Introduction to Aircraft Design
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Lecture-54
Estimation of Lift Coefficient

Let us have a look at how the lift coefficient is estimated. Before we go ahead we must learn to distinguish between the 2 dimensional and the 3 dimensional value of lift coefficient.

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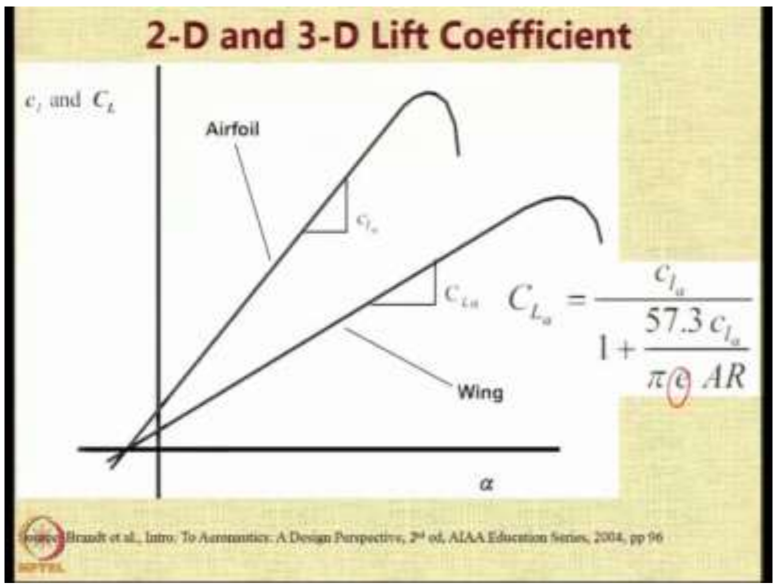

The 2 dimensional lift coefficient is for the aerofoil and it is normally depicted as small c subscript small l alpha or c_{l_α} in small case this is usually a larger value as you can see here it is a larger value as compared to the lift coefficient of a wing which is the 3D lift coefficient including the 3d effects and that is normally depicted as capital C capital L alpha or the C_{L_α}.

And this particular reduction between the 2D and the 3D value is because of the 3D effects on the wing. So our task is to estimate the 3D lift coefficient of an aircraft whose geometry is made available to us and the simple relationship between the capital C_{L_α} and small c_{l_α} is expressed in terms of the wing aspect ratio and the Oswald's efficiency factor e as shown in this equation.

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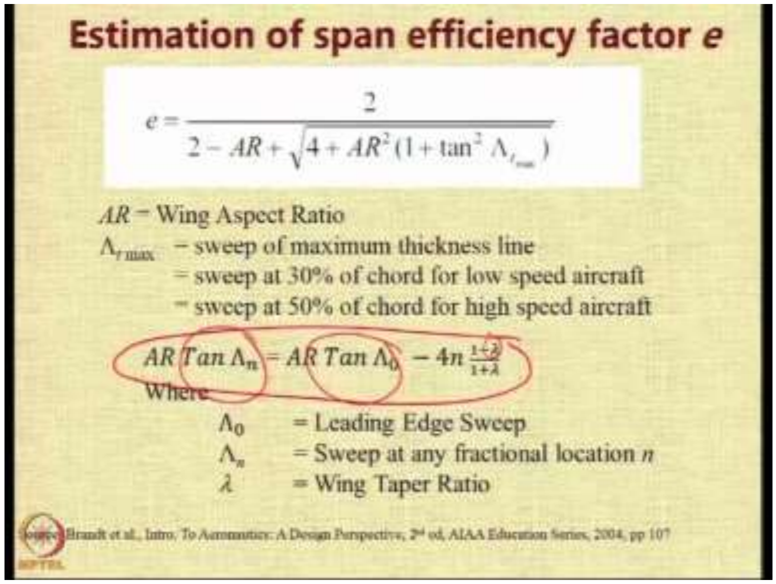

Estimation of the span efficiency factor is a very difficult task and the formula available have a lot of variation. One way to estimate the Oswald's efficiency factor or one formula to estimate it is as listed here in this particular formula the terms that play a role are the wing aspect ratio and the sweep of the maximum thickness line. This is a geometrical value and if you do not know this value then you can assume it to be the sweep at 30% of the chord for low speed aircraft and at nearly half the chord for a high speed aircraft.

