Introduction to Flight
Professor Rajkumar S. Pant
Department of Aerospace Engineering
Indian Institute of Technology, Bombay
Lecture Number 05.2
Aerofoils: A Visit to the Past

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Let us just go and look at little bit on historical development. How did we get Aerofoils and were they there right from the beginning? Ok. So there is a short video, which tries to capture approximately 100 years of historical development in aviation. So, I think it is a very interesting video, so maybe we should just watch it.

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It is a brief history of aviation, so obviously everything starts with a dream or an imagination to emulate the birds. So we have the story of Daedalus and Icarus who tried and then after that people began looking at it scientifically.

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So the first recorded information about working of the system comes from the Vinci and then these two brothers, they made the first hot air balloon.

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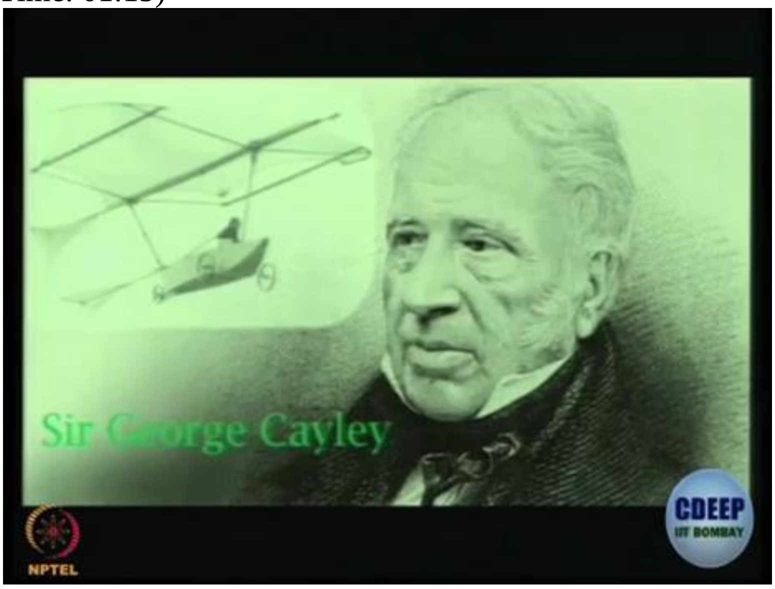

Sir George Cayley is considered to be the father of the modern aircraft.

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Before Wright Brothers there was this German gentleman called Otto Lilienthal who was an expert in gliding, during his lifetime he has done 2500 flights but the last one, the one that killed him.

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And then we have our friends, the two Wright Brothers, Wilbur and Orville Wright, on this Wright flyer, Wright flyer 1.

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Look at the Aerofoils of these aircraft in the historical past, crossing the channel 24 miles was a big achievement. There you see bi planes and during the first World War we had some heroes, who are known to be capable of shooting down enemies, they are the aces, these are the World War 1 aces. After the war you had some very dramatic people like this person standing on the aircraft or hanging below the aircraft and here you go.

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Then people said no we can use aircraft for some meaningful purposes also, instead of just stunts. So we use them for airmail and then people began pushing things, more and more, longer and longer ,within a century Charles Lindbergh. Look at the wing, look at the cross section, look at the aerofoil. Fixed landing gear, across the Atlantic Ocean for the first time, 33 hours, ok, and then of course after this there have been many many many many many new other new developments.

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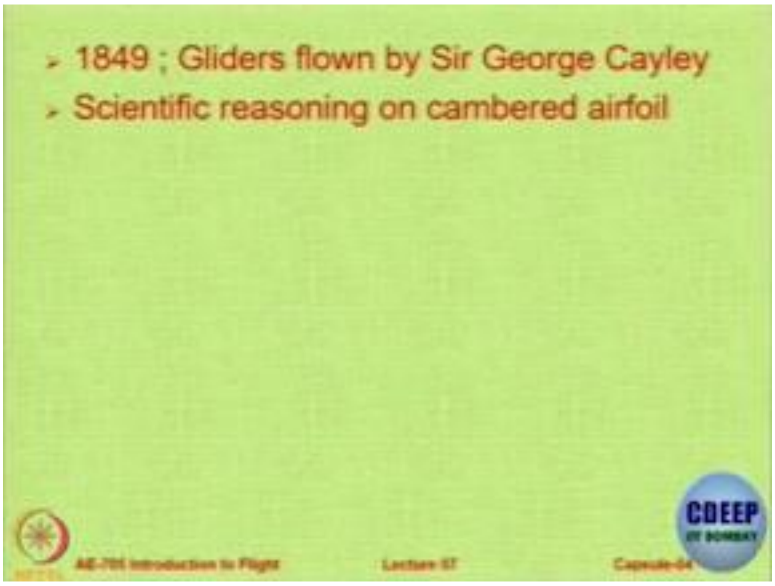

Ok, so Sir George Cayley also flew some gliders, quite many years ago and he was the first person who began looking at aerofoils and coming up with the idea of giving them what is called as camber. Although the all aerofoils did not have camber during that time, ok.

