Aircraft Design

Prof. A.K Ghosh
Department of Aerospace Engineering
Indian Institute of Technology, Kanpur

Lecture – 16
Wing Design: Aspect Ratio

Dear friends. Let me continue from last lecture. And you must be observing that after getting an idea how to get initial gross weight, managing the mission requirements. You have being spending lot of time on wing aero foil, aero foil characteristic, shape of aero foil. And whenever talking about shape of an aero foil we are talking about what is the point where the airfoil locally can have Mach one because we were interested to know what is critical Mach number.

We also try to understand how the stalling angle of an aero foil gets affected, because of it is shape. We also realized location of maximum Kimball plays an important role in C L max. We have also see the how nose radius plays an role to whatever significant level for C L max. And somewhere when you are discussing about cambered aero foil. We are happy that cambered aero foil is required for raising the C L max, but we have noticed as I increase the Kimball there is a Cmac moment, non dimensional which is negative in sign; that means, to generate a nose down moment. And we only mentioned that when you are trying to design, an aircraft yes Kimball will increase C L max, but you have to handle the Cmac negative as well to balance that airplane.

If we recall stability and control courses, you will immediately catch why I am talking about Cmac negative to be handled. In any case when will be progressing towards configuration design. We will have explicit revision and try to synthesize this understanding. You get at one point of time we need C L max to be higher, that is very about Kimball, but you should also understand Cmac negative will be there and the penalty when it to handle those things the from aero foil will graduate it to wing, and immediately terms like aspect ratio came. And we have seen aspect ratio plays very important role a lot of time, we have spent on aspect ratio.

Today I will also touch upon aspect ratio few things, please understand this design course is not telling you 1 plus 1 is 2, the design course the greatest challenge is how to make 1 plus 1 equal to what you want. Sometime 1 plus 1 you may require 0.5, sometime 1 plus

1 you want 2.5 in a symbolic manner. That is how to synergize is the advantage is and how to minimize that disadvantages that is the beauty of a design right.

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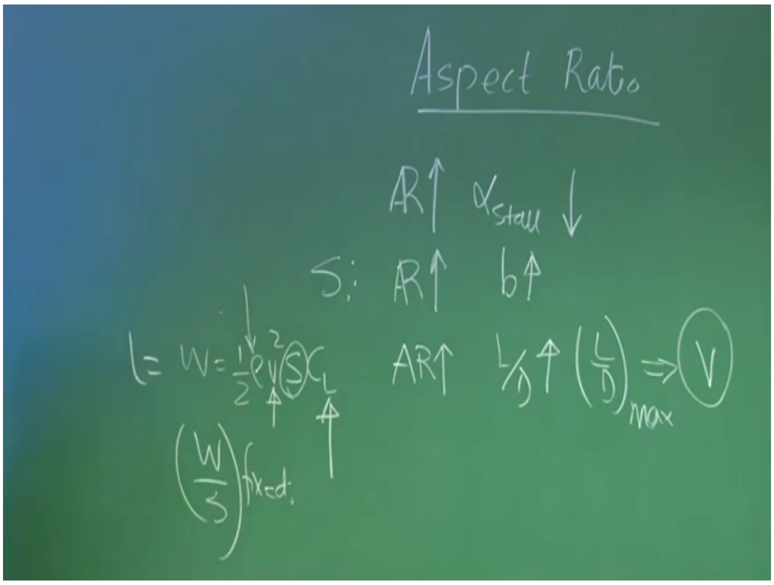

So, it is very important that we understand fundamentally few parameters, because we need to use them for configuring an aircraft. If I go for aspect ratio, which we have seen if aspect ratio increase, alpha stall reduces. Because self downwash is reduced right. Similarly for a given S, if S is fixed for given S is aspect the ratio increase what we are meaning is actually span is increasing. If I increase aspect ratio generally we will find L by D will increase. At the same time, we understand that for each aspect ratio to get L by D max. It corresponds to a particular velocity or speed, if you have to maintain lift equal to weight to weight we know that right.

