Introduction to Aircraft Design
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Lecture – 44
Estimation of maximum L/D

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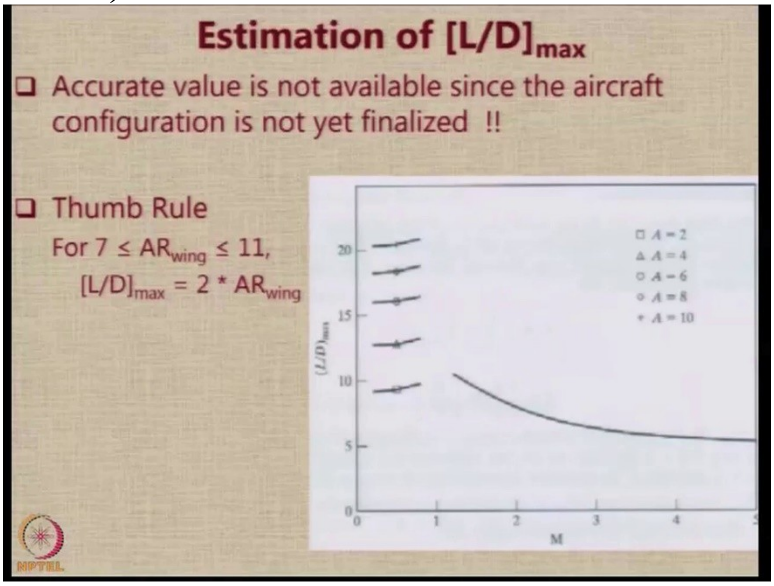

Let us see how we get an estimate for the maximum lift over drag ratio. Once again, we are going to mostly use historical data; Why? The reason is that we cannot do anything better because we are at a stage in design where we cannot get the accurate value of this parameter because we have not even finalized the configuration. All we know is the type of the aircraft that we are designing.

So, there are certain thumb rules available some guidelines available one simple guideline is as a function of the wing aspect ratio. So, for aircraft which have aspect ratio between 7 and 11 which is the typical value for you know many low speed transport aircraft, the regional turboprops etc, you can assume the $\left(\frac{L}{D}\right)_{max}$ to be twice the wing aspect ratio based on this particular graph. However, please note this is only a very crude estimate and maybe this is to be used as a starting value I do not recommend that we should use this value in the calculations.

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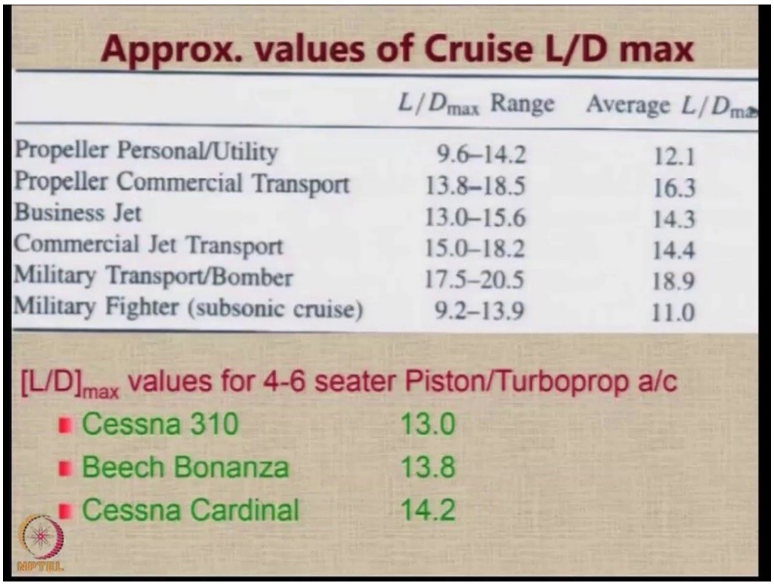

	L/D_{max} Range	Average L/D_{max}
Propeller Personal/Utility	9.6–14.2	12.1
Propeller Commercial Transport	13.8–18.5	16.3
Business Jet	13.0–15.6	14.3
Commercial Jet Transport	15.0–18.2	14.4
Military Transport/Bomber	17.5–20.5	18.9
Military Fighter (subsonic cruise)	9.2–13.9	11.0

This is just a very very basic value instead it will be better to go for picking up a value of the $\left(\frac{L}{D}\right)_{max}$ based on some historical data which is actually available. So, some average $\left(\frac{L}{D}\right)_{max}$ values are available for typical aircraft and for a few select aircraft, which are piston top turboprop type, you can see that the $\left(\frac{L}{D}\right)_{max}$ is of the order of 13 to 14, 14.2.

