Introduction to Flight
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Lecture No. 06.5
Factors Affecting Induced Drag

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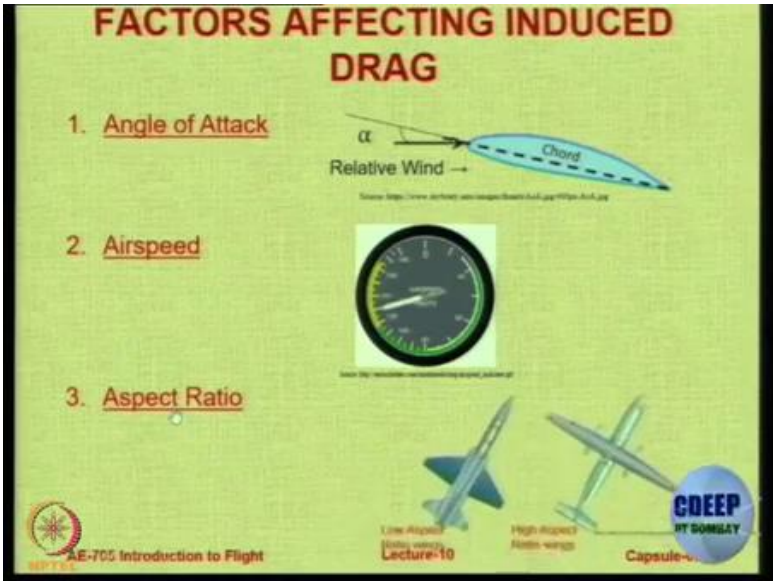

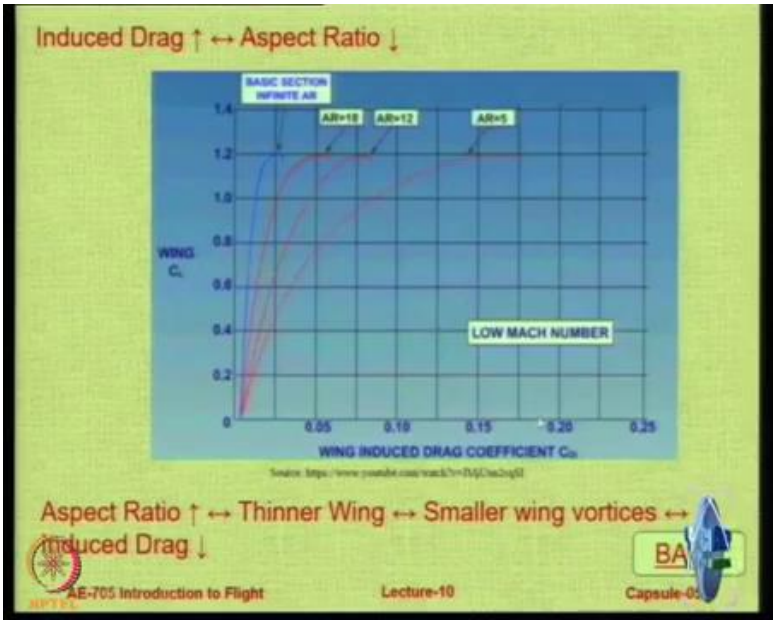

Let us look at some other effect aspect ratio itself, that already we have seen. So, you can see that as the aspect ratio is increased the slope of the lift curve. So, Cl versus the wing induced drag co-efficient is reducing, so; this is another way. So, when you make larger aspect ratio wing you have a thinner wing or; you have a more slender wing. The wing vortices are weaker

because you are going further and further away. So induce drag comes down. So, these are some of the ways in which you can address the induced drag.

So, what you do for angle of attack, do you reduce it or increase it to reduce the induce drag? Reduce angle of attack you will have higher Cl for the same lift. So, that will create more or less induced drag; Answer me? If you reduce angle of attack, what happens to Cl? Also reduces, correct. So, if you increase air speed Cl reduces, if you increase aspect ratio then also there is a reduction. So, these are the ways in which you can do it.