The other interesting observation useful observation you must have through spend we are talking about aspect ratio you see here carefully we have said for a given S, if I increase aspect ratio span increases right. Let me exactly I am telling you the decision, what S I need to have is not dependent on primarily or aspect ratio, is depending on something else. For example, if lift equal to weight to weight then I know this will go to half rho V square S into C L. If I have a design limitation to have a C L particular number, if I decide particular I will (Refer Time: 06:25) flying if I decide the (Refer Time: 06:29) speed then S is fixed this is one way of perceiving it.

Another way or design perception is we say W by S is fixed for the particular mission. So, it is see shown that S is fixed for other criteria primarily, here the genesis is here right. After all area will decide how much lift will be there, but then we also know if this is the area is required for lift if the rho and speed everything is same, that if I have same area like this moving and one same area like this moving you know my intuitively that this man is what we are looking for. So, there we try to talk about aspect ratio right.

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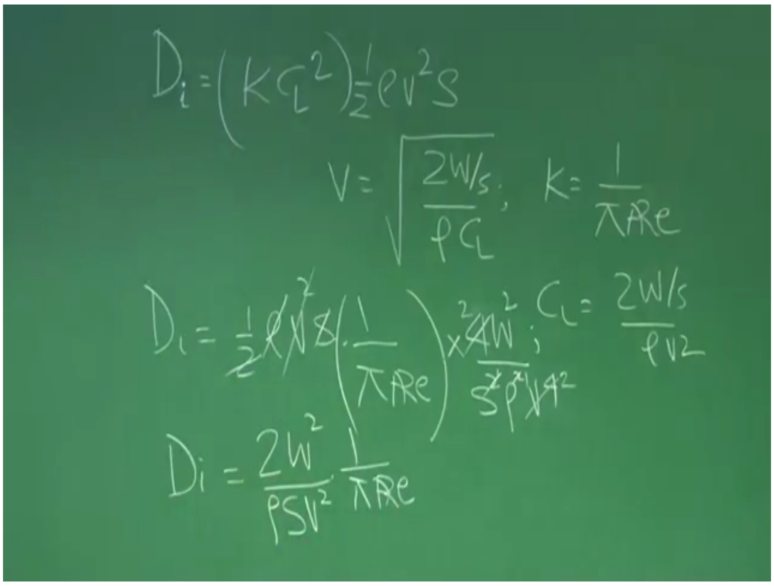

And if you see now the induced drag which is for low subsonic, I write like K C L square into half rho V square S the half rho V square S, into C V I this is the induced drag that for a level flight V is nothing, but under root 2 W by S rho C L. And if I see now the expression for induced drag this will be half rho V square S for K, I will write 1 by pi aspects ratio e. So, into 1 by pi aspect ratio e this is the K part half rho V square S into K in the C L squared. So, what will be C L C L will be 2 double y S rho V square. So, I write it here C L square means 4, W square x square rho square V to the power 4. This is the induced drag.

Now, see, I could easily reduce this power, S V square it is V 2 4 and summer here 2. So, 2. So, you get Di is equal to 2 W square by rho S V square into 1 by pi aspect ratio into e.

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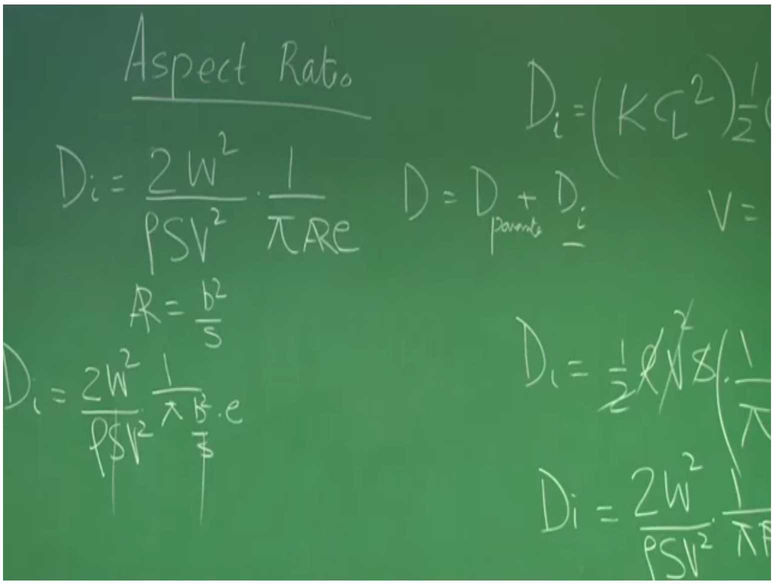

