Aircraft Design

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Lecture - 30
Revision

Good morning friends. We have been talking about T by W thrust loading and W by S wing loading. We have developed the background understanding. Today quickly we will summarize, because it is important to understand. There are many conflicting requirements, let us say for wing loading you will find wing loading requirements are different for different mission, then how do choose which wing loading I should give weightage.

So, I thought today in 25-30 minutes we will just summarize.

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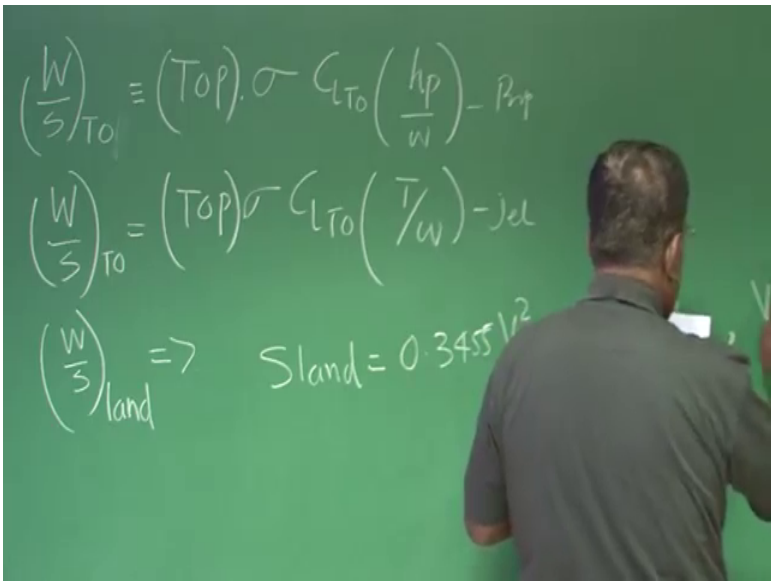

And let me write what we have done. For wing loading takeoff after having the understanding that when I am talking about wing loading takeoff. In takeoff the most important thing is how fast I achieve the V lift off or takeoff speed that gets connected to V stall, and when I say how fast these acceleration that again connects it is to T by W. All this things we have seen.

Then we also try to understand how to use statistical data based on some correlations some model data driven model. In that connection we found W by S takeoff initially from for conceptual stage I can use this formulation, this is call a popular driven this I C engine backup. And then W by S takeoff, this is takeoff equal to takeoff parameter into sigma into C L takeoff T by W for jet driven; if it easily see the correction of W by S and T by W.

Similarly we will talk we have discussed about W by S landing. And when I talk about W by S landing, we understand that when the aero plane takes off it has a full fuel, when is coming for landing some percentage of you we will be consumed depending upon what sort of mission it has got. So, the weight we will change the wing area remain same, so W by S landing will be different for many aircraft which are suppose to drop external stores. So, W by S reduces because primarily because the weight has reduced because we have rejected out or drop some stores.

For W by S landing we approach is like this and we followed let us say one regulation based on f a r 25 which roughly say is you take 3455 V A square. A and V and this regulation I will be taken as 1.3 times V stall.

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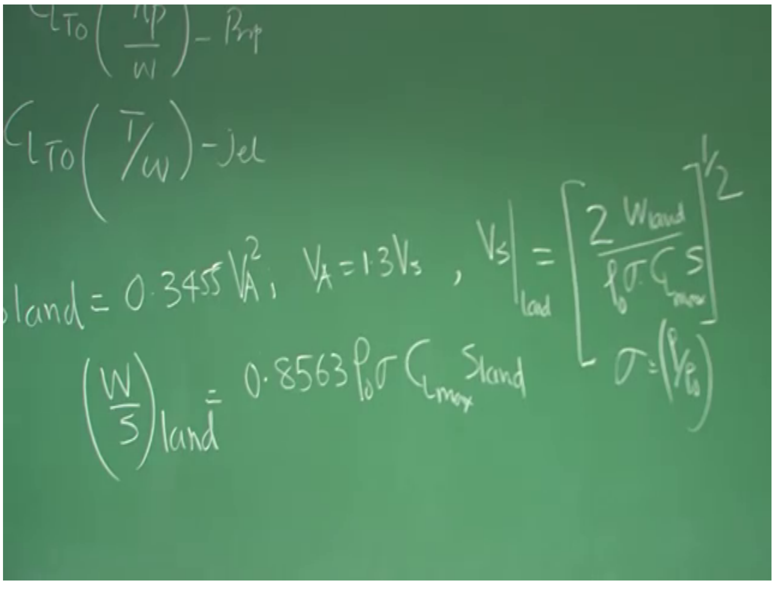

