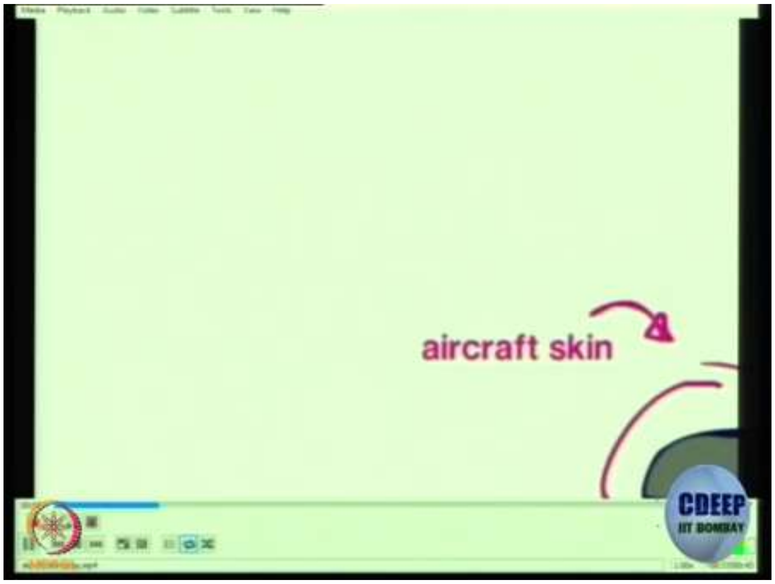
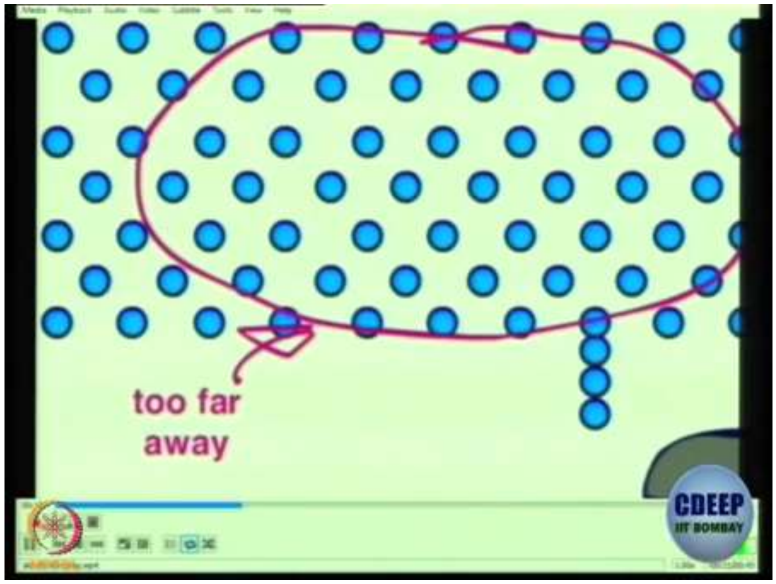
Introduction to Flight
Professor Rajkumar S. Sant
Department of Aerospace Engineering,
Indian Institute of Technology, Bombay
Lecture No. 06.6
Skin Friction Drag

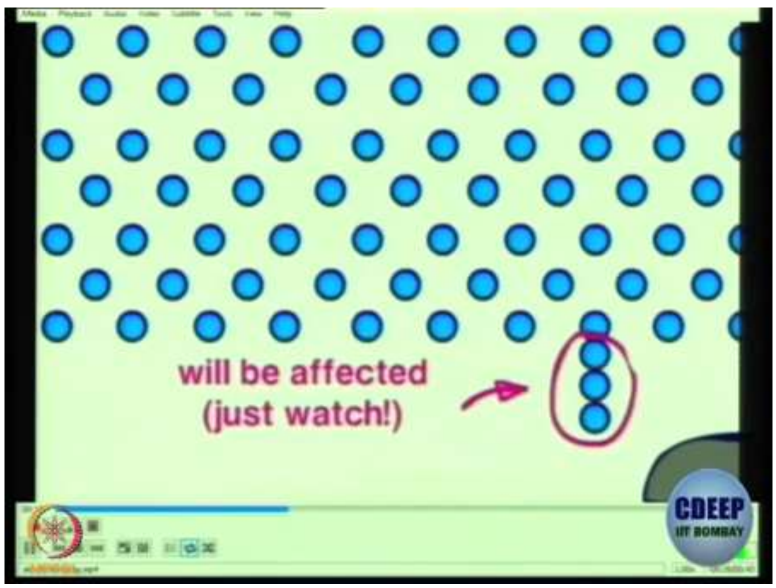
(Refer Slide Time: 0:14)