So, this Di induced drug is 2 W square by rho S V square into 1 by pi aspect ratio e. And what is aspect ratio, defined this as span square by S. So, then Di becomes 2 W square rho S V square, 1 by pi b square by S into e or this S, S it is canceled.

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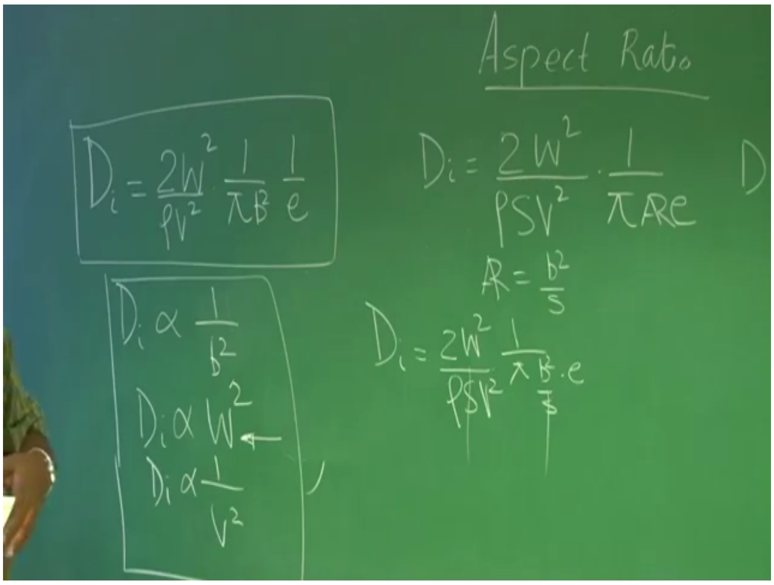

So, I have expression for Di as 2 W square rho V square 1 by pi b square to 1 by e right. Watch this expression carefully while we are addressing this induced drug. Because drag has drag because of shape and the velocity regime which called parasite. Parasite plus drag induced. If we can somehow reduce the induced drag, which is induced because of lift then I can improve the lift to drag ratio right.

So, what this expression is telling me is telling me the induced drag rhos 1 by b square. So, for a given S, if I go on increasing the b induced drag component will reduce that is a design understanding of aspect ratio and area relationship. What is the another observation the Di is professional to W square. So, the weight is more your induced drag will be also more. Please see this expression. Naturally because weight is more we require more C L and this also says Di is proportional to 1 by V square.

So, as the speed is increased, induced drag will reduce understanding is very simple airplane performance one, you have seen to maintain level flight the speed is higher, then C L requirement will be less and induced drag is proportional to C L square. So, when we are talking about discussing about weight, we should also be very C L ear that if unnecessarily we are increasing the weight, we are definitely going to pay penalty in terms of induced drag. And hence your lift to drag ratio for their pay in may it suffer right. So, this is another way of looking into aspect ratio. What we have done we have said aspect ratio, I am visualizing as if any I same I am not changing the aspect ratio means, I am changing this span it is well understood if you go on increasing the span it will create structural issues. You have to be careful it should not hang like this there could be a problem of for your land airplane, will do like this slide banking may the tail may hit the ground this is common phenomena for large span gliders. That is why the gliders will find will have large span gliders will have a tail wheel here as well. So, they take the load.