So, Phillips was the first person to talk about optimizing the shape of aerofoils to achieve a particular mission and later on we had so many other people who studied various types of aerofoils; two names stand out here, the one of Otto Lilienthal and Octave Chanute. They have contributed immensely to aviation.

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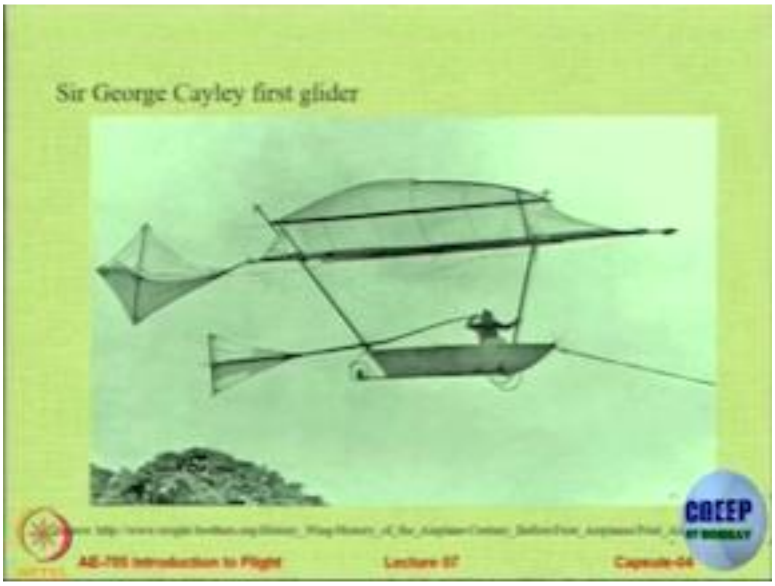

So this is the first glider which was flown by Sir George Cayley, designed by Sir George Cayley ok. You can see it is being toed by a cable. So it is being launched by a cable.

Where are the aerofoils? There are no aerofoils here. What you see is just flat cloth placed over a structure, but given some kind of a shape and actually it occupies a particular shape based on the winds, ok.

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So then we had Lilienthal, as I said, a very famous aerodynamicist I would call him or glider designer, who tried out various things including ornithopter, which try to mimic the flight of the birds. Once again no aerofoils, only flat plates but curved and twisted at various places.

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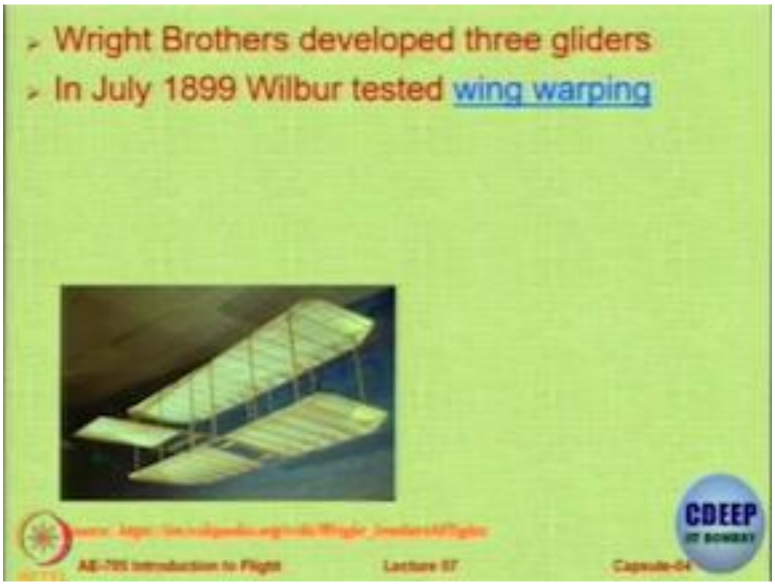

So then even Wright Brothers also developed some gliders, ok. This is the one of the gliders that they developed. Again if you see the aerofoils are not there, these are again flat parchment sheets, with little bit or rounding in the front, the focus mostly is on making a structure which can withhold a person and the control system, ok, and which side of the aircraft fly? Does it fly from your right to left or from left to right? What do you think?