So, V S during landing configuration it is 2 W land is landing by rho naught into sigma into C L max to S to the power half; sigma is nothing but rho by rho naught where density at the altitude where you are landing and rho naught is C local density. And using this we have shown that W by S land is equal to 0.8563 rho naught sigma C L max into S land.

So, it clearly tells you what is the density of air ratio at the altitude varying on a land, what is the C L max value, and what is the length within which you want to make the aircraft stop, right.

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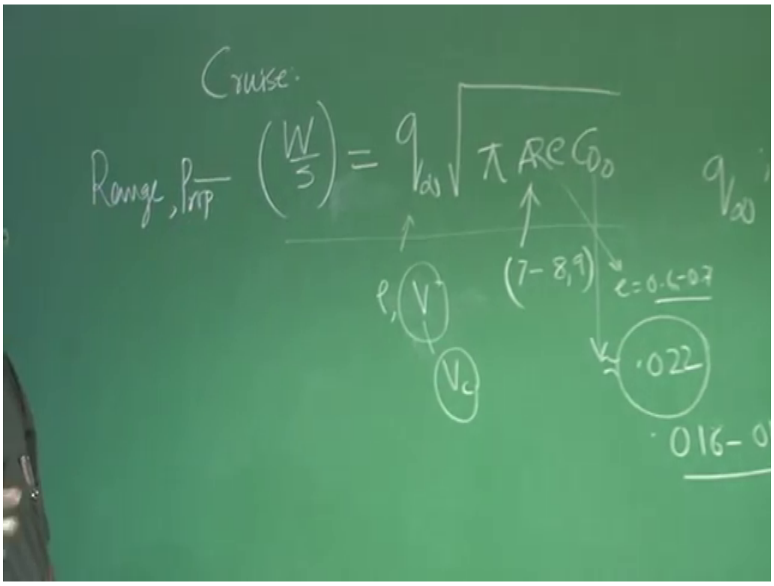

So, this is W by S landing this is W by S takeoff. After that we also have discussed about cruise where you have seen W by S cruise; or for cruise mission W by S is equal to q infinity under root pi aspect ratio e C D naught; this is for range maximum and of course we are acting for a propeller driven aircraft. So, this is W by cruise where you want to maximize the range for a popular driven aero plane. And if you want to calculate W by S I need to know what is the value of q infinity.

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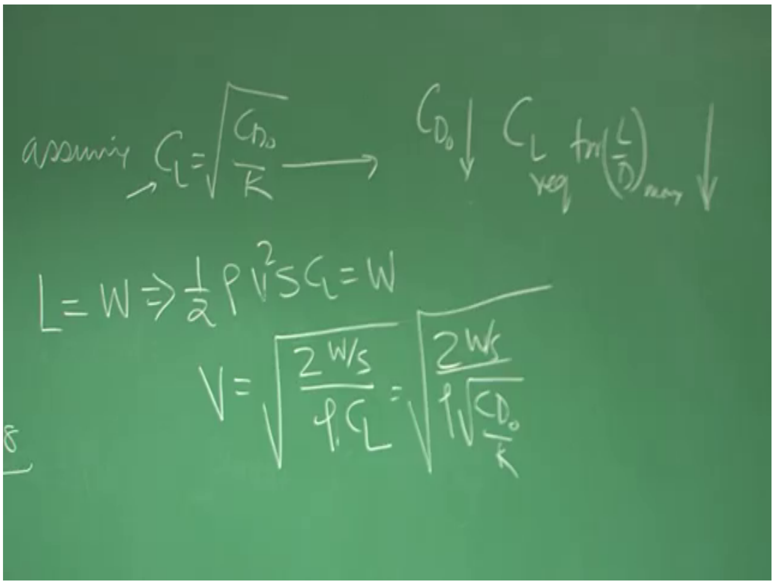