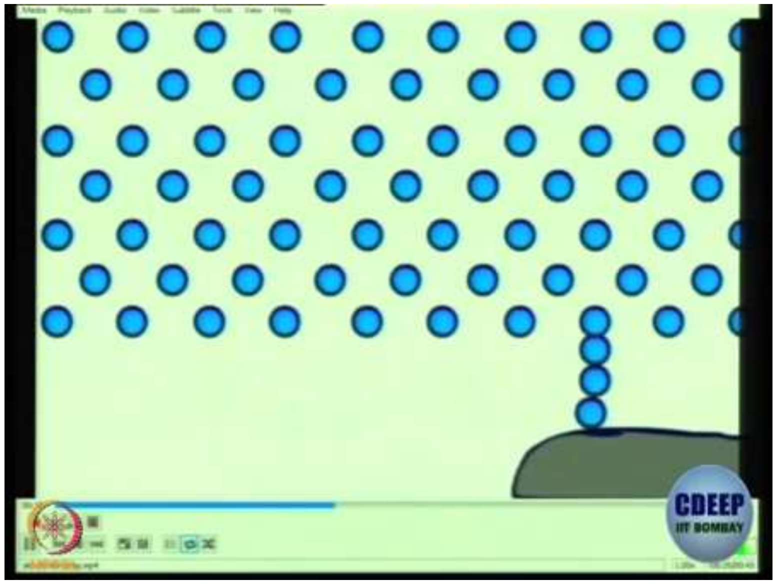
Then skin friction drag, skin friction as is mentioned there is created by the movement of air flow near the skin of the aircraft. Let us have a very nice look at a, look at a nice video on how it is done.

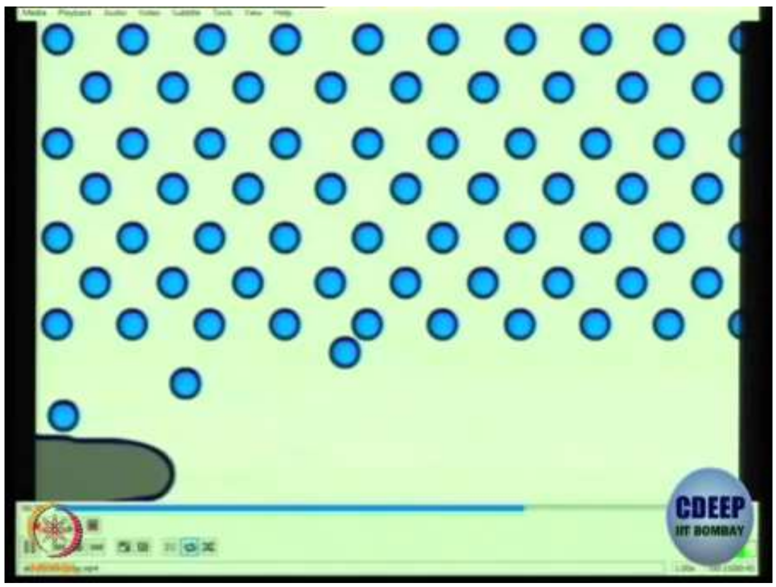
(Refer Slide Time: 0:29)

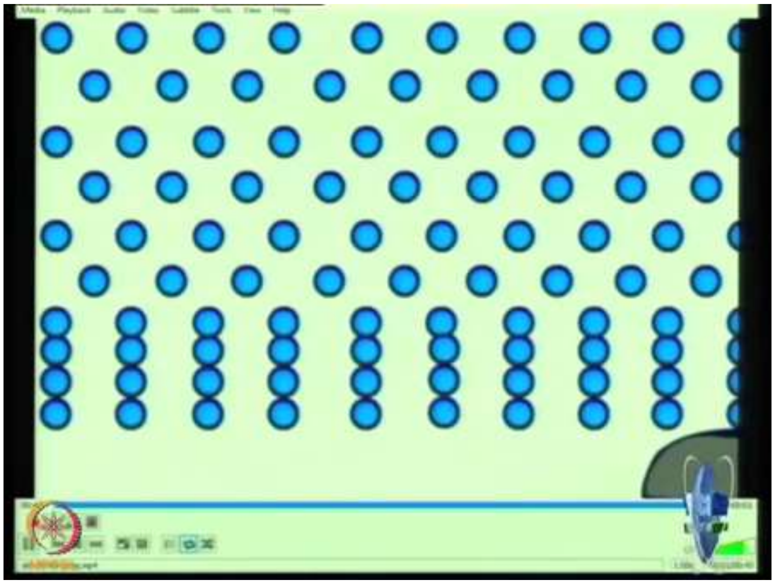



too far
away
CDEEP
IIT BOMBAY


will be affected
(just watch!)
CDEEP
IIT BOMBAY


CDEEP
IIT BOMBAY


CDEEP
IIT BOMBAY

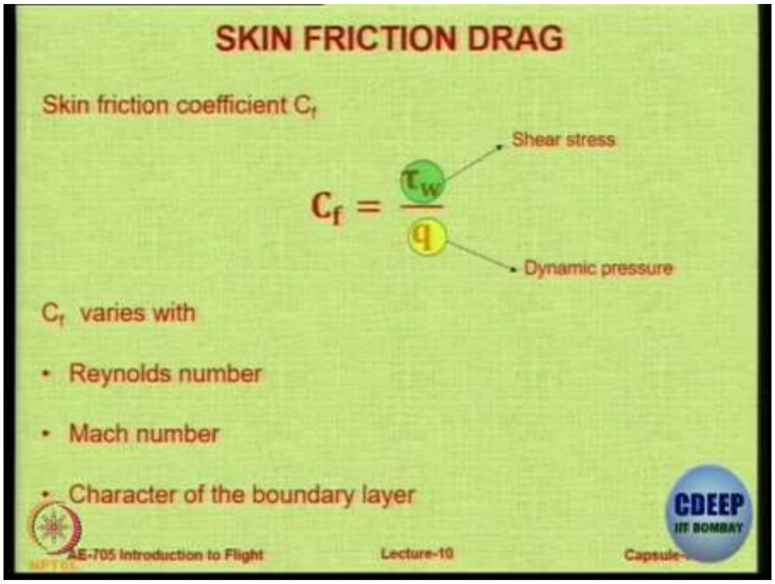


Video: The aircraft moving through the air is having to move through twin ends of air particles. Here is the skin of the aircraft and here are the load of air particles. These air particles are too far away to be affected by the aircraft, but these three will be. In this very slow down film, you can see that if the aircraft moves, then the air, air particles close to the skin are absorbing some energy from the aircraft and are accelerating to the aircraft speed.