So how many of you say that it flies from your right to left, raise your hands. A few people, but most of you feels it goes from left to right, ok. That is because you are conditioned by the thinking that the tail should come on the back, ok. This one is from Wright Brothers, who put tail in the front, so this flies from right to left. Alright, so Wilbur tested the concept of wing warping or wing twisting.

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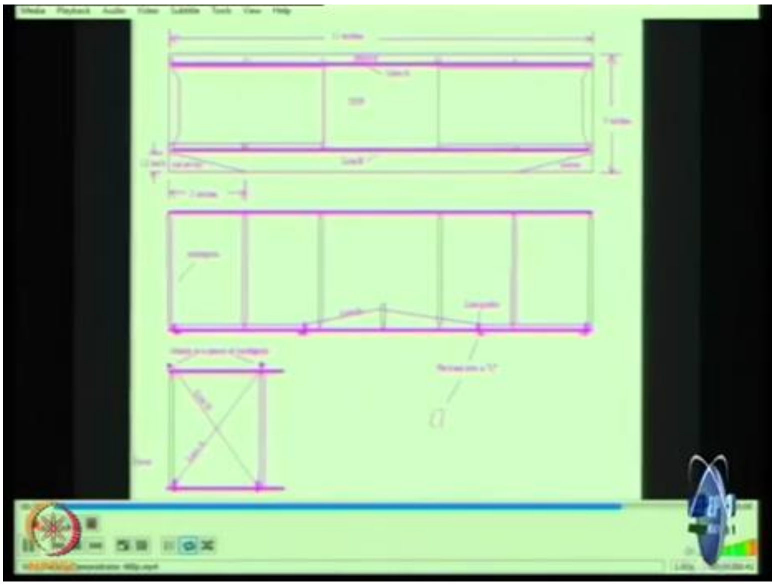

Let us see what this concept is, its a small example, its a small demonstrator, just shows the basic structure of the box type wing that was designed by them. Look at the wing tips, they are twisting. So it will be nice if somebody can build up a model of this one, this wing warping mechanism and instead of using a hand you can use a remotely control servo to twist it and to show the working of the wing.

So in 1901 we had a glider and these gliders basically because they fly slowly and not as efficient as todays gliders, these tend to have a very large wing area, so they became very difficult to handle and because of that there were many deaths and many accidents, because people were not able to manage or control these gliders. One more reason is the forward elevator which becomes very sensitive to the control, so according to the designers of these gliders, the Wright Brothers; they were interested in controlling it proactively, they were very good in flying, but they were not interested in stability, they were more interested in control, ok.

So the last capsule of this course is going to be on stability and control, so there I will elaborate this point little bit further. So because they were using forward elevator, there were many last minutes escapes. Several times they came close to crashing or came close to getting majorly injured because it is very difficult to control, ok, alright.

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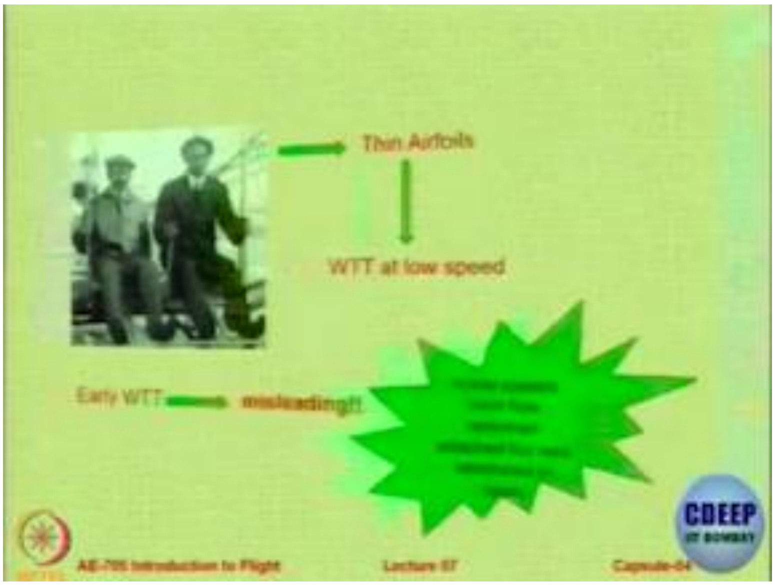

So the aerofoils used by Wright Brothers was essentially thin aerofoils or just flat sheets with some curvature in the front ok and they did a lot of wind tunnel testing, one of the special contributions of Wright Brothers is the use of a crude wind tunnel to test the working of their own design, ok.