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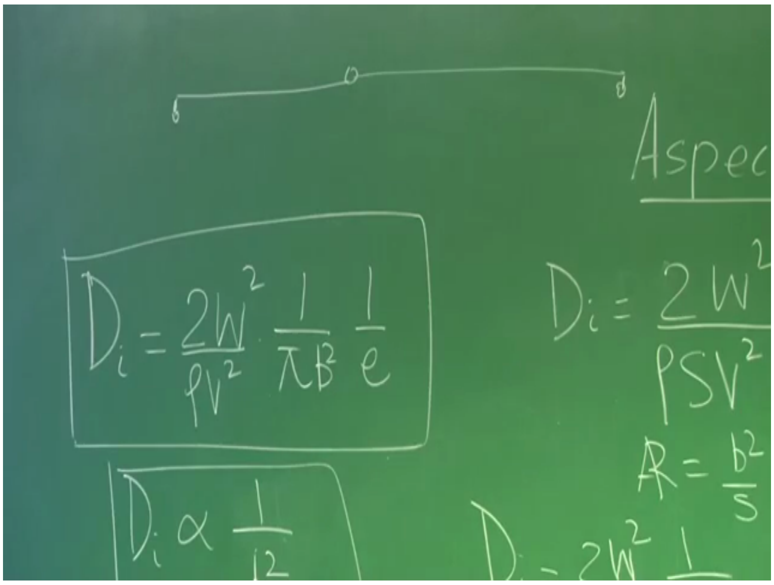

So, whenever the damage they replace that saying that finally, we want to design we want number to start with a guideline number is.

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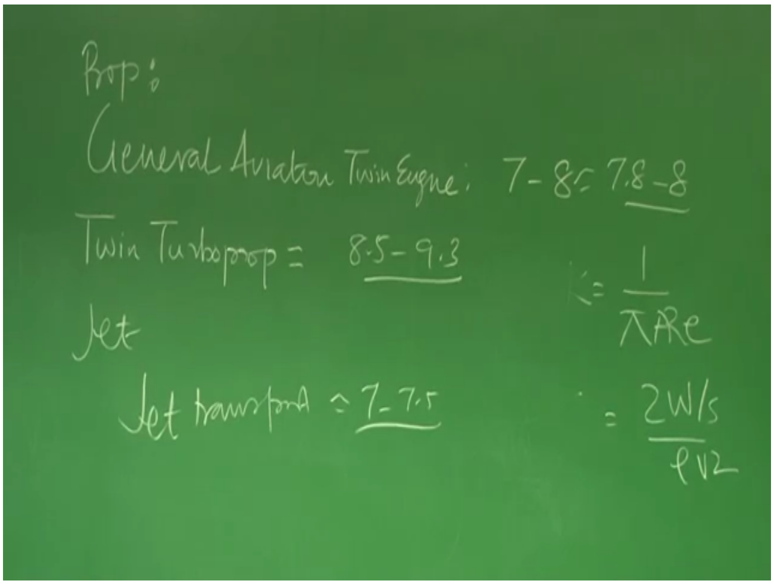

If you are talking about general aviation gets a twin engine, aspect ratio around 7 to 8 is good. In fact, I will say little higher 7.8 to 8 this the range right. Single engine little less, but same order to start with twin turboprop. This number will be around 8.5 to 9.3, around this range, which is historically available these are all the guidelines when you try to conceptualize initial configuration right. For jet of course, these are popular driven you understood this for a jet.

Typical jet transport I will prefer around 7 to 7.5 around this number aspects ratio will be there. And if you further increase the speed you will find the aspect ratio will go on reducing it called the 6 5.5 like that, but these are good enough number to start a configuration. Now todays youngsters they are not just happy with wing or a conventional tail, they do not like a diagram if I draw it like this.