And please understand here this expression who has derived assuming C L is equal to under root C D naught by k, because we were we were maximizing range. For maximizing range for a popular driven aero plane C L by C D is to be maximum which tells me C L equal to C D naught by k.

So, if you are really flying with this C L; that means at that cruise lift should be equal to weight; that means half rho V square S C L is equal to weight. So, V should b equal to 2 W by S by rho C L, and the C L is 2 W by S of course; the C L is under root C D naught by k. The message is once I am trying to fly at a C L say C D naught by k, then if you want to maintain lift equal to weight for a given S and given weight, then V is also fixed, right. And generally you will find the V we will come little lower, but the operator may require for a pre specified V.

Theoretically you can have that pre specified V by flying at different-different altitude rho, but practical limitation is this altitudes are fixed by designers. When this tell please fly at this altitude varying then will be more sufficient or a air traffic control or we will tell this is the altitude it is available for you.

So, this sort of when conflict or decision making point come also think you are trying to conceptualizing a design and you want to know; what is the W by S. I should keep to maintain range best range at the stage you have fairly good idea about what is the aspect ratio and looking for may be 7 to 8 or 9. We have already done a preliminary estimation e it is better to take e as point six to point eight of point seven and typically C D naught initially what should I take were most of the existing aero plane you will find order is 0.0 to in this 2 2, 2 3, 2 5 around this, but if you want looking into high performance civil aero plane may be your dream liner bowing series. So, they have attempted of this sort of a number 6 to.

The important understanding is if you reduce C D naught right then the C L required C L required for L by D max also goes down. So, in this expression for a given aspect ratio if C L requirement goes down; that means, for the given aero aerofoil you are flying at a lower angle of attack if C L has reduced; that means, you can fly at a different-different higher speeds, but the same altitude right. So, that is way you try to satisfy both the speed as well as the range requirement right.

So, the whole design exercise goes on here how to reduce C D naught this is one of the advantages right same time you will see that if you go on reducing C D naught theoretically the phugoid mode may get unnecessarily more excited we will just keep on your note book underline it we will come back when we are talking about stability and handling requirement design for such aero planes. So, message is yes if I ask you a question, if you are having this expression at a conceptual stage whether you can get some value of W by S for a cruise for range maximum for a properly drew in aero plane can I have some idea or not. So, comes if I want to get W by S I need to know what is the dynamic pressure.

So, I need to know the altitude and what speed I am going to fly and then aspect ratio this value is you can take it is generally preferred that you will see your base line aircraft for the mission requirement for which you are by designing a conceptual aircraft look for another aircraft, which is closer to that and pick their speed close speed and try to iterate around that and put that speed at see what is the C L required here go back here and see for that C L what is a denote and k is required all this iteration we will go back and forth right.

Similarly, for jet W by S for cruise this we have derived and that comes to few infinity.

