Introduction to Aircraft Design
Prof. Rajkumar. S. Pant
Department of Aerospace Engineering
Indian Institute of Technology, Bombay

Lecture - 59
Constraint Analysis- Introductory Remarks

A very important aspect of conceptual design is constraint analysis. And in this particular presentation, we look at how this procedure can be carried out for us civil transport aircraft.

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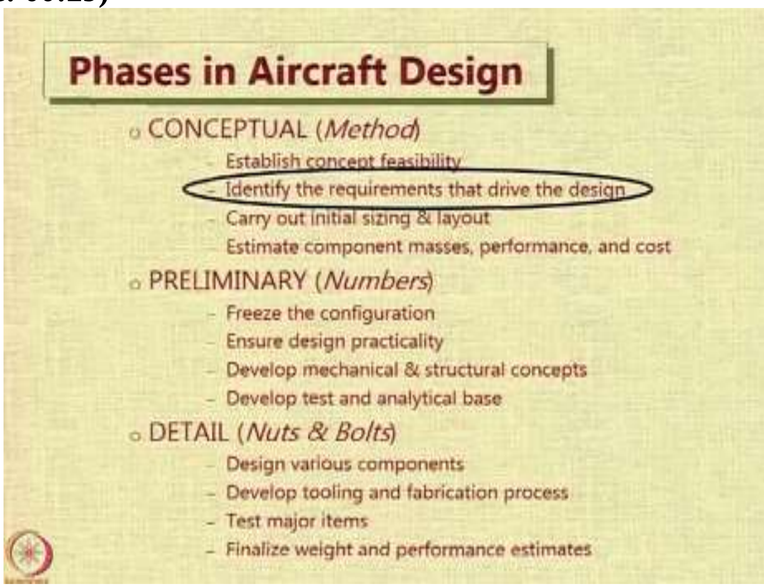

Just a recap about its importance: We saw earlier that there are 3 phases in an aircraft design and one of the key tasks to be done in the conceptual design is to identify the requirements that drive the design. This particular task is carried out using what is called as the constraint analysis.

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So, typically, the constraints which are imposed on the transport aircraft could be driven by the customer requirements such as what is the design Mach number and what is the maximum cruise Mach number, what is the climb rate when you operate at specific altitude say climb rate at sea level or climb rate at 1 kilometer altitude, what would be the stalling speed permitted at takeoff and landing.

For example, there could be constraints on balance field length; there could be a constraint on the FAR 25 takeoff and landing distances, a constraint on ceiling. Apart from this, there are requirements which are specified by the airworthiness agencies essentially for safety. So, 2 main requirements which are applicable for transport aircraft are the second stage climb gradient and the missed approach gradient.

So, while the terms which are given by the customer are quite well known and people hear about them, the 2 airworthiness requirements are not very well known or very apparent. So, we will spend some time understanding what they are and defining what they are.

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Raymer has suggested that in aircraft design there are these big 6 parameters, which if you can get the value of these parameters, then you have actually got the handle on the aircraft. Of these, few are wing related, the thickness to chord ratio, the taper ratio, the sweep, the aspect ratio and two of them are aircraft related which are the wing loading and the thrust loading or power loading depending on whether you are using jet engine or a turbo fan turbo jet engine or a power driven engine or that means piston prop or turboprop engine.

So, the thickness to chord ratio, the taper ratio, the sweep and the aspect ratio are basically related to the aircraft configuration and we have already had a look at some of the considerations through which these are decided. But, the constraint analysis tries to arrive at the right value of these two aircraft related parameters the wing loading and the thrust loading or the wing loading and the power loading.