Another important requirement is that you normally are given the data for the sweep at the leading edge or sweep at the trailing edge. And if you want to calculate the sweep at any location n or any fractional location n for example 30% or 50% and you know the sweep at the leading edge that is lambda 0 and the wing taper ratio then this particular formula can be used to estimate the value of $\tan \Lambda_n$ which is used here as a function of $\tan \Lambda_0$ AR and the taper.

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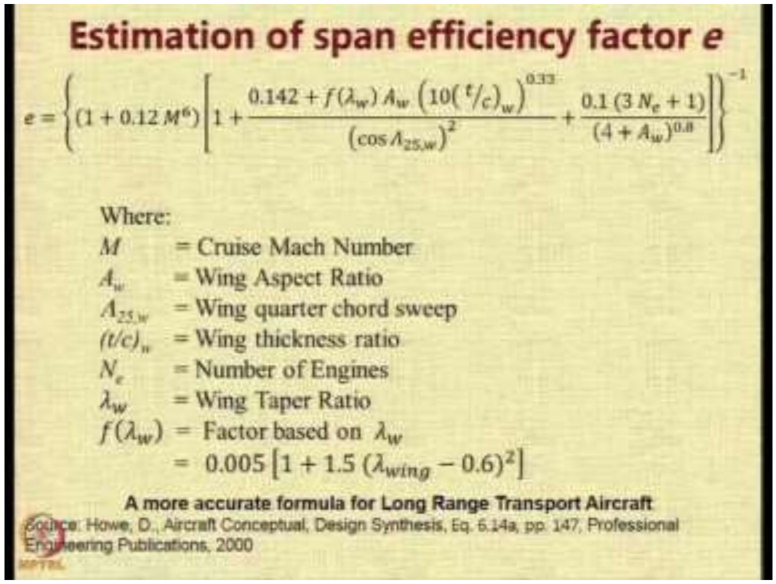

A more accurate a more detailed formula for estimation of the span efficiency e for long range transport aircraft is given by Professor Dennis how in his book here you can see it is a very long formula and it relates the span efficiency or the span efficiency factor e with the Mach number the aspect ratio the quarter chord sweep the t/c number of engines taper ratio and a factor based on the taper ratio.

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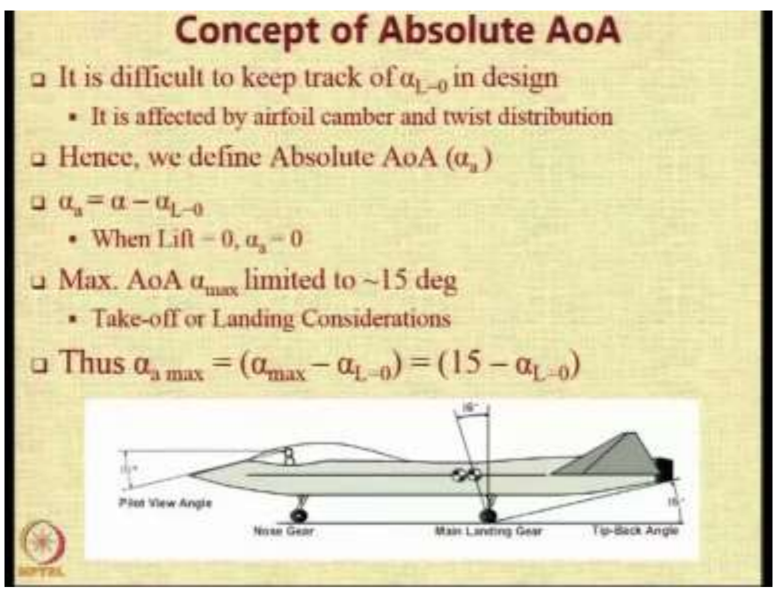