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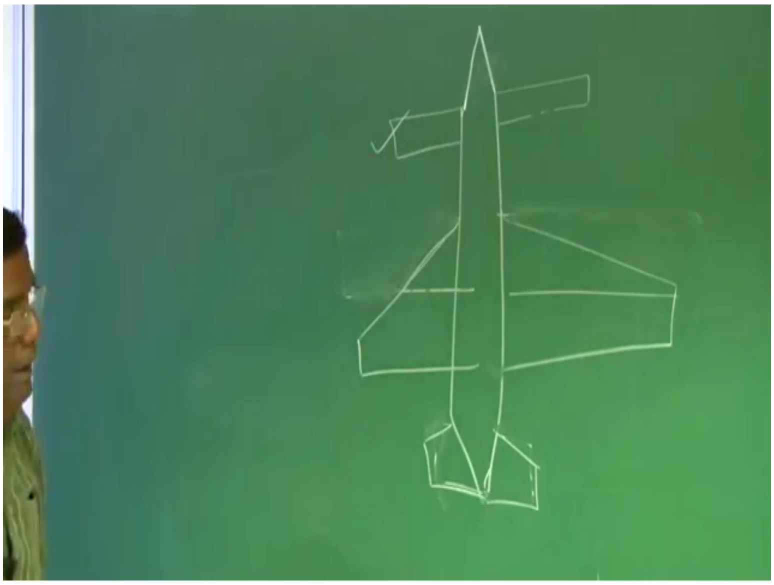

If I draw plane like this, they will say what is this. Why they do not like? They say why not something here they will prefer something like this they will prefer it should look like this. They will prefer here something like this. And here they will like what is the perception, perceptional difference between the earlier figure. And this figure the moment I draw like this this will speak about speed that is the high speed, and today the youth they do not want sluggish right they wants things to be fast.

So, although casually I have drawn these I thought we must touch upon these things before we go for next stage of our conceptual design. So, what is this top portion this is what this is scanner right.

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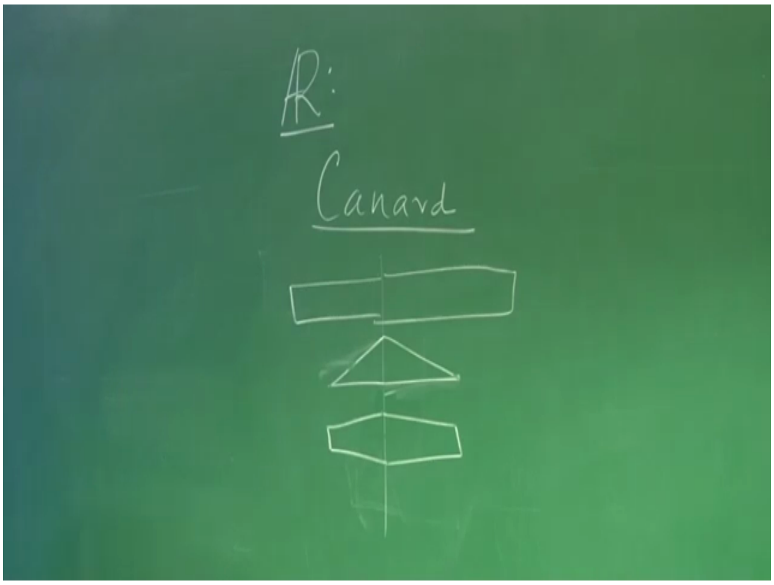

So, let us see, since we are talking aspect ratio I thought we talked about canard little bit. Canards are basically control surfaces, which are of different shape, we will find depending upon speed zone your flying, but concentrate on low speed airplane.