Air particles close to the aircraft move closer to the same speed than those that are further away. This absorption of energy by pure means of air particles is because of skin friction drag. Obviously, the picture would look like this to start left. The aircraft moving through the air is having to move through twin ends of air particles.

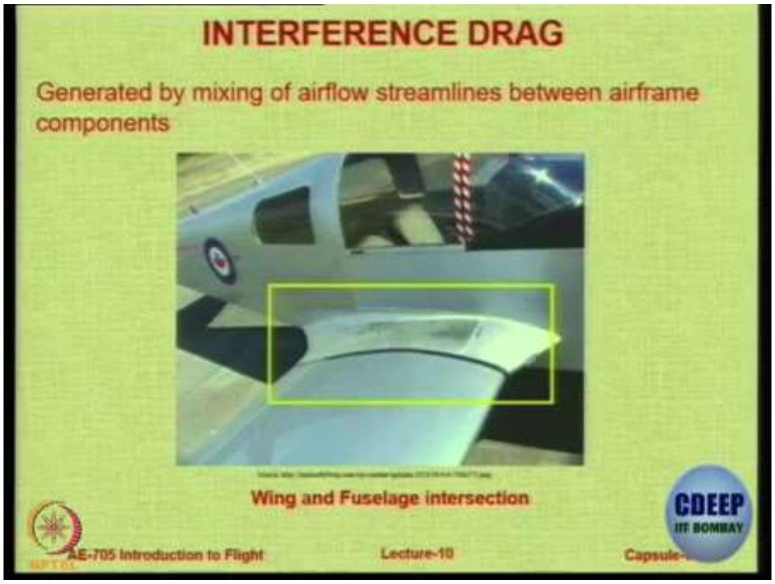
Professor: Alright, so as the aircraft moves, the particles which are near its surface are going to be dragged with it, they are going to consume energy and that is the skin friction.

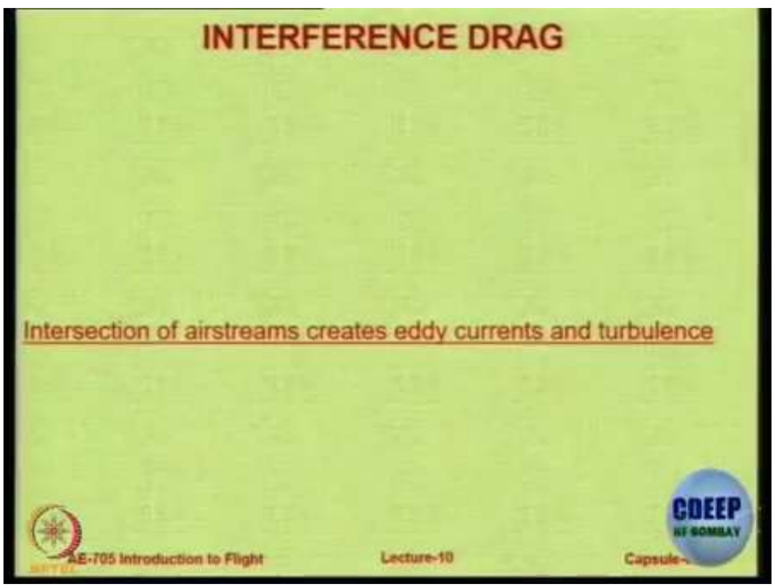
(Refer Slide Time: 1:29)



So, we define this by a skin friction coefficient which is basically a ratio of shear stress by the dynamic pressure. So it is a function of Reynolds number because Reynolds number is present in half rho V square, Mach number because we are affected by Mach number and also the nature of the boundary layer, whether it is laminar, turbulent, okay.

(Refer Slide Time: 1:49)





Then we have interference drag. It is present in all situations where two bodies are brought together. So, you have drag of a wing some 'X' units, drag of the fuselage 'Y' units. When you bring Y and X together, the drag will not be X plus Y, but may be 1 point 1 times X plus Y. So, this 10 percent extra is the interference drag. Because generally there is a negative interference between body A and body B and vice versa, generally.