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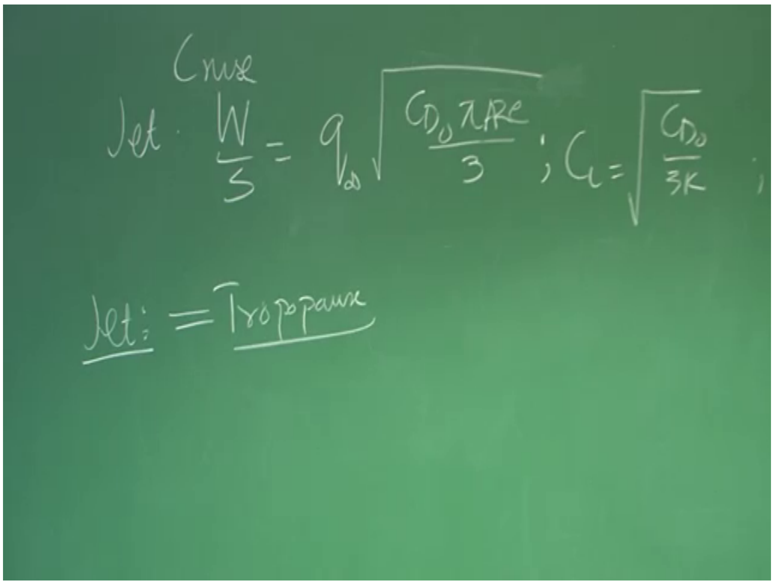

It is C D naught by aspect ratio e by 3 typically when you are talking about jet you would aspect that speed will be higher right and when I do this jet remain aircraft I am looking for a cruise based cruise I know that here C L is equal to under root C D naught by 3 k you can cross check from earlier nodes. So, again the story you same you pick a C D naught based on the historical data again it will be around 0.0 to 0 that aspect ratio may be 6 or 7 e I will always recommend you start between 0.6 at 0.7 and q infinity is what altitude typically for a larger aero plane if it is a jet driven engine the recommender engine recommender will recommend you fly in Tropopasue; what the temperature remains almost constant a specific thrust a specify consumption is most efficient.

So, if you have that altitude then you know how to use this expression again you have to take the help of some historical data to look for what sort of velocity the operator is looking for whether it is feasible or not right another important thing comes.

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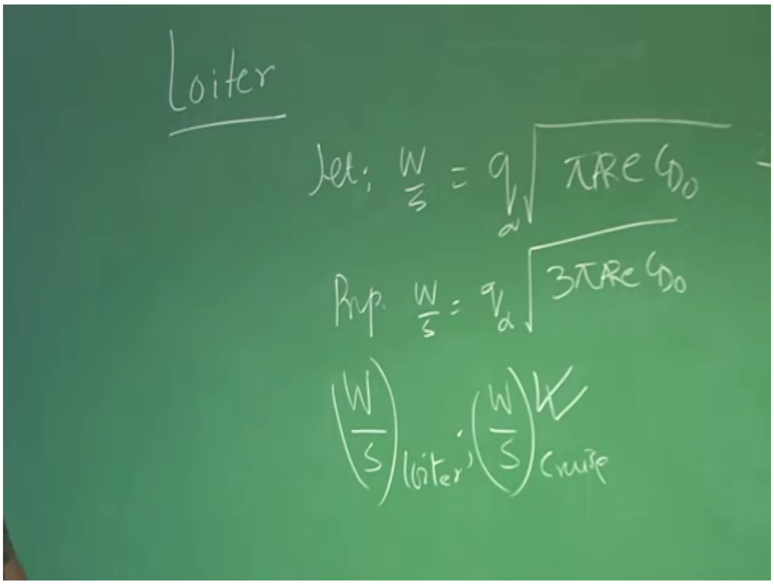

When you are frank to look for loiter, but please understand when you are designing a transport aero plane we give more weight is to the range rather loiter. So, indirectly I am telling you to wing loading; we will get more weightage during selection based on the range requirement right. So, for loiter you have seen for jet W by S equal to q pi aspect ratio p c g naught and for a propeller W by S equal to q infinity to 3 pi aspect ratio e C D naught.

Same argument goes how to select few infinity or C D naught, but if you are designing a transport aero plane you know that between W by S requirement for loiter and W by S requirement for cruise I will definitely give more weight is to W by S requirement for cruise because that is the main purpose of the aero plane. However if I am designing some surveillance or regards aircraft, I may give W by S loiter more importance then the range requirement right. So, this thing goes on changing based on what is the final aim another thing we talked about instantaneous turn rate.