So they did low speed wind tunnel testing in their own workshop and the results that they got in the beginning were misleading And there is a very interesting story in which the Wright Brothers did some internal testing and they found that the data that they are getting is totally different from what is published by other people, ok, so and then how they how they actually figured out, in fact they wrote a letter saying that ‘our result do not match with your result, we see that the flow remains attached at the low speed and the wind tunnel but when reality when we fly we do not find the flow to be completely attached’. So the wind tunnel testing was misleading, one reason for this was the transition strips were absent, ok.

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So therefore they were not able to replicate the same conditions. These are pictures of some World War 1 aircraft and interestingly these are in the side view so you can look at each aircraft and you will find that the aerofoil is basically a flat plate which is some curvature. So all World War 1 aircraft, they had an aerofoil which was of this particular type. So the ideas like providing camber, rounding, thickness, they came, they were known but they were not implemented in that time, ok

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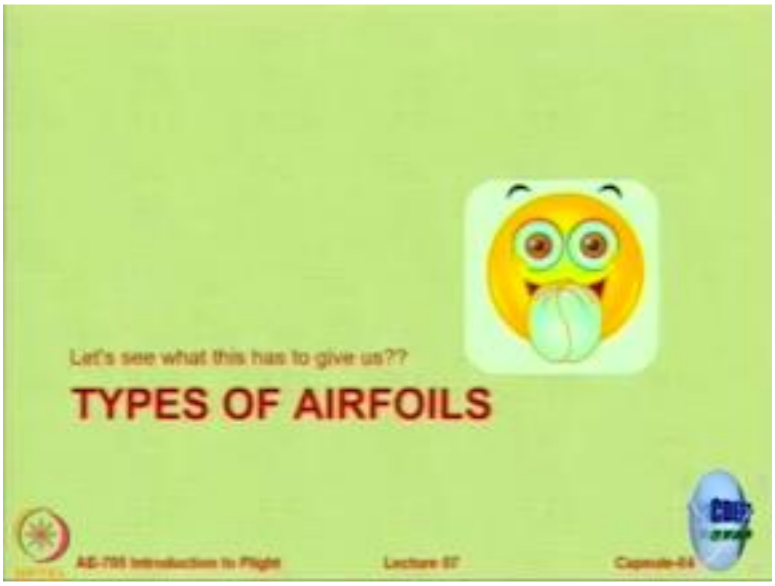

So you can see for example, this World War 1 plane. If you look at the tip you can see, you get a rough idea about aerofoil cross section. So notice it is essentially a flat thing. So then we look at types of aerofoil, we look at what kind of aerofoils are there.

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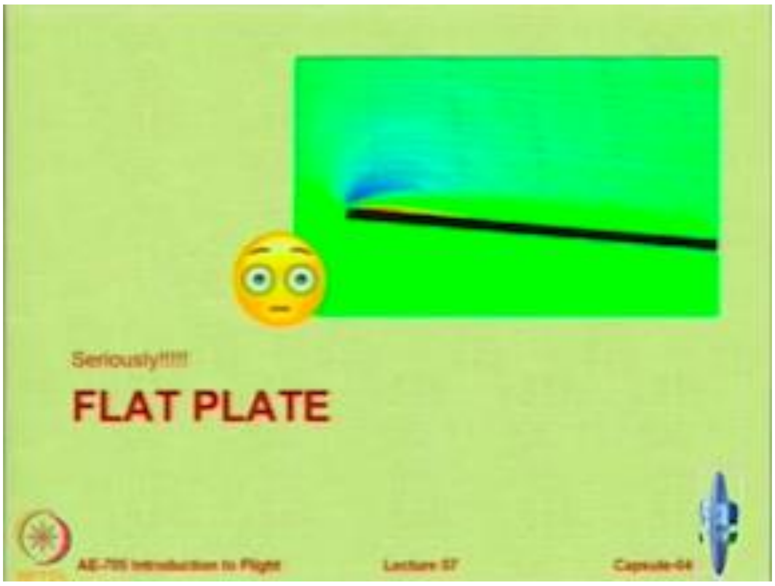

So flat plate is also an aerofoil and flat plate can also generate lift. It is not necessary for you to have curvature or rounding In the next class I am gonna talk about dynamics of creating lift and there I will explain to you how a flat plane can also create lift, and here is proof, here is a CFD picture of a flat plate and you can see there is a difference in the pressure, ok. The blue zone is very visible on the top of the aerofoil, so you can make out that there is a pressure difference, the pressure at the top is lower so it is going to be upward force.