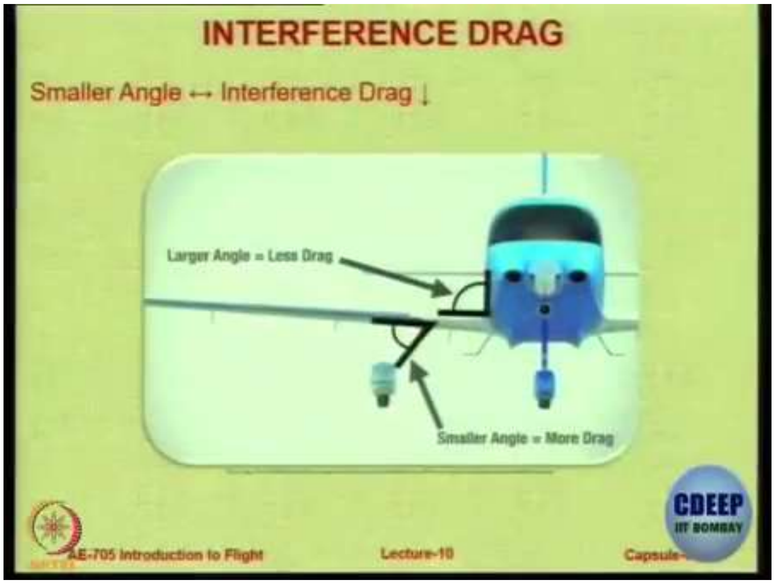
But here again people say by very careful design, you could have positive interference or you have less negative interference. So, in general, interference drag is always going to be present. You can minimize it, but you cannot say that I have completely removed it.

(Refer Slide Time: 2:41)

You can see here, because of interference between the fuselage and the wing at the root you see a lot of turbulence generated and that turbulence is a one that is creating condensation of the water vapor. You do not see that much condensation happening towards the wing tips. It is more at the roots, wing tips are also doing something but the concentration is more towards the root. It only shows that at the roots that there is a larger mixing happening, that means there is larger interference.

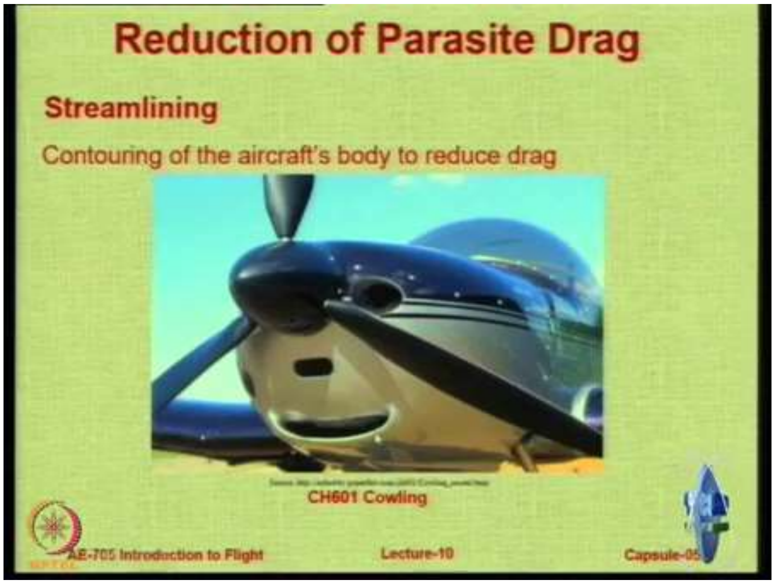
So this is a visual indication of the fact that interference drag is more when there are interfering bodies in the presence. Also notice, between the flaps and the spoilers in the previous video or just before, you saw that, there is a large disturbance created there, that also creates an interference drag.

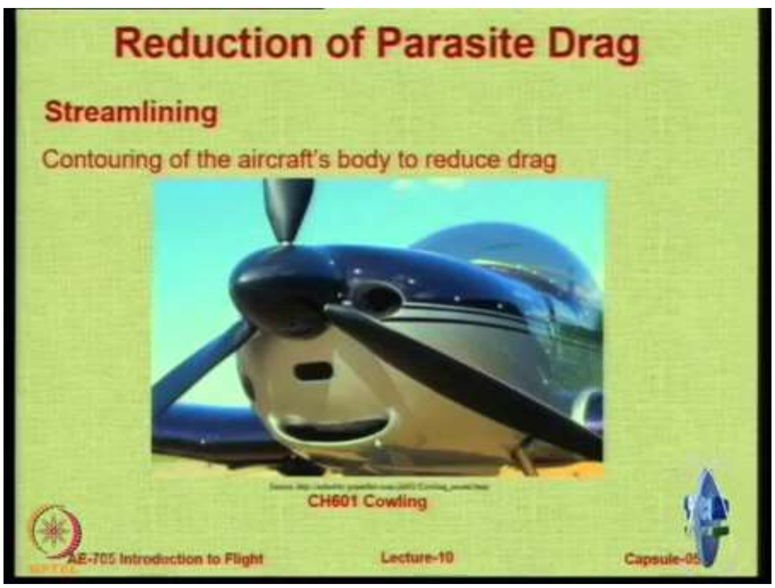
(Refer Slide Time: 3:42)