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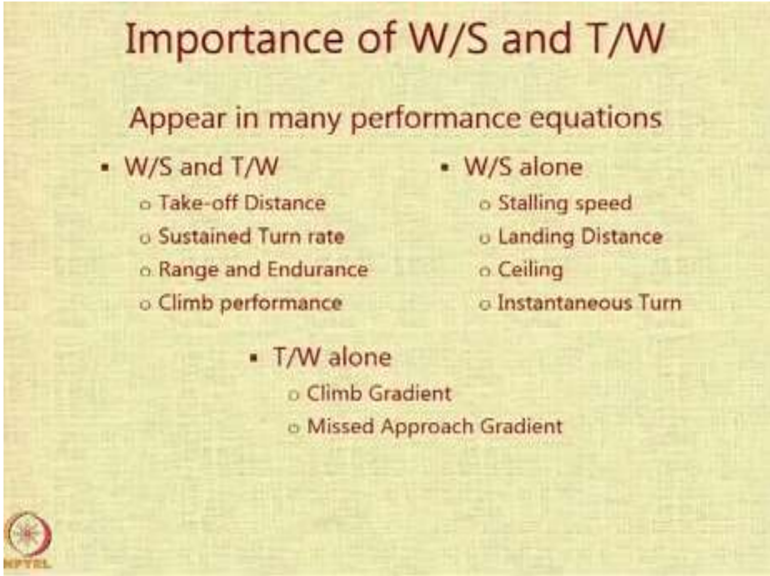

So, let us understand what they are and why are they important. So, wing loading and thrust loading affect certain performance parameters such as takeoff distance, sustained turn rate, range, endurance and they affect the climb performance. So, in the performance equations related to these 4 or 5 performance parameters T/W and W/S appear together. There are some performance equations in which only the W/S occurs such as stalling speed, landing distance, ceiling and instantaneous turn.

And, there are also two requirements in which the wing loading does not have any role but just a thrust loading has a role. These are the climb gradient and the mist approach gradient.

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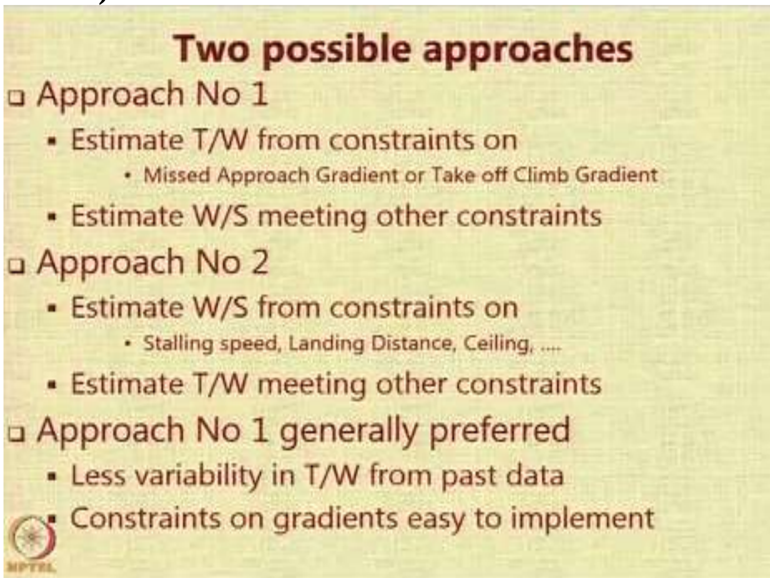

So, based on the information that we have just seen, there are two possible approaches. 1 approach would be that since thrust to weight ratio depends only on missed approach gradient and take off climb gradient. So, therefore, what you do is, you estimate the thrust to weight ratio from these two considerations or you estimate the minimum thrust to weight ratio required to meet these two requirements.

And then you find out the corresponding value of W/S or Wing loading that you need to meet the other constraints. So, that means, approach number 1 is fixing T/W first and getting the W/S later. Approach number 2 is that since there are some parameters like stalling speed, landing distance ceiling and instantaneous turn rate that depend only on W/S and not by T/W, why not fix the W/S from those considerations and get the value that is permit minimum value.

So, why not calculate the highest value of wing loading from these constraints and then find the corresponding T/W value that meets the other constraints. So, there are 2 possible approaches and any approach can be used to do the constraint analysis. However, approach number 1 that is fixing the thrust to weight ratio first is generally preferred. One reason for that is that, if you look at the past data, the variability in the value of thrust to weight ratio for a particular aircraft type is lower.

In other words, most aircraft that belong to a particular type have the thrust to weight ratios within a small band. And secondly, the constraints on missed approach gradient and take off from invariant are very easy to implement as compared to the other constraints as we will see very soon. Thanks for your attention. We will now move to the next section.