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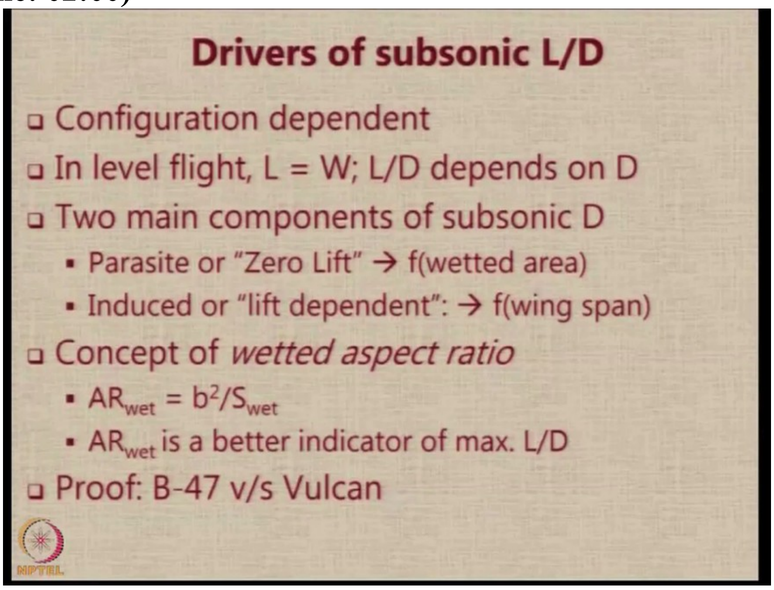

Let us understand what are the drivers of subsonic $\frac{L}{D}$? The subsonic value of $\frac{L}{D}$ is very strongly dependent upon the aircraft configuration. In level flight, we go for a condition that lift is equal to weight and hence, the $\frac{L}{D}$ will depend based mostly on the D because the L is almost constant. So, now, if you want to look at a look at $\frac{L}{D}$ you have to look at D very carefully.

Now, for subsonic aircraft, there are 2 main components of the drag or D. One is the parasite or Zero lift drag which is a function of the wetted area of the aircraft and the other is the induced or lift dependent drag, which is a function of the wingspan because it is a function of aspect ratio which is span square by area. So, if we want to get a handle on both these aspects, the span as well as the wetted area.

We should consider not just the aspect ratio, but the wetted aspect ratio. The wetted aspect ratio AR wet is defined as the square of the span divided by the wetted area of the aircraft. And the wetted area aspect ratio is a much better indicator of max $\frac{L}{D}$ as compared to just the proof of this lies in a comparison between Boeing B 47 and Vulcan aircraft.

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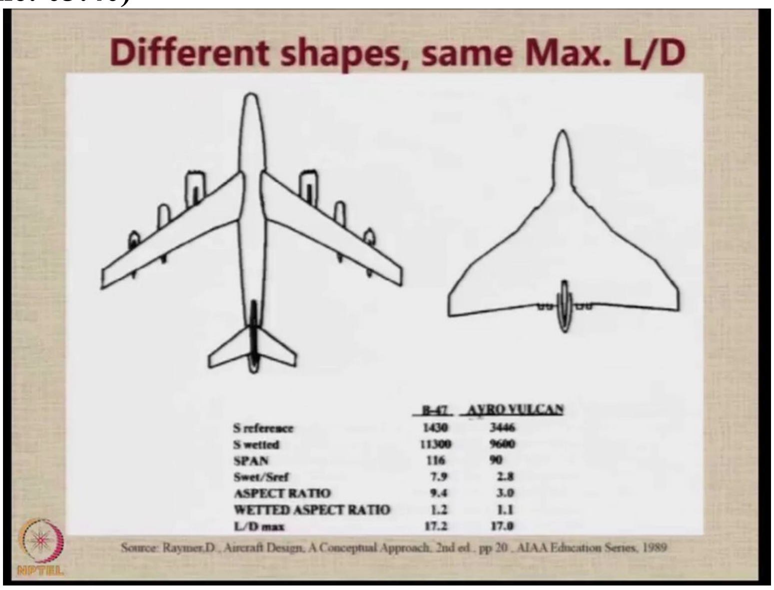

Raymer, in his textbook has given this example, it is a very nice example, which shows that you could have a totally different shape, but you may have the same value of maximum $\frac{L}{D}$. So, here we have 2 of these, these 2 aircraft on your left is the Boeing B 47 which is having a slender wing with large sweep back. And on the right we have a Vulcan which is all wings virtually all wing it is bordering to have actually blended wing body but there is no blending here because there is a distinct fuselage.