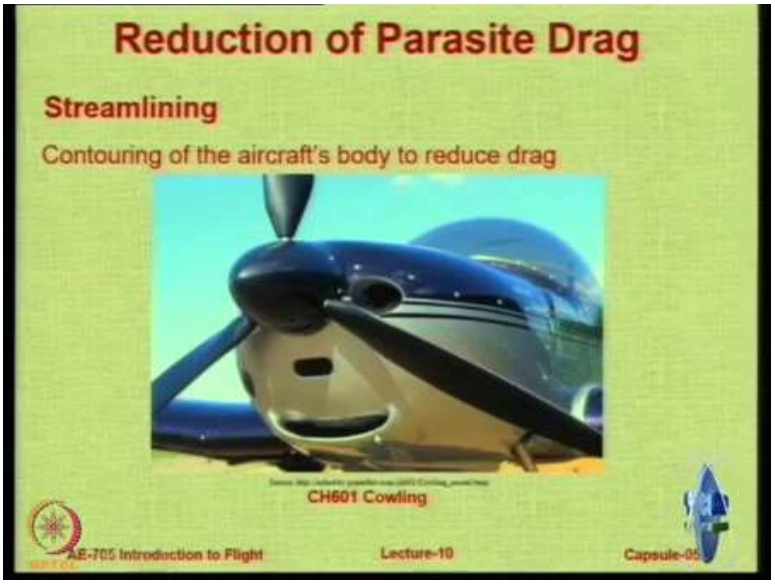


So, if you have a small angle between the fuselage and the wing, the interference drag is going to be lower. Similarly, if you bring the landing gear nearer to the wing, there will be higher interference. So, there are certain suggestions or hints available for how to locate the two bodies relatively. So, whenever you do a course on aircraft design, you will see that there are many many ways in which you can attempt to reduce the induced drag, sorry the interference drag.

(Refer Slide Time: 4:16)







Most common way is by proper contouring of the body, proper shaping of the body such as streamline shape, if you notice, how they have put a streamlined cover on the landing gear and even the wing root junction. Especially if you focus attention on this particular place this beautifully streamlined and this particular so this streamlining is normally done only through wind tunnel testing.

It is very difficult to do this numerically, although some people do it. But using CFD analysis to do streamlining is not very elegant because how many cases will you run. So, wind tunnel testing is normally used. Notice how we have streamlined the cowling or the covering over the engine. And there is a nice beautiful intake for the air to come in. It is not a very sharp or a harsh intake, especially the intake behind the spinner or behind the centre of the, so this intake if you see this one this one they are all streamlines so that the induced parasite drag is reduced, okay.

Notice here how the aircraft's body is contoured. So all these things are done, especially I am very interested to show you the covering of the of the landing gear. All these are there for making it look beautiful and also to reduce the drag because of interference and form drag, thik hai. Look at the contouring of the engine or the Nacelle. But you see on the back there are some serrations okay. So now why are these serrations provided? Does anybody know, this is a a engine of Boeing 777 I think. And it is also there in 787, yes? what?

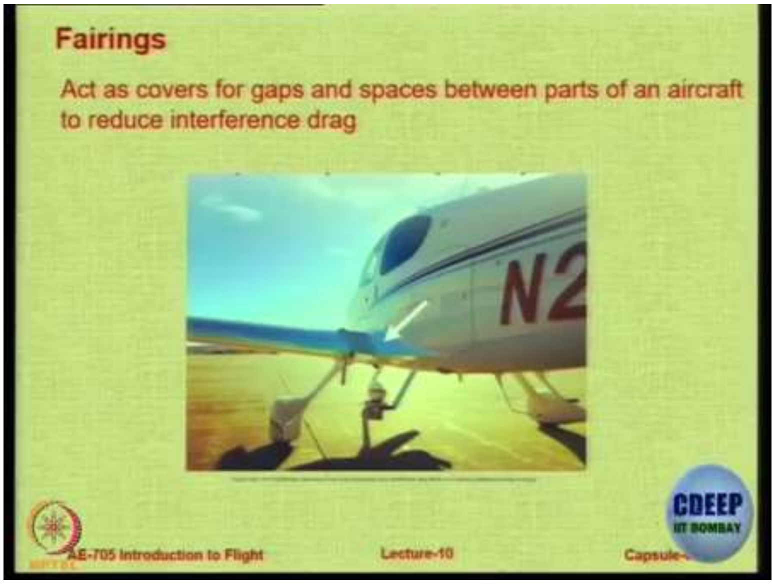
Student: Those are chevrons.

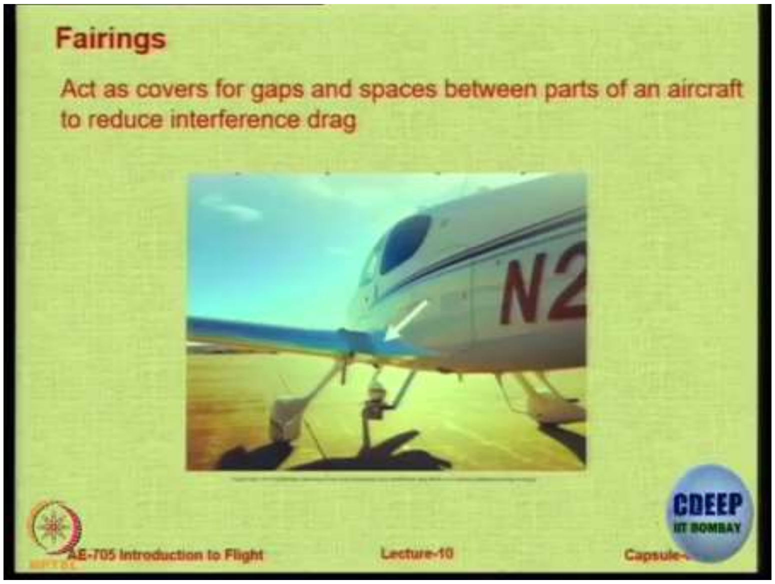
Professor: Those are chevrons okay.

