Introduction to Aircraft Design
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Lecture – 41
Estimation of Empty Weight Fraction

This is the first step in the initial sizing of the aircraft and unfortunately, we do not have much Leave way here, we have to rely almost completely on history here. Because as I mentioned, the aircraft has not yet been designed, the aircraft is not in front of you, only what you know is the type of the aircraft and hence you have to go purely by historical information.

But we have some help available from historical data. So, according to the procedure suggested by Raymer the Empty weight fraction

$\acute{w}_e = A W_0^C K_{VS}$

K_{VS} which stands for variable sweep.

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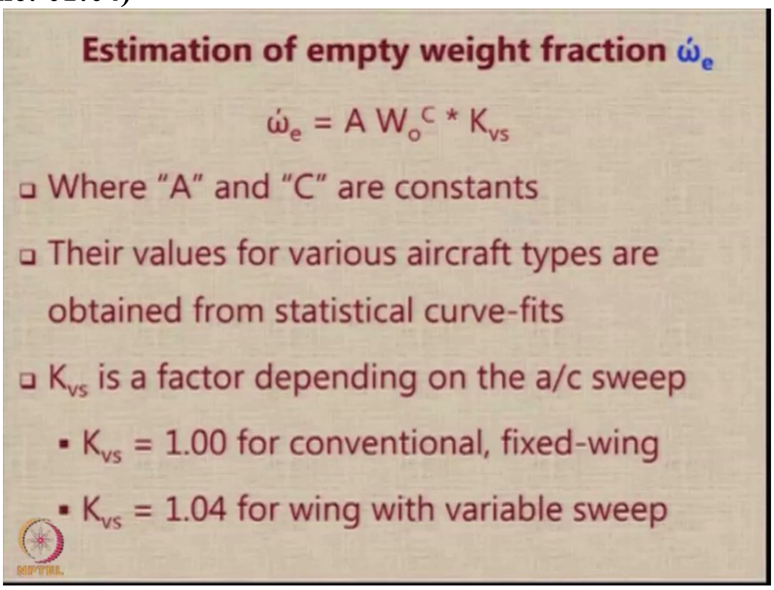

A and C are constants which are a function of a particular aircraft type, their values are obtained by a statistical fit of existing data $K_{VS}$is just a multiplication factor that tells us the effect of providing variable sweep. So, K_{VS}= 1.04 basically tells us that if you provide variable sweep in a aircraft, which you would probably never provide in the transport aircraft, then you have to have a weight penalty of 4% of the total weight.

And if you do not provide variable 3 which is most commonly true for transport aircraft, then you only have $A\,W_0^C$.

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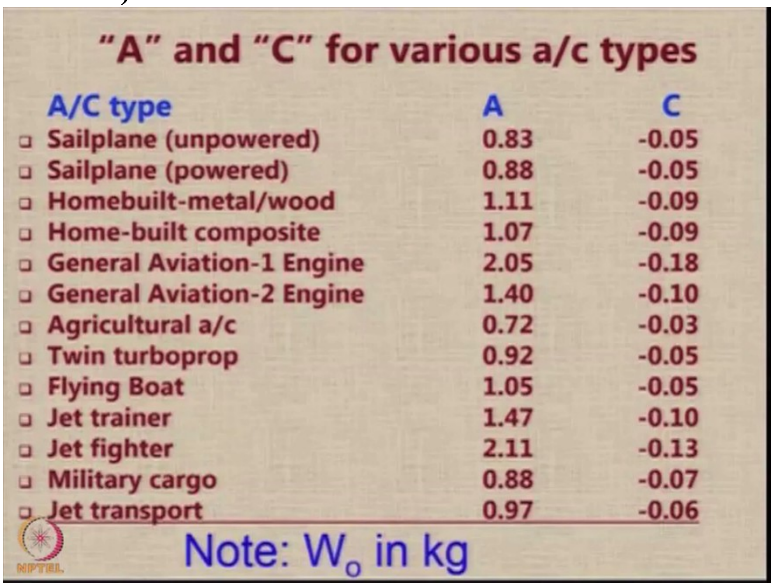

"A" and "C" for various a/c types

A/C type	A	C
Sailplane (unpowered)	0.83	-0.05
Sailplane (powered)	0.88	-0.05
Homebuilt-metal/wood	1.11	-0.09
Home-built composite	1.07	-0.09
General Aviation-1 Engine	2.05	-0.18
General Aviation-2 Engine	1.40	-0.10
Agricultural a/c	0.72	-0.03
Twin turboprop	0.92	-0.05
Flying Boat	1.05	-0.05
Jet trainer	1.47	-0.10
Jet fighter	2.11	-0.13
Military cargo	0.88	-0.07
Jet transport	0.97	-0.06

Note: W_o in kg

The values of A and C for various aircraft types have been specified by Raymer in his textbook, so, he categorizes the aircraft type under these various categories. And for each of these categories, there are suggested values of the coefficients A and C to be used. Please note that these values are to be used when the gross weight is in kilograms. There is a separate set of values which are specified in the textbook when the gross weight is in pounds.

Now let us observe a few interesting things here. What we notice here is that the exponent C is always going to be a negative number for all the aircraft types. So, what does this tell us. This tells us that as W_0 increases for a given aircraft type for all aircraft, as W_0 increases, the empty weight fraction reduces. In other words, a smaller aircraft which weighs less will have a higher empty weight fraction, a larger aircraft which weighs a lot.

Will have a larger empty weight, but it will have a smaller empty weight fraction. The coefficient A is the one that tells you about the sensitivity of the gross weight to the increase in the size.