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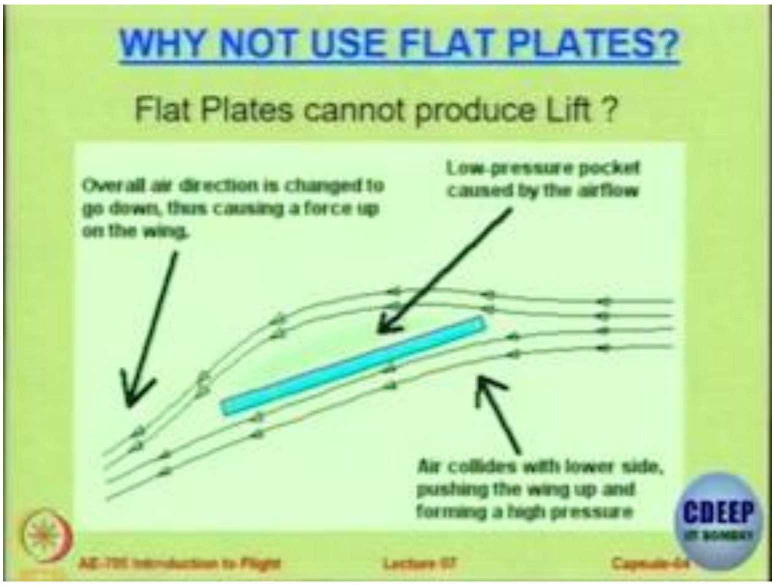

Then the question is, why not use flat plates? Flat plates can make you fly, ok. I have built some small test gliders and I fly them using flat plates. I do a demo in many places and before me so many people have flown aircraft. So then question is, why not use flat plates? Why go for curvature, aerofoil, shaping? What do you think? What is the need? When you can manage with a flat plate then why should you go for such complicated things like providing a profile or a shape. So let us see who can answer this question? Why not use flat plate?

Student: I think it reduces flow separation and it provides space for storage…

Professor: Ok, so the problem is not to generate the lift but the problem is to sustain lift at angle, ok. So this is a question which many people ask, flat plates can not produce lift, the answer is no they can produce lift but there is a problem. So as you can see, here is an example of how flat plate can produce lift, ok. They can produce lift but why don’t we use them? So the answer will be available through a small video.

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Video: The first I set was with the unprofiled wing. You can see the wing experiences airflow separation at fairly low angle of attack. Airflow separation is the generic term given to the occurrence where the boundary layer or the layer of air closes to the surface of the wing has velocity of close to zero. This is visible in the form of turbulence and eddies as you can see here. The surface ends the wing at stall, you can also see the oscillating, trailing policies, characteristic of a wing at stall here and here. When we look closely, we can see a small trailing vertex present even when the wing is at low angle of attack.

Professor: I want to play it again, so that you can see carefully.

Video: The first I set was with the unprofiled wing. You can see the wing experiences airflow separation at fairly low angle of attack. Airflow separation is the generic term given to the occurrence where the boundary layer or the layer of air closes to the surface of the wing has velocity of close to zero. This is visible in the form of turbulence and eddies as you can see here. The surface ends the wing at stall, you can also see the oscillating, trailing policies, characteristic of a wing at stall here and here. When we look closely, we can see a small trailing vertex present even when the wing is at low angle of attack.

Ok, so the main problem as Ritu rightly mentioned is that at a particular angle a flat plate is sufficiently good, you may just have to round the leading edge to avoid immediate stagnation pressure creation of the air. Because, a flat plate will have some finite thickness, so for that thickness and that thickness portion in the front the flow come to a rest. So if it is rounded slightly or give it some kind of a shape in the front and in the back it becomes very easy.

So you are always aware that the flow will be coming to you only at say 3 degree angle, you can make a very optimally shaped flat plate for that angle and it will give you very good lift. This is what you see in the ceiling fan. What do you see in the ceiling fan? Do you see the aerofoil in the ceiling fan? Ok. You see a flat plat with some bend. That bend is basically to ensure that the air is consistently and strongly pushed down, because you do not want the fan to lift up but you want the air to come down on you, right.

So you give, you take a flat plate, give it give it some shape towards the back, that is all. So, if I if I want to operate a fan at a particular angle continuously I can manage with a flat plate. But in an aircraft as your speed changes you have to align your aircraft with the wind at different angles and that is where a flat plate will will be immediately a problem.