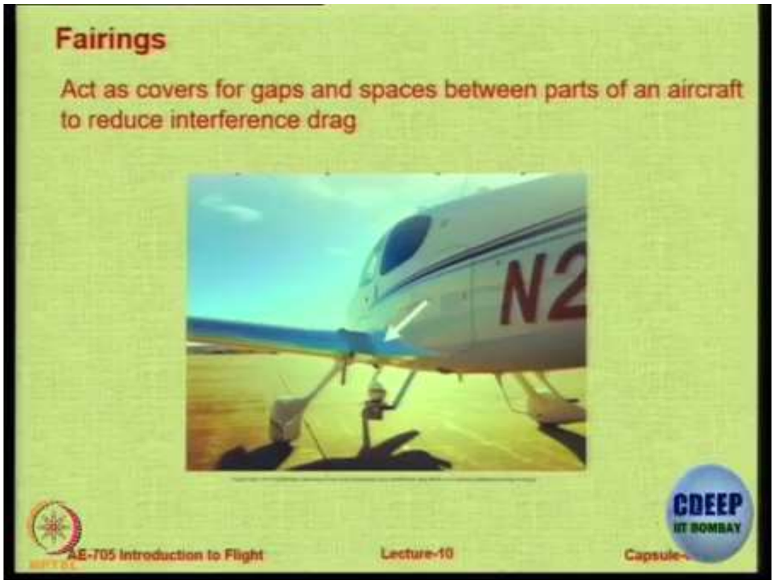
Student: They are used to reduce the noise.

Professor: Correct. So, this this particular configuration or shape of the rear of the nozzle is a chevron nozzle and the aim of this is to reduce the ground level noise, so this is Boeing-787 Nacelle, right.

(Refer Slide Time: 6:38)

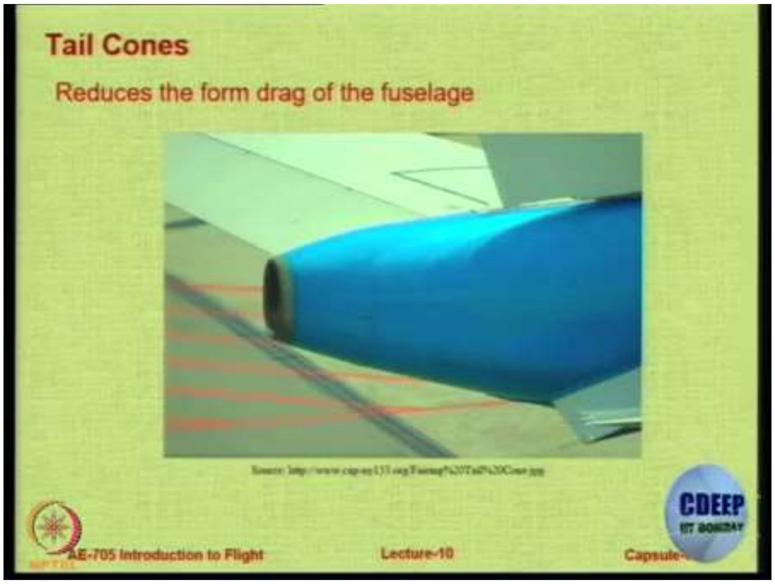


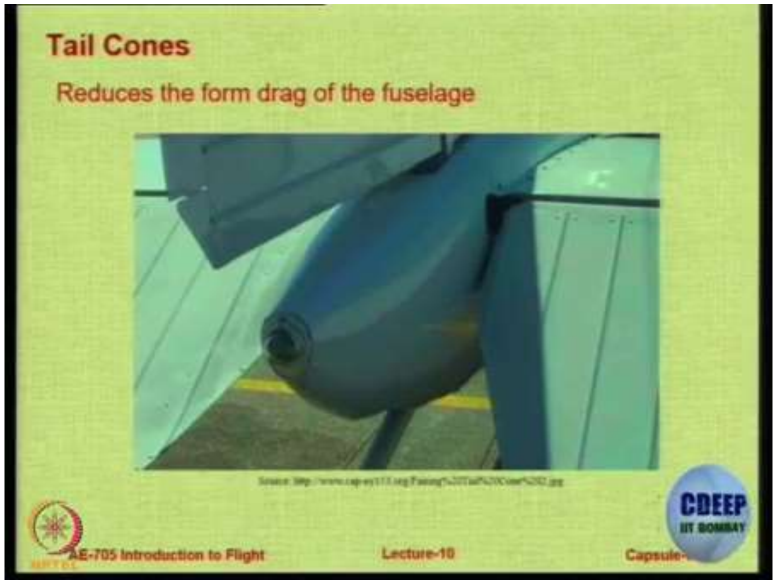




Okay you can see, wherever there are interference of two particles, we normally provide some kind of a fairing and the additional weight and the cost of fairing is worthwhile because it reduces the interference drag by a very large amount. Similarly, covers and cowlings or fairing, you can see flap track fairings, so these members have been given a particular shape essentially to reduce the drag. We need to have a flap track so that the flaps can move, but if you leave them exposed, they will create drag, so you normally flare them.