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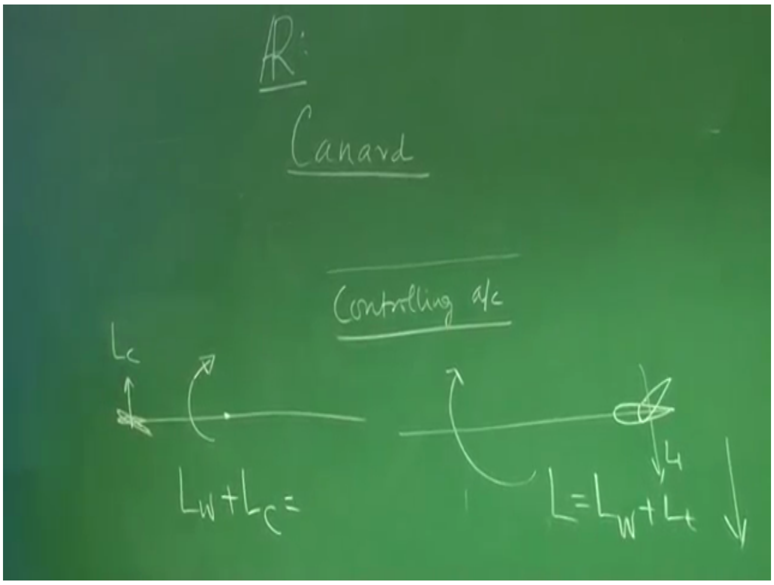

The low speed airplane and canard is used for control laying controlling that controlling the airplane, what is the difference between canard controlling an airplane and an (Refer Time: 17:50) controllitically airplane.

You know this, but let me also tell you if this is a f tail, if I want to give an nose of moment then I have to deflate this elevator up like this right. Which in turn means yes it will indeed give a nose of moment, but net lift which is lift on wings the lift on tail will reduce because lift on tail is acting downward, but same those of moment if I all to give through canard then I put a canard, here and now what I do I deflect it like this. If I deflect like this, it gives the force here or which gives you nose of moment. Now you see this lift on canard gets added with lift of wings. So, your total lift increases.

There are other issues with canard, but this is general first thought advantage, but now question comes what is the advantage if you have canard with higher aspect ratio because you are focused on aspect ratio.

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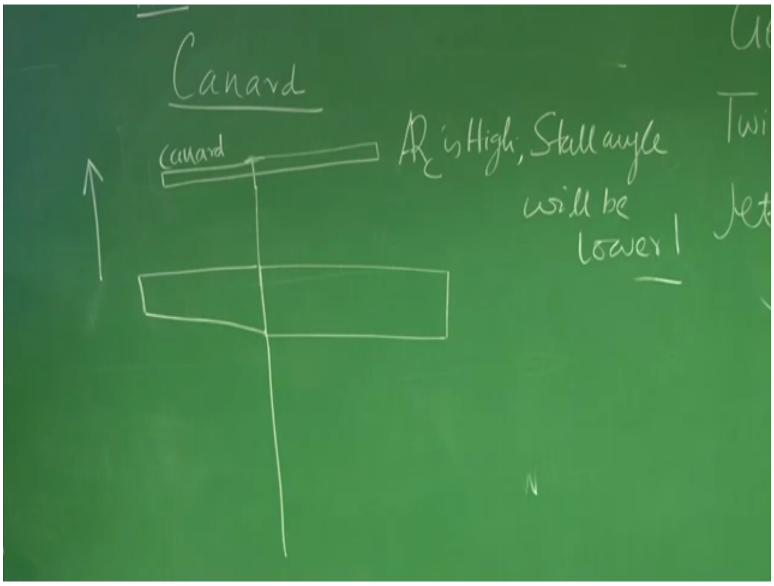

Imagine this is the wing. And you have put a canard here. I will flying whatever it is this is canard systematic right. If I put canard with high aspect ratio; that means, canard ARc canard is high. So, it is stall angle will be lower. So, think of if the airplane is approaching stall, then before the wing stall the canard will start giving signal of getting stall earlier than the wing stalls.

So, now the pilot can manage he gets an warning right, to generally for that reason canard may have high aspect ratio, purely from stall angle point of view somebody will tell me, why not and why unusually making canard high aspect ratio why can not to make a canard highly Kimball wing canard. Generally, we avoid Kimball etcetera in control surfaces, but nobody stops to us putting those if we know how to handle their consequences. And those are the thing we will be talking in terms of stability and control design at an appropriate time in this course.

Thank you very much.