So, we noticed that the reference area of the wing in the case of B 47 is 1413 whereas it is 3446. This I am assuming is in square feet because this data is from Raymer textbook. The wetted the wetted area is much larger for this aircraft because there are slender very very slender wings and also there are this fuselage and tail surfaces, the span is not very different 116 versus 90.

So therefore, $\frac{S_{wet}}{S_{ref}}$ will be approximately 8 for B 47. And approximately 3 because Vulcan is mainly wing only. So, you have the wetted area, basically, the S_{ref} is going to be the projected area of the wing. And the S ref is going to be the S_{wet} is going to be the area of the top surface of the wing bottom of the wing. And of course, the other things, the aspect ratio of this aircraft is 9.4, whereas that for the Vulcan is 3, but the wetted aspect ratio for both the aircraft is almost the same.

And hence, the $\left(\frac{L}{D}\right)_{max}$ for both the aircraft is also almost the same. So, this particular example shows that if the wetted aspect ratio of if the velocity ratio of 2 aircraft is similar, we can expect them to have the same or similar $\left(\frac{L}{D}\right)_{max}$ values.

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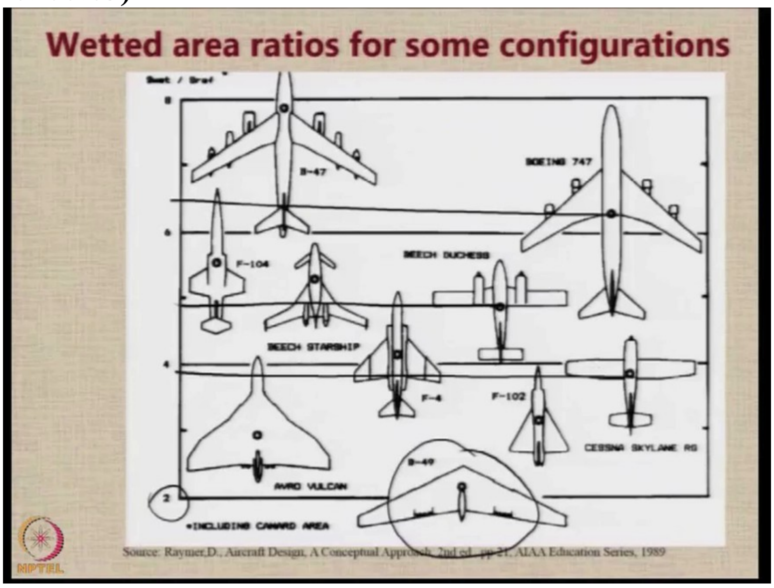

So, Raymer has given a very simple procedure for getting a quick estimate of the $\left(\frac{L}{D}\right)_{max}$ of the aircraft that you are designing. Raymer says that, although you do not have the configuration designed, you still have some idea about the baseline aircraft that you are going to probably use in your calculations you also have a rough idea of how roughly your aircraft will look like. So, will it be like this? Or will it be almost a flying wing?

Will it be like F4 or will it be like Boeing 747. So, in this particular chart, what you do is, since you are geometrical calculations have not yet been completed, you can just eyeball the aircraft and use the typical configuration value. So, for each aircraft, there is a point and on this graph. So, for example, your aircraft is looking like this, you can assume that the $\frac{S_{wet}}{S_{ref}}$ value will be approximately 5.

On the other end, if you are looking at something like Cessna skyline, it will be 4 if you are looking at something like 747, it will be maybe 6.25. So, like that, and if it is a flying wing like B 49, it will be just twice the reference area. So, it will be nearly 2.

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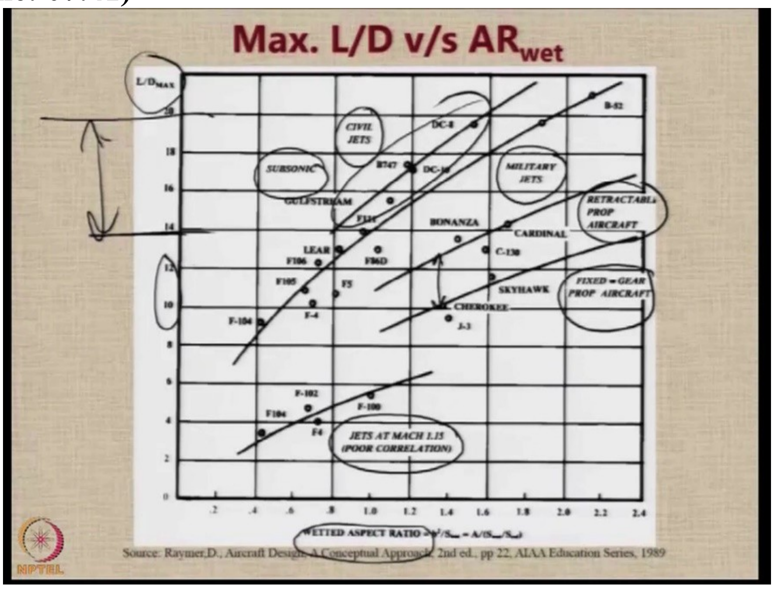