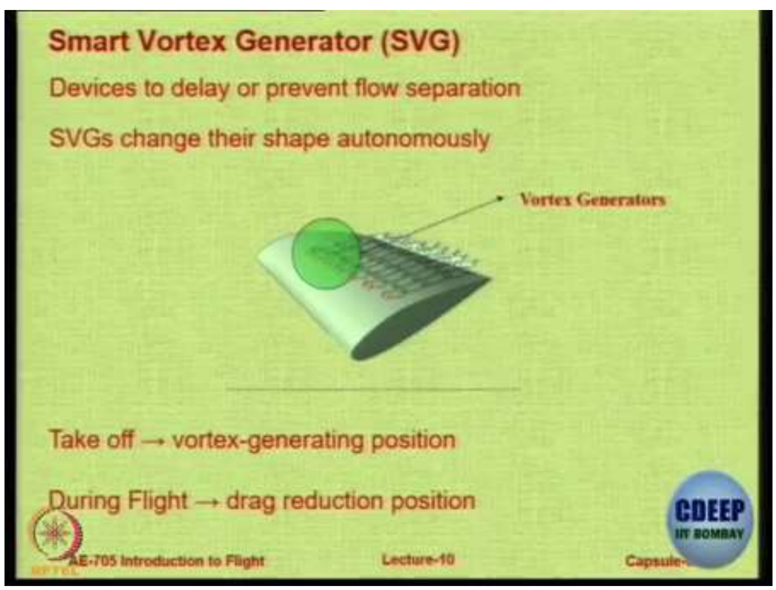
(Refer Slide Time: 7:24)





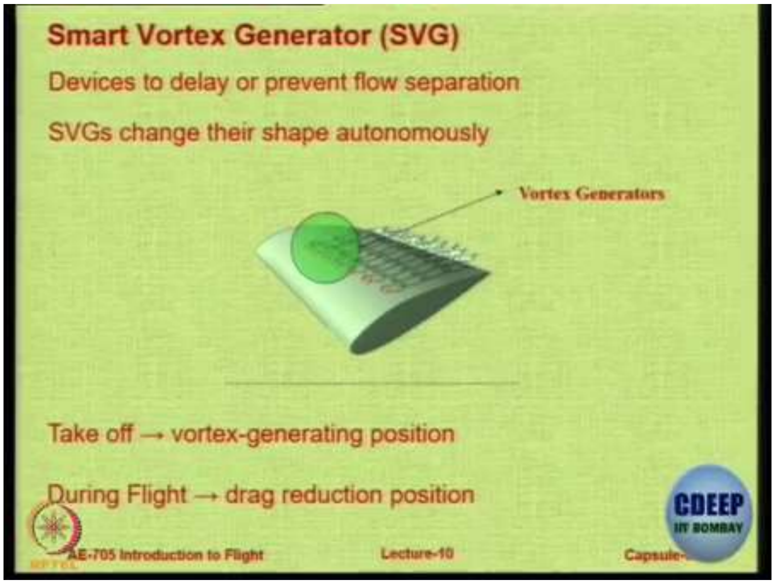
And also the tail cone. So what is inside this particular area normally? What do we have inside this? APU, Auxiliary Power Unit, okay. So, the tapering of the rear and the shaping is done essentially for reducing of the form drag of the fuselage.

(Refer Slide Time: 7:51)



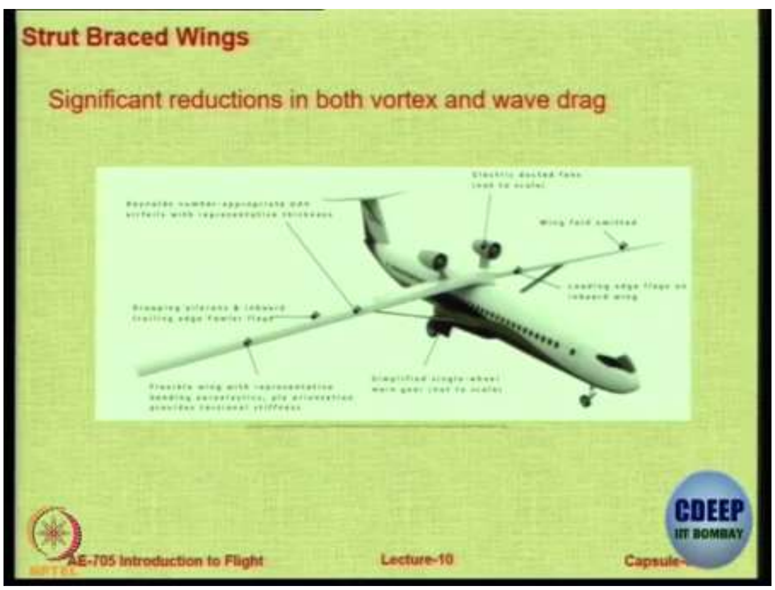
And then we have also seen this creation of smart vortices. So you can generate the vortices and these can help you. There can be many positions but this is still an area of research, some aircrafts already have them, but large scale vortices large large scale vortex generators are not there.

(Refer Slide Time: 8:15)



Another example of reducing the drag of the aircraft is to join them to the tail, so structurally also you have a continuous structure, it helps each other, plus you have thinner wings, smaller chord and high aspect ratio. So, it acts acts like some kind of a support.