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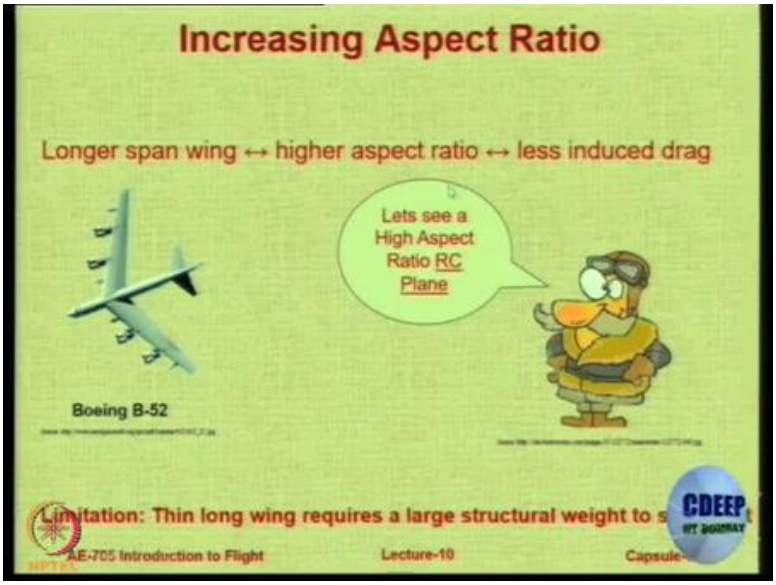

So, let us see one example of a high aspect ratio plane, but; this is a remotely controlled plane.

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Normally, you do not see RC plane in such a larger aspect ratio.

Video: And she is still in the air. Wow she is going on this vertical. Wow she is fast.

But, remember that if you make a wing very slender and very thin then, structurally you have to put extra efforts to make it stiff and rigid, ok. It is not coming at no cost.

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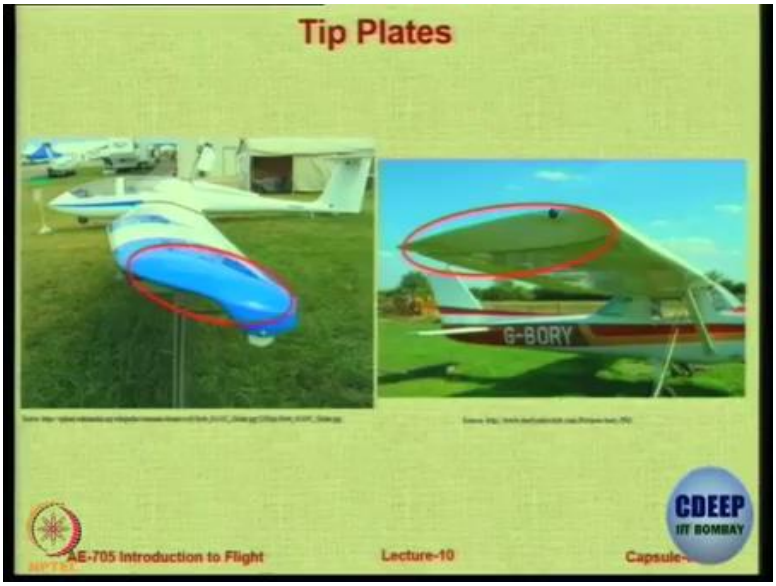

The other way of induce drag management would be, to pro-actively work on the strength of the vortex. The 1 way is to put tip plate. The one on your left, the one with the blue end is called as hoerner wing tip it was given by Sighard Hoerner. And, the one on the right is some kind of a device to create method to reduce wing tip.