So the initial aerofoils that people used were flat plates with a small curvature in the front. So that at range of angles you still do not have a flow separation and that is how we got the wings of the aircraft during the first World War and other low speed applications. But soon people realized that it would not be enough we have to do something more to get a better information, ok.

So the answer is this if the if the leading edge is sharp, ok there will be easy flow separation as you saw in the video also quickly a vortex will be formed and that is going to consume energy from free streams, so you will have more drag and the angle at which you loose lift or solving angle becomes very small. Therefore if you want to stay up in the air you need to have more powerful engine because drag is going to be larger.

So then people said ok, let us go for rounding and let us go for cambering or shaping the aerofoil. So there is a hypothesis here, that the cambered aerofoil will perform better. Now, let us investigate, let us see what are the conditions under which this hypothesis can be true.

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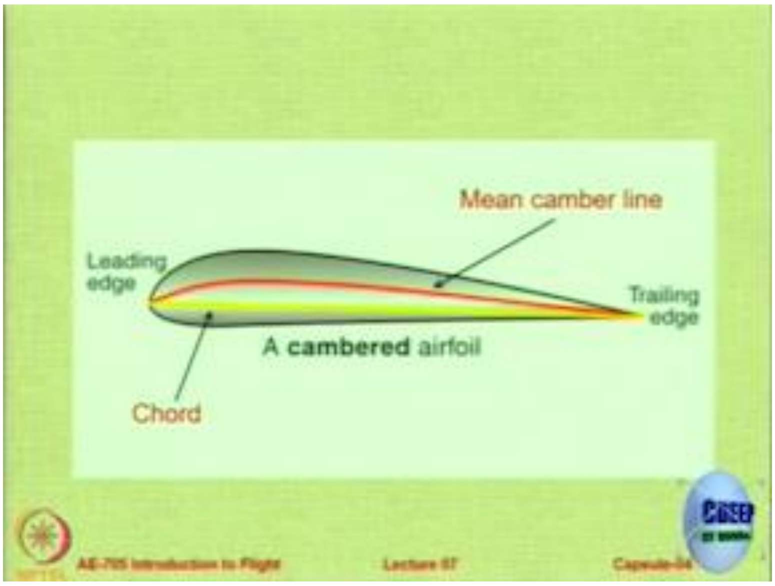

So first we should define what is a cambered aerofoil, an aerofoil in which the cambered line and the thickness line are not identical. Because there is a presence of a camber, right. So these are the terminology, which we have already seen.

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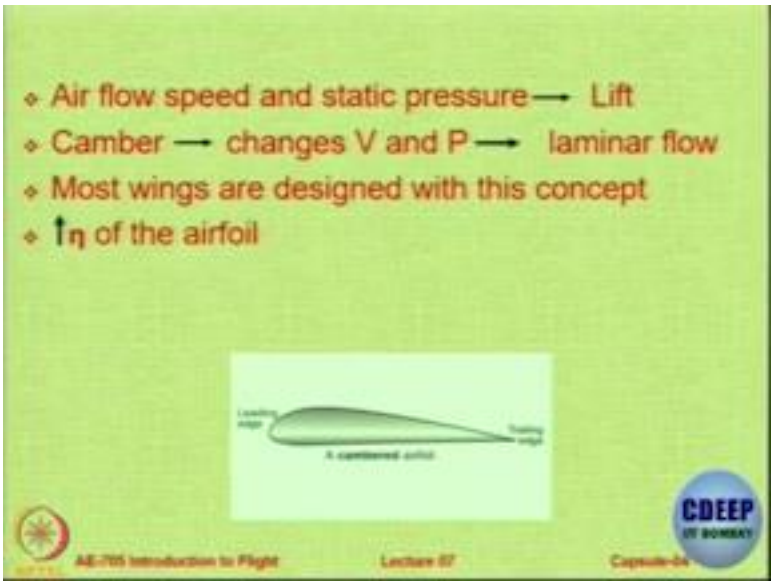

So airflow speed and static pressure both of these are going to generate the lifting force as we will see in the next one, now if you provide camber or curvature you change the velocity, acceleration. You change the increase in the you you result or cause increase in the velocity and hence more changes in the pressure; but this is true only if the flow is laminar, to some extent it is true even turbulent flow but mainly it is true when you have undisturbed flow and most of the wings are designed with this concept that you provide a curvature so that the ambient air comes in and because of curvature it accelerates, as it accelerates you can expect lower pressure and therefore you can get lift. So the efficiency of the aerofoil increases if you provide camber, but in certain circumstances this may not work, as we will see some time in the future.