So, this way, you can use this particular chart to get a ratio of what is the typical expected value of $\frac{S_{wet}}{S_{ref}}$. And then there is another chart where the wetted aspect ratio on the x axis. This is the wetted aspect ratio that means span square by the wetted area, this is plotted and on the y axis you have the expected value of $\left(\frac{L}{D}\right)_{max}$ and there are lines for various aircraft types.

So, for example, you have one line for civil jets, you have one line for aircraft, which have a fixed landing gear, but they are propeller driven, you have another parallel line for retractable prop aircraft, indicating that the retractable prop aircraft normally have a higher $\left(\frac{L}{D}\right)_{max}$, the increase in the $\left(\frac{L}{D}\right)_{max}$ is approximately 2 as you can see, the gap between these 2 lines is approximately 2 you know approximately from 10 to 12 which means, the $\left(\frac{L}{D}\right)_{max}$ is going to increase by a numerical value of 2.

Similarly, there is one line for military jets, the other line for subsonic jets and high speed jets and then he says there is a poor correlation with the actual data. So, with whatever best information you have, you should be able to get the $\left(\frac{L}{D}\right)_{max}$ values and you should be able to use it. So, what we notice is that for most of the civil jets which are falling along here, the $\left(\frac{L}{D}\right)_{max}$ is between 14 to 20 that is the typical value of $\left(\frac{L}{D}\right)_{max}$ and for you know lower the lower values are applicable for aircraft with propeller driven aircraft and the fixed landing gear. The $\left(\frac{L}{D}\right)_{max}$ there tends to be from between around 10 to 12 or 14.

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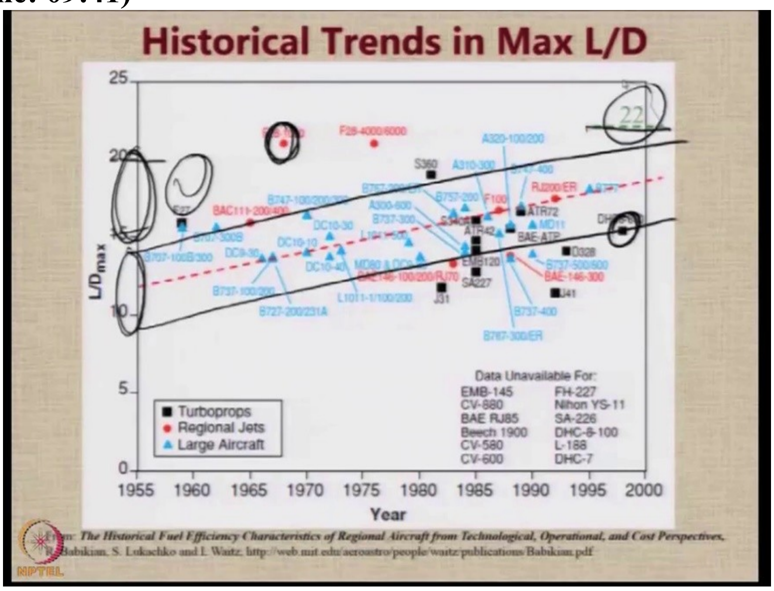

You can use other information also. For example, here is data taken from Babikian et al from MIT who have plotted the value of trends in the value of $\left(\frac{L}{D}\right)_{max}$ over the years from 1955 year 2000, and they use the color coding they use symbols like this for the turboprops symbols like this for the regional jets and for other the blue triangles are all the large aircraft. So, you can see there are some spreads also most of the aircraft are actually falling within this particular band.

In other words, the $\left(\frac{L}{D}\right)_{max}$ is probably going to be between around 10 to 15 and these trends are increasing and modern day aircraft have $\left(\frac{L}{D}\right)_{max}$ bordering between around 15 to 20. So, this is the kind of value and perhaps the limit would be around 22 that would be the max value that you can expect to be generated. But there are attempts being made to increase the $\left(\frac{L}{D}\right)_{max}$, Thanks for your attention, we will now move to the next section.