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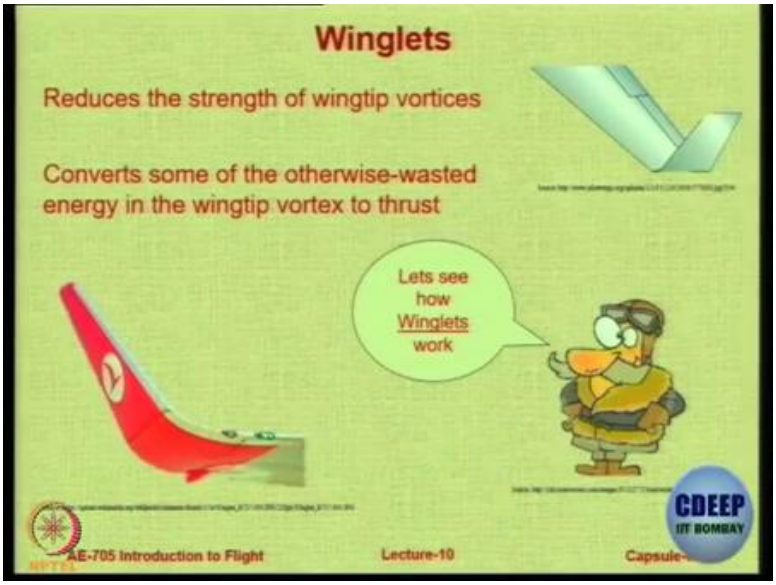

The other way is winglet, which is very common and most of the modern aircraft now you see with winglet. In fact, there are some people who say that; winglet can actually be design in such a way that can give you negative drag. Now, that is a questionable claim because that goes again in the laws of physics. You have air stream coming from front, how can you do something

just by putting a tip so, that it give you forward force. But, there are people who say that, by very careful design of a wing tip you can reduce induce drag so much; that it is almost like giving it some more additional thrust.

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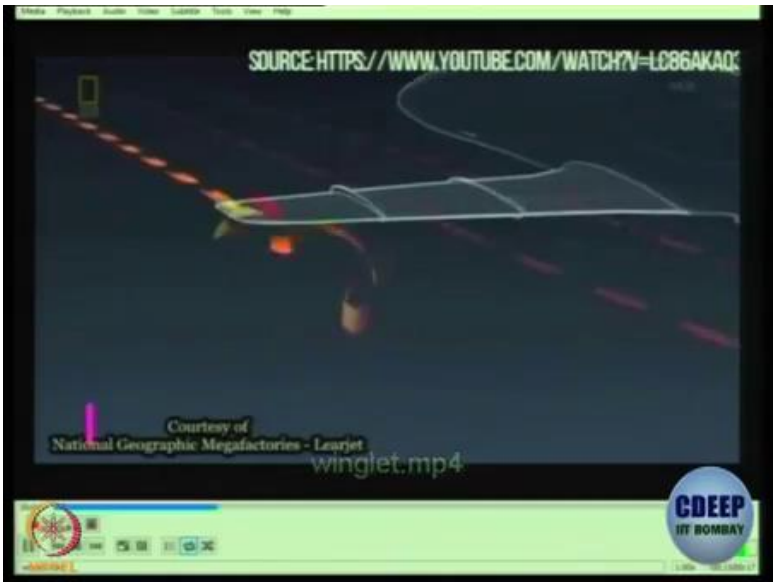