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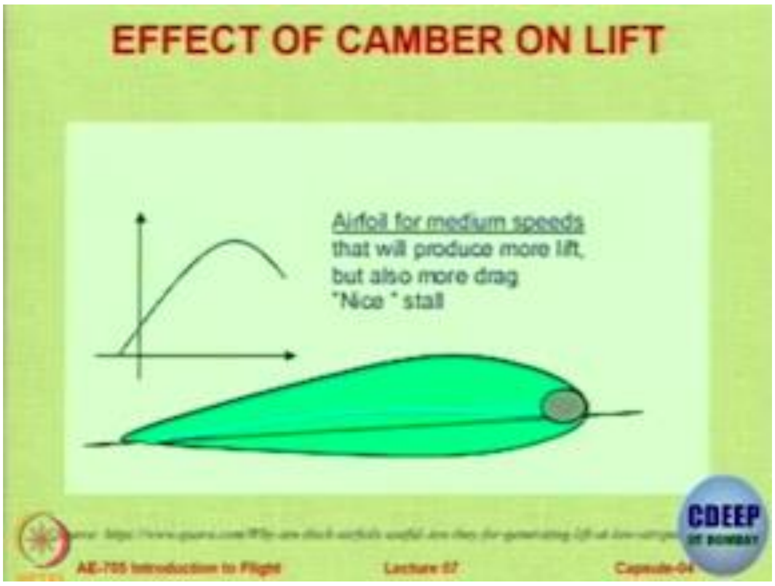

So here is a discussion about the effect of camber on the lift, ok. So there is a curve called as a lift lift curve which is shown there. On the X axis you have the angle, at which the aerofoil faces the free stream or the angle of attack. On the Y axis we have the lift coefficient or measure of the lift generate.

So if you have a medium speed aerofoil, ok then it is good to have a minor camber or a mild camber because you will produce more lift due to acceleration but also you will have a smooth stalling characteristics shown by the gradual reduction in the lift beyond the angle, ok.

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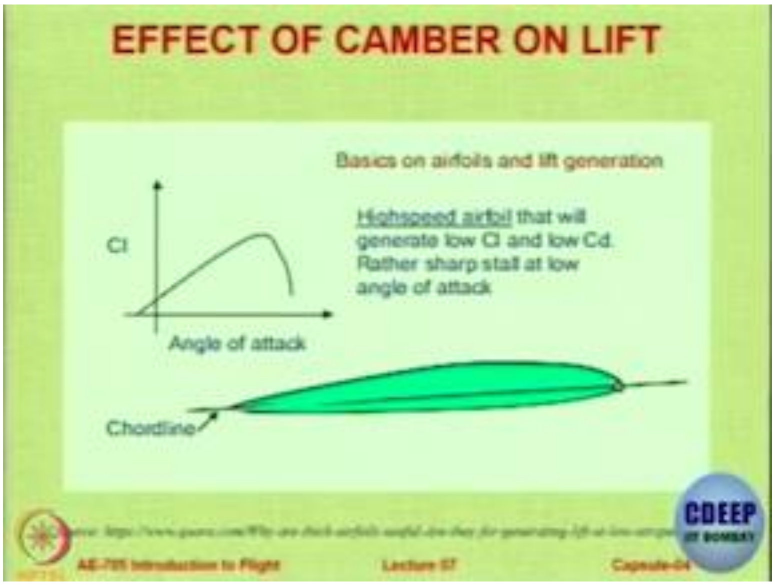

Now if you have a high speed, if you design something for high speed then if you provide too much of camber you can have a problem, ok. So in this case you will start getting a sharp because if you provide too much camber and too much rounding for a high speed aerofoil, very soon the flow will accelerate to numbers that you do not wanted to exceed.

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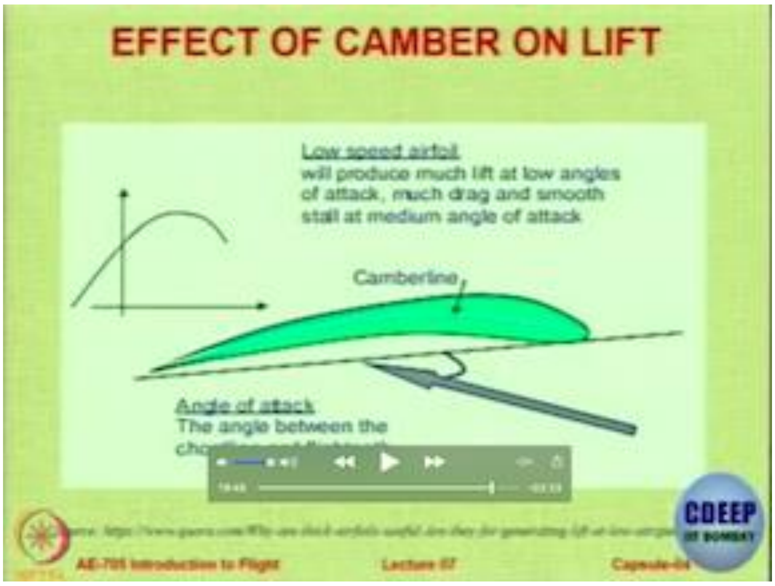