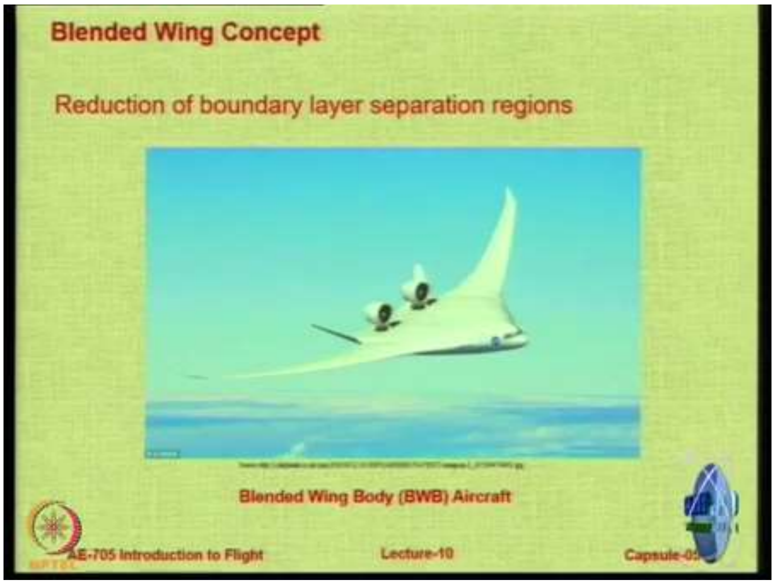
(Refer Slide Time: 8:42)



And then in the, in some of the modern designs, where extremely large aspect ratio wings are being presented, strut braced wings have been proposed. So, there is a big study going on in Virginia Tech on strut braced wing.

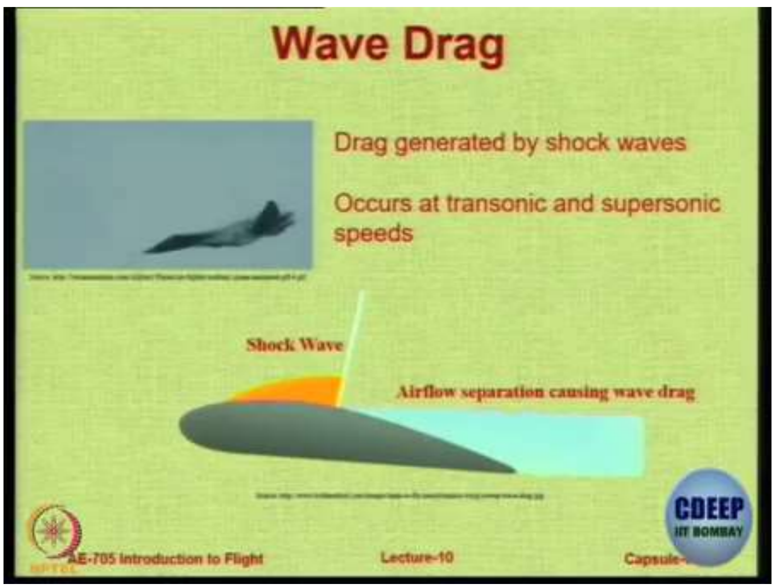
And a lot of analysis have been carried out, to bring out how a strut braced wing can be, overall it can lead to a much better aircraft compared to a conventional one. But then there is a problem, you have to be careful about the interference drag of the struts, if you do not design them properly, like we saw in the previous example, they can really cause massive interference.

(Refer Slide Time: 9:27)



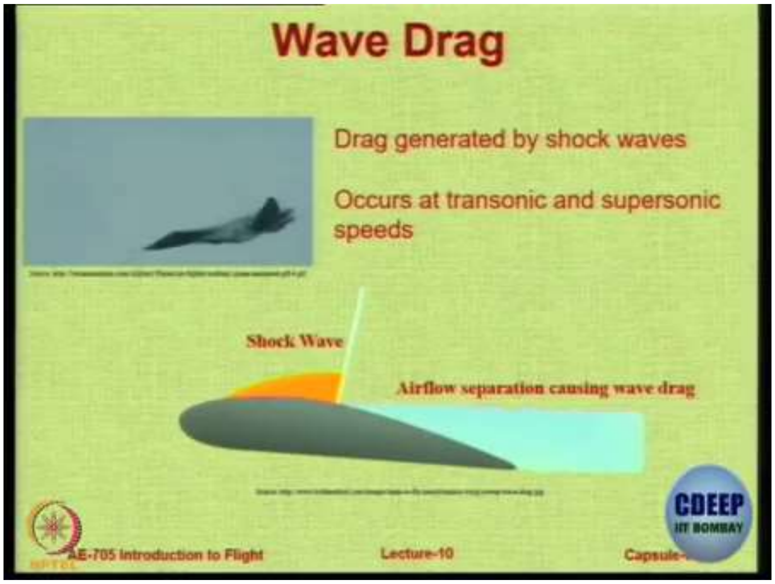
Another concept that is very common nowadays is blending wing body, where, where is the fuselage and where is the wing we do not know, both of them are blended together. So you, you put all the payload and the passengers in the wide, in the central root chord of the wing and you blend the whole thing with the aircraft. So, this particularly, this is specifically what is being suggested for the next generation commercial aircraft, okay.

(Refer Slide Time: 9:58)



So wave drag, now wave drag is something that we have seen in the last lecture. So I will not spend too much time on wave drag. Basically, it is wave because of the shock waves, okay and we have seen the same picture last time.

(Refer Slide Time: 10:14)



One way of reducing the wave drag is to sweep the wings backward and forward, this is an example, okay. So let us see a swept wing in action. We saw a video last time also.

Professor: X 29.

(Refer Slide Time: 10:56)

Then I mentioned to you about the Kuchemann Carrots or Kuchemann bumps, which are these so called anti shock body and this particular body is there to reduce the drag at transonic speeds. So these are intentionally, this is not like use a flap track and do it, this is something completely different. You can also see them in the design of the Concorde aircraft. Okay so with this I come to the end.