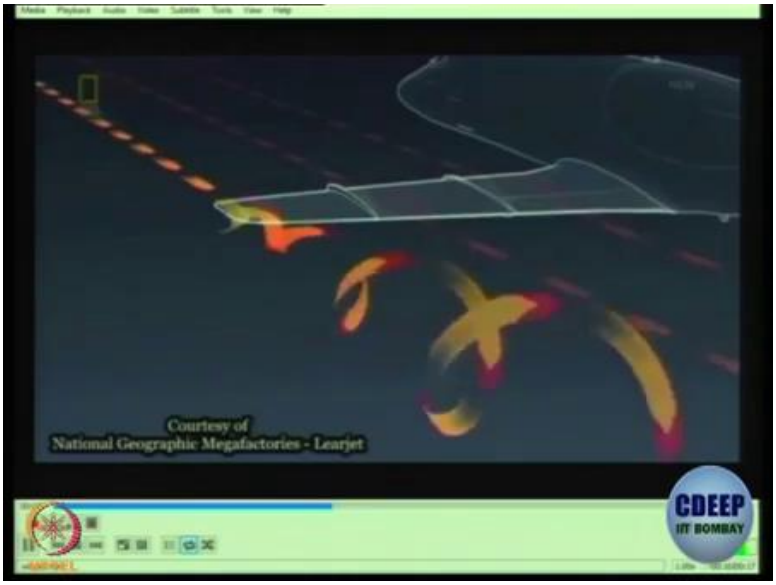
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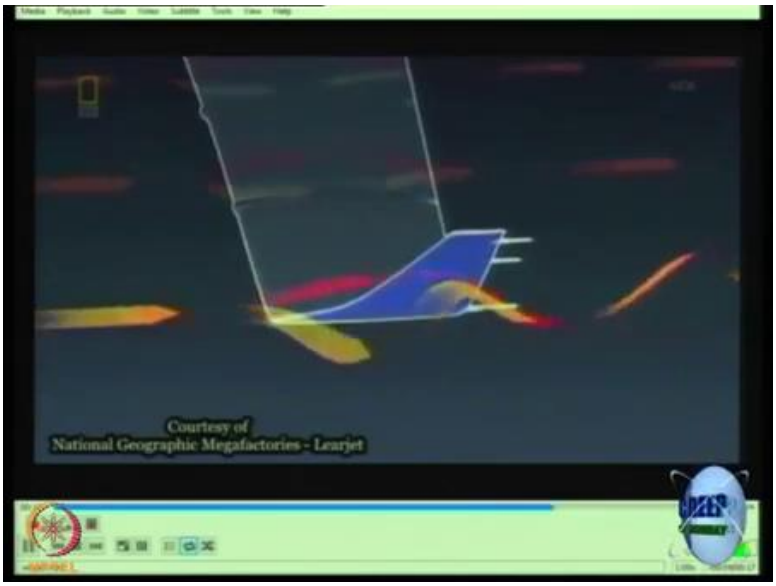
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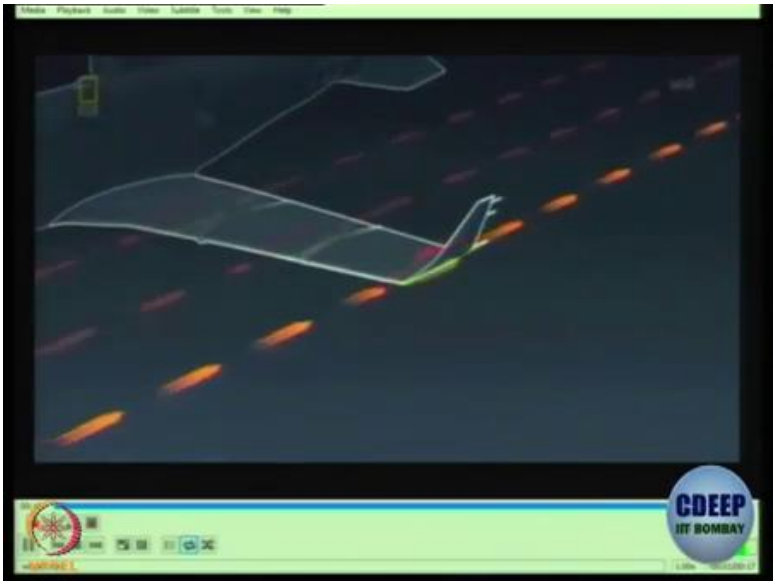
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Professor: There are some people who have done very interesting thing also on wing tip, which I will show u.