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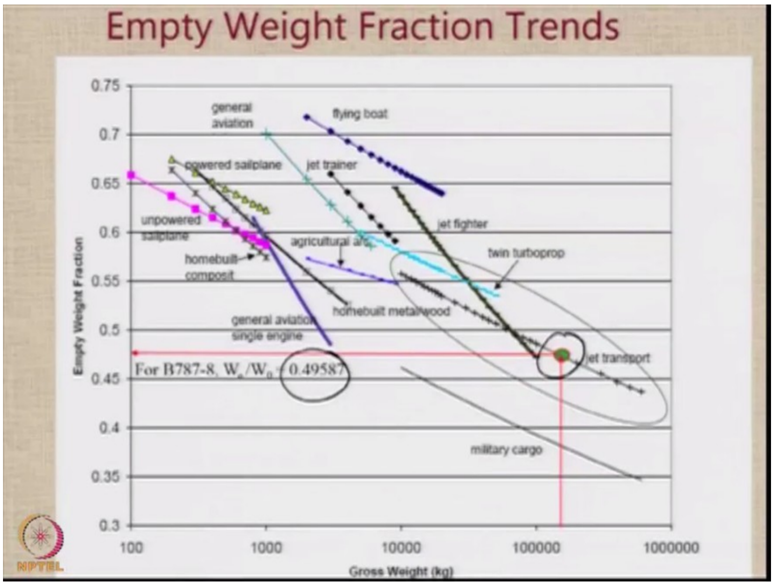

So, let us see this information in a graphical fashion. So, what we notice here is that the jet transport aircraft follow this particular line. Now, I want to put in a word of caution here. In this particular graph, you are seeing the figures where there are these symbols attached to each of the lines. And you may assume that these symbols correspond to actual points. But that is not true.

These symbols are just given to allow you to distinguish between the various types of aircraft because there are so many lines here. So, and we could not even use so many colors. So, we have just included a bunch of symbols, so please ignore the symbols, but use them only as an indicator. So, a jet transport aircraft typically has an empty weight fraction, which can be starting from approximately 0.55 or 55%.

And it can go as low as around 44%. This is only based on historical data. What do we see here, we see here that the flying boats have the highest empty weight fraction, never below around 0.64 and generally as high as 0.71, 072. And the military cargo aircraft, they have the least empty weight fraction, which can be as low as 35%, when they tend to be very large. Another point to be observed is that this graph has a logarithmic scale on the x axis.

It is not a linear scale, there in mind, it is a logarithmic scale. And the y axis, of course, is just a linear scale. So, on a linear log plot, the trend lines appear to be linear. And we can use them to get an idea about what would be the expected empty weight. So how do we use this graph, let us say you are designing and a jet fighter aircraft and these jet fighter aircraft, gross weight of this aircraft is expected to be some number, let us say 10000 kilograms.

Then it is empty weight fraction is likely to be around 0.65 by looking at this particular. So, what you do is you come up on the line and then go on the x axis and read the number this is how you use this particular graph. But in our case, unfortunately, we do not have an estimate of gross weight. On the other hand, we are actually going to estimate the gross weight. And we need to know the empty weight fraction.

But empty weight fraction depends upon the gross weight. So therefore, we have to use this formula which was shown. This particular point shown in the graph this particular point corresponds to going 787 - 8, which has got an empty weight fraction of approximately 0.49. Remember I told you that many transport aircraft they have an empty weight fraction, roughly 50%, which is very much true for Boeing 787.

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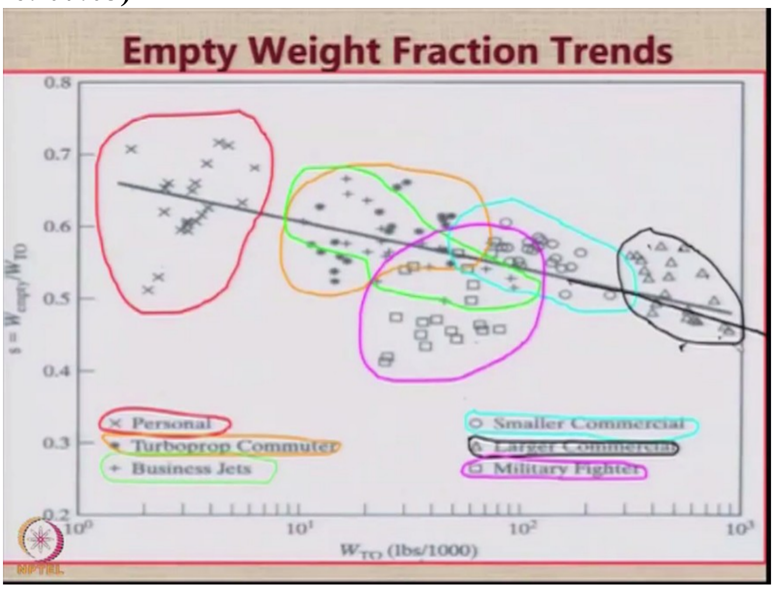

This graph taken from the book by Professor John fielding actually gives you better information about the spread. So, we notice here that the aircraft do not fall along a straight line. These lines are just such statistical inferences, you can see that there is a huge spread. Even if you look at one particular type of aircraft, let us say for example, we are looking at you know, we are looking at large commercial aircraft.

The large commercial aircraft again, this is a log linear graph, they do not follow a straight line is not that they are all on this line. They are above and below this line different manufacturers they have solutions that you get are not exactly along the straight line. So therefore, one has to keep in mind that there are bands and what we use in our estimate is only a number which has come from history. Thanks for your attention. We will now move to the next section.