Let us understand the concept of absolute angle of attack before we go ahead. Now there is one angle at which α there is one angle α at which lift is equal to 0 that is called as alpha lift equal to 0 $\alpha_{L=0}$ lift is difficult to keep track of this particular parameter because it is affected by the twist distribution and by the airfoil camber. So what we do is we define an absolute angle of attack we call it α_a. Such that α_a is defined as the geometry angle of attack

$$\alpha_a = \alpha - \alpha_{L=0}$$

So when lift equal to 0 then α_a = 0.

So for a typical aircraft the maximum angle of attack alpha max during takeoff is limited to 15 degrees or so because of the fact that if you take off at an angle more than that Or if you angle more than that then that tail is going to hit the ground. So keeping in mind the takeoff and landing considerations the angle of attack during these operating scenarios is limited to around 15 degrees. Therefore α_{amax} that is a maximum value of the absolute angle of attack will become

$$\alpha_{a,max} = \alpha_{max} - \alpha_{L=0}$$

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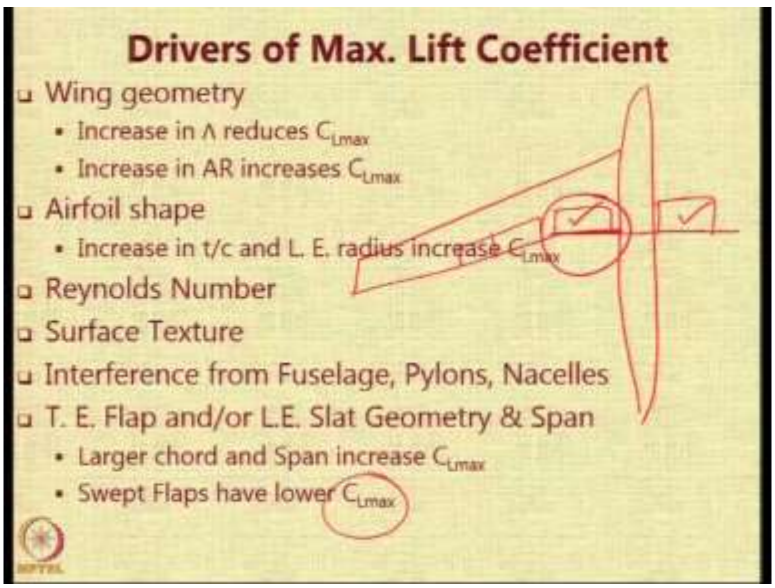

Now let us see how to estimate the C_{Lmax} value and before we do that we need to understand what are the drivers of the maximum lift coefficient? The first design driver is the wing geometry increase in the sweep reduces C_{LMax} and increase in the aspect ratio increases C_{Lmax}. Similarly aerofoil shape if you have increase in the thickness to chord ratio and if you have larger leading radius you will have a higher acceleration of the air over the aerofoil and therefore you will have higher C_{Lmax} values.

Reynolds number surface texture and the interference from fuselage nacelles and pylon are other factors trailing edge flaps and or leading edge flaps geometry and their span also affect the value of the C_{Lmax}. If you have a larger chord and a larger span obviously more part of the flap more part of the wing is flap and taking part in the high lift. So C_{Lmax} will be higher but if you sweep the flaps then you have lower values of C_{Lmax}.

This is one reason why in many transport aircraft you will see a typical configuration of the wing would be that you have the wing like this it will have a sweep but in the central portion you will have flaps which are going to be straight flaps and these tend to be the large chord flaps and then you have the smaller chord flaps which could also be in parts. So the reason why we go for this kind of a flap with trailing edge sweep 0 is because swept flaps have a lower C_{Lmax} value. So at least this flap and this portion of the flap the inboard flaps are going to have higher values of C_{Lmax}. Thanks for your attention. We will now move to the next section.