Video: Deep Pressure air travelling beneath the wing close around the wing tip and, into the low pressure air travelling over the wing. It causes a vortex, a mini tornado the drag, the fitted winglet form a barrier, breaking up the vortex and the drag. Deep Pressure air travelling beneath the wing close around the wing tip and into the low pressure air travelling over the wing, it causes a vortex, a mini tornado the drag a fitted wing form a barrier, breaking up the vortex and the drag. As high pressure air is travelling beneath the.

Professor: Ok this is how the winglet work.

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This is another interesting way; this is an attempt to copy the working of the birds. If you ever look at the tip a bird, you find they are like the fingers. They are not flat they always open up slightly, and they keep on manipulating them. So, they are proactively, they have used evolution to learn; to how much to bend in what way, in what frequency. So, some people have attempted this, by putting this kind of grid.

And notice that the angle of this is controllable by the pilot. So, there is a claim that, you can reduce the induce drag by 60 percent by using such kind of configuration. So people have mostly attempted either in gliders, or in RC planes but, atleast I do not know of any actual aircraft, powered aircraft which contain tips like this; and which is now commercially available, ok. So, there is claim, now we have to see and we have to find literature.

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This is another interesting way. Instead of having a tip, just create some kind of a Spiroid. So, you eliminate now there are 2 wing tip, which are joint together. This has been used in many aircraft. As u can see there are practical aircraft with passenger. Which have a very unique kind of wing tip called as a Spiroid tip.

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So, more about this can be uploaded by people on the MOODLE page, some innovative way or, other interesting way to reduce induce drag. For example, there are people who say you can

put a small turbine on the back of the wing tip. And that turbine can generate power actually, using the air which is curling. Ok let look at parasite drag.

video: Parasite drag is a direct result of the air resistance is the aeroplane flies through the air. There are 3 types of parasite drag, form drag, interference drag and, skin friction drag. Form drag, result from it turbulence created is the air tries to flow around the aircraft. Aircraft with larger cross section will have higher drag, than thinner more streamline design. Other item like landing gear and antennas on aircraft will also create form drag.

Interference drag: the curves and locations over the aircraft where different surfaces meet. For example, where the wings attached to fuselage. Skin friction drag is caused by the rough and, perfection of an airplane surface. A good example of this, now the rivets located in the aeroplane skin. These bumps disrupt the air flow from others, move along the surface. Parasite drag is a direct with…

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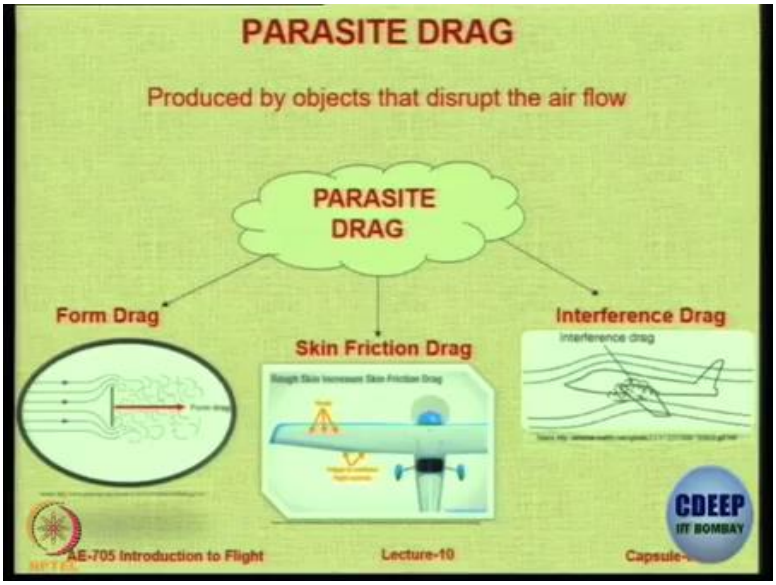

Professor: So, you just saw that any object, that disrupts the flow of air; by virtue of its presence, that create what is called as parasite drag. It has 3 component form drag because of the form of the shape or frontal area of the body which creates the difference in the pressure on the upper and lower surface, or behind and forward of the body so, that what is form drag. Then, you have skin friction drag and you also have interference drag. So, all these 3 together they are not at all connected with generation of lift. Even if you have no lift, you will still have these 3 drag. So, we call them as parasite drag.