Then if you have low speed aerofoil or if you have a low speed requirement, ok so this is an example of the aerofoil which are seen in the engine components, in the compressor and the the turbines and the rotors, there we go for thin cambered aerofoils, ok.

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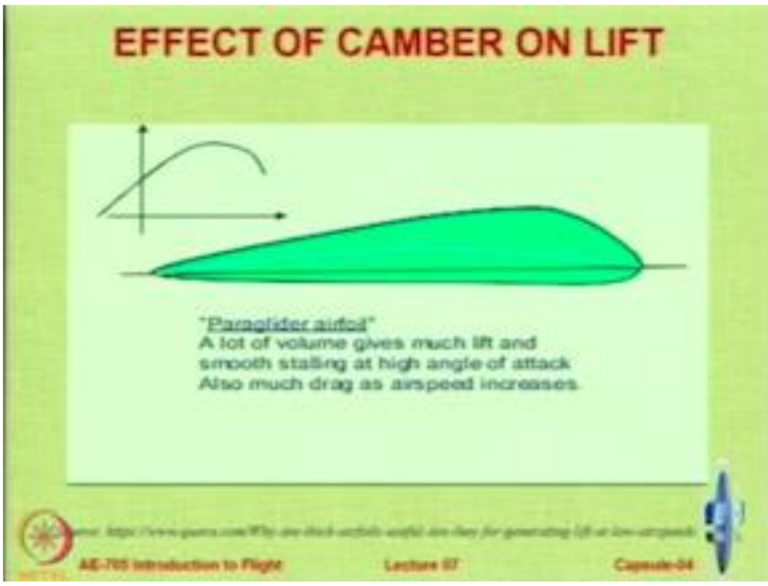

So if you are going for a para glider, something that glides for a very long distance. So in a para glider you have a very thick aerofoil with less curvature with a reasonable curvature, ok.

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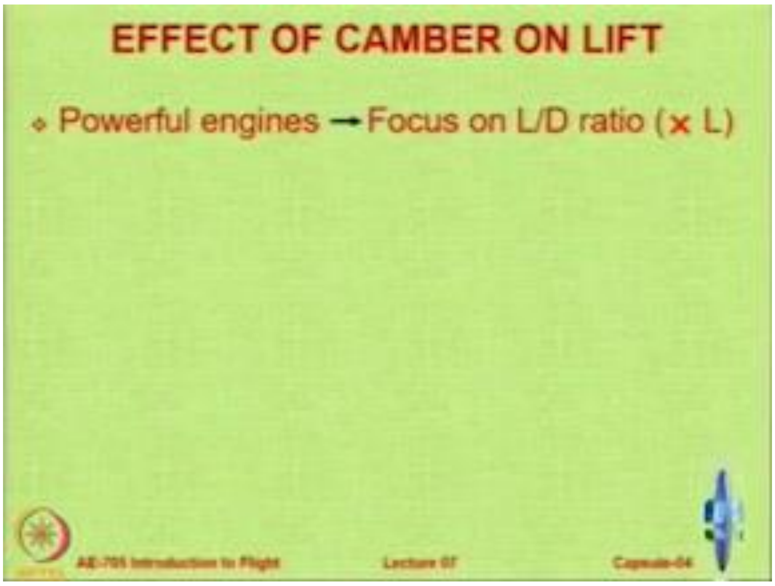

So depending on the application that you have in mind the shape of the aerofoil that is suitable for that application keeps changing. So one has to have an information about, how do you determine which is better for which application? It is determined either by experience or by wind tunnel testing for a particular application.

So in the tutorial session that we conduct we will do some experiments and try out and see how these parameters change. So if there is a focus on the lift over drag ratio improvement, not just increasing lift but increasing lift over drag then you need to have better aerofoil. If you just want to have more lift, you may take an aerofoil which will give you more lift but then may be very bad drag. So the focus, so the drag is the basic key to, it is the key aerodynamic characteristic and that has to be kept as low as possible