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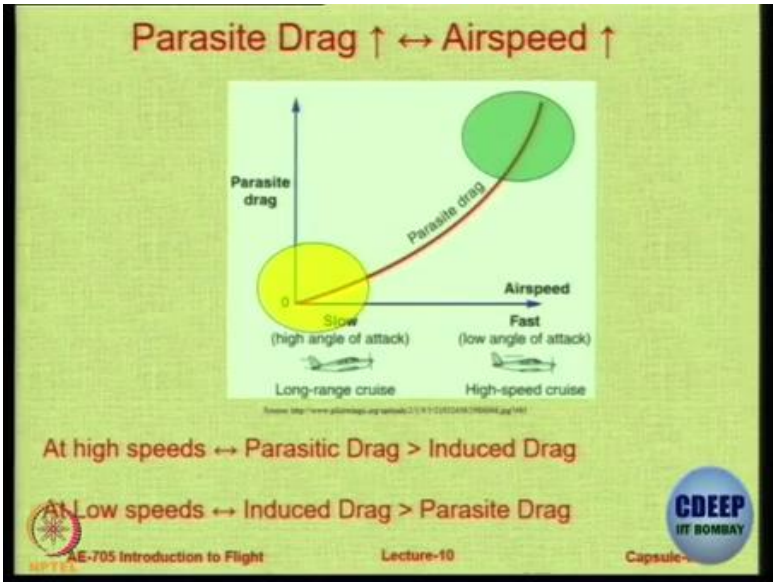

And, this drag increase as the air speed increase. In general if you fly slowly, at a high angle of attack or if, you will higher form drag. But, when you fly fast, at low angle of attack, at that the time rubbing of air on that surface could give you more. So, it depends on which of this term is more in magnitude ok. Generally, at high speed parasite drag is far for more than induced drag.

Because at high speed Cl is low, when Cl is low, $\frac{C_L^2}{\pi Ae}$ is low. So, high speed aircraft are more concerned about, parasitic drag reduction. Low speed aircraft are more concerned about, the induced drag reduction ok. So, all aircraft in which you see special type of tip device. When you say high speed it does not mean mach number 0.7 or, high speed basically mean very high speed.

Actually, beyond mach number 0.9 or 1 or 1.52 those aircraft, they do not bother to put any wingtip device. Because they say induced drag is not going to be our main problem. We are more bother about wave drag, skin friction drag and, parasite drag.

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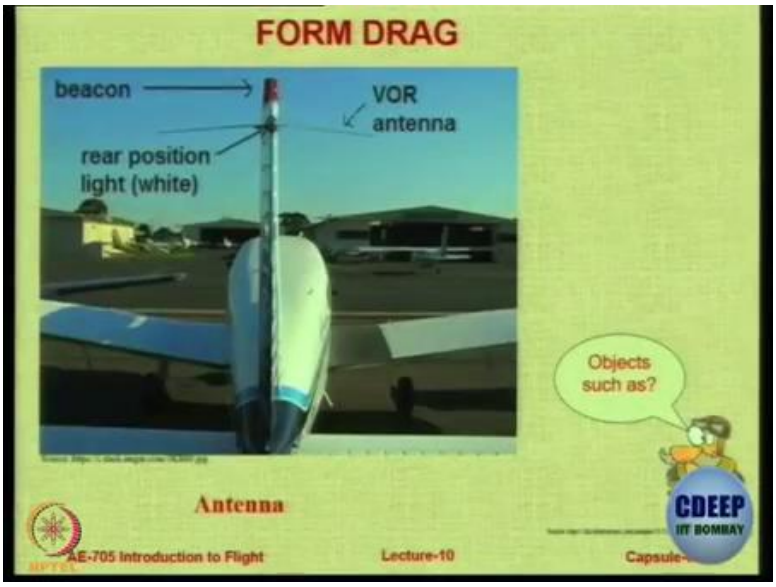

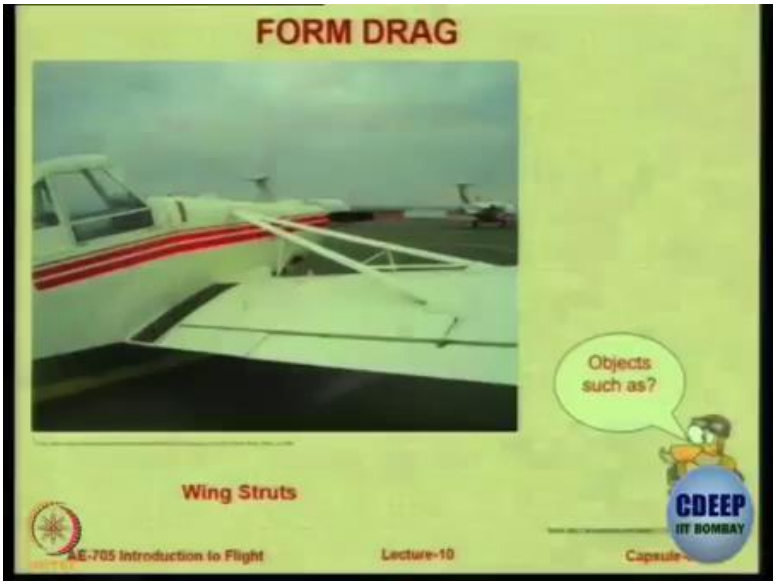

So form drag, very high form drag because of landing gear when it is extended. Very high form drag because of antenna, beacon or, anything projecting out. Also, very high form drag because of object, which are obstructing the flow such as wing struts. Now, tell me why do you think in this aircraft that; you see hear they have used this wing struts. What are the wing strut doing, why are they there, anybody? Here yes.

Student: Sir my name is Rishi. I think wing strut are provided to give support to the wing because the wing it seems to be very thin, so because of the bending moment it cannot sustained the force.

Professor: Let us look at this argument further, what do you notice about the wing. It is mounted below on the bottom; we call this as low wing. So, why do you have a low wing in this aircraft, what do you think? The hint is that black strip that you see on the wing root. So, why do you think this aircraft has a low wing, any guesses? Take a mic mention your name.

Professor: No, I do not think no I do not think you can connect propeller power with high wing or; low wing there is no connection, I can give you many examples of propeller power aircraft which are high wing ok, Dornier 228 is propeller.

Student: The wing would be exactly…

Professor: What is it?

Student: That would be exactly.

Professor: No, see there are many aircraft which have propeller and, which are high wing or, mid wing or, low wing. So, propeller location is not. I told the hint is his black strip. Yes.

Student: It seems that it provides some provision for the pilot to step on roof of the wing.

Professor: Exactly, so the black strip is an area where, you put your step; walk over the wing and, get inside the cockpit. So, that you do not depend on any ground base facility to enter the aircraft, a trolley or, a stair ok. So, therefore, the wing is on the bottom. Now, you could mount the strut on the bottom or, on the top to support it. On the bottom, it would have been better because that would have given you the strut in compression. Here, the strut will be also in compression because the wing is going to bend up.

But, when the load come on a wing, with strut on the bottom strut is in extension. So, this is actually bad because, compression is not good because there can be buckling, it is a very slender strut. So, you are actually creating a tendency of buckling. But, there is no place on the bottom because, wing is at the bottom. So, therefore, if you have to put strut you have to do this, you have to put it on the top. You can minimize the tendency of buckling by joining the member sideway.

So, it is a compromise solution, not a very good solution. Because, the top surface of the aircraft is where the maximum lift is generated and there you are putting up these messy thing. It is not a very good solution. Not elegant does not look neat, create a lot of drag; so does not be very high form drag. But perhaps the designer have found that is the best solution given to circumstance ok.

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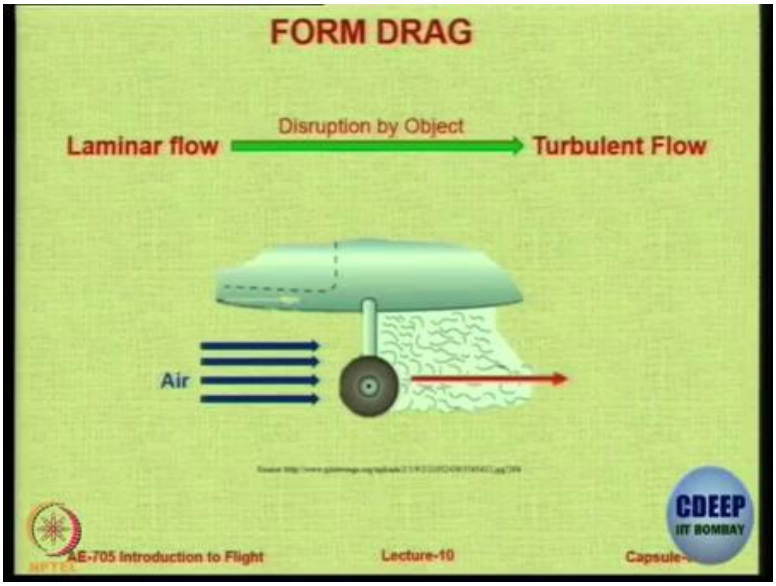

Then form drag can also be because of the disruption. So, by presence of an object the flow becomes turbulent, it could be a protruding rivet or it could be something else. So, you can also have form drag because of the presence of some surface. We have already seen this in first lecture.

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Just after you land you can these thing come up, they create extremely high parasite drag and, that is intentional. Because, at this point we do not want lift, we want to spoil or kill the lift. So, you create high parasite drag by projecting some surface, almost perpendicular to the air stream ok.

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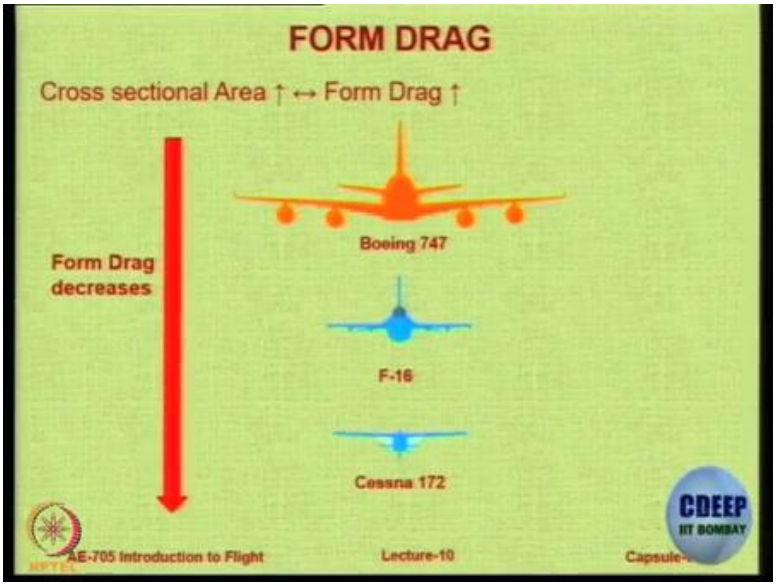

So, as the cross sectional area of the aircraft increase, the form drag will increase. So, from 747 to f16 to Cessna 172 there is a reduction of section area, just by virtue of the size. And, therefore you have a lower form drag ok.