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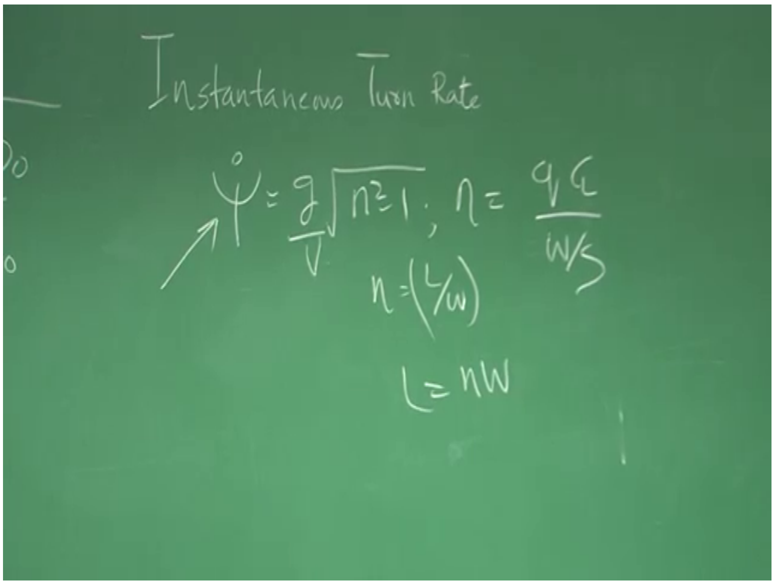

Where we have shown you know that of course, this psi naught is g by V under root n square minus 1, where n equal to q C L by W by S. So, depending upon what sort of instantaneous turn rate, you require at what dynamic pressure because we will related to turn rate for a different load factor all this grace club because you understand n is L by W.

So, depending upon; what is the n at; what speed you are looking for you can have psi naught and once you have and dynamic pressure and C L then you know; what is the wing loading? Using this equation to get C L you know that L equal to n W from their you can find out C L this is more important for fighter aero plane mostly in a dock fight mode fighter mode and we have realize that during is say ten years turn rate the drag we will increase. So, it is possibility why possibility you such a turn rate when you do you go maximum turn rate, but you lose the altitude right that may not be advantageous for your duck fight mode.

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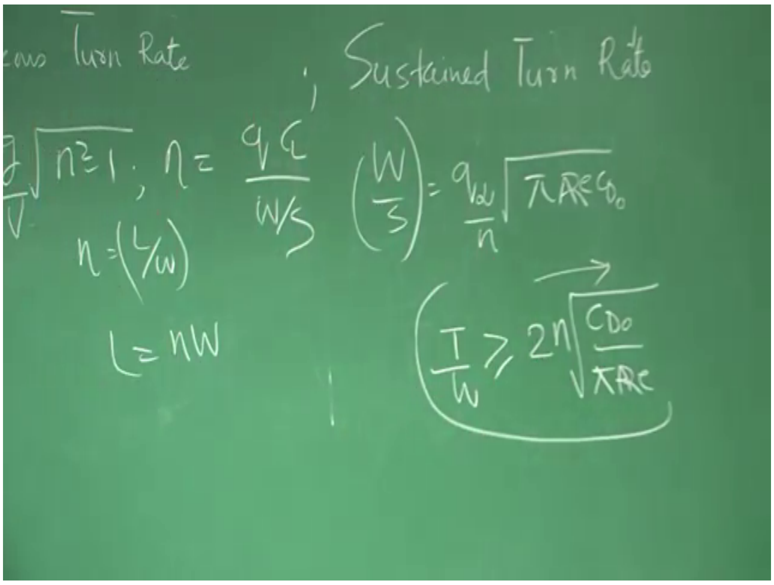

So, you talked about sustained turn rate and their we showed that W by S for a sustained turn rate is q infinity by n under root pi aspect ratio e C D naught there is a what of caution that W by S for sustained turn rate you may appear to very very low.

But one good point we got irrespective of whatever wing loading is required for sustained turn rate T by W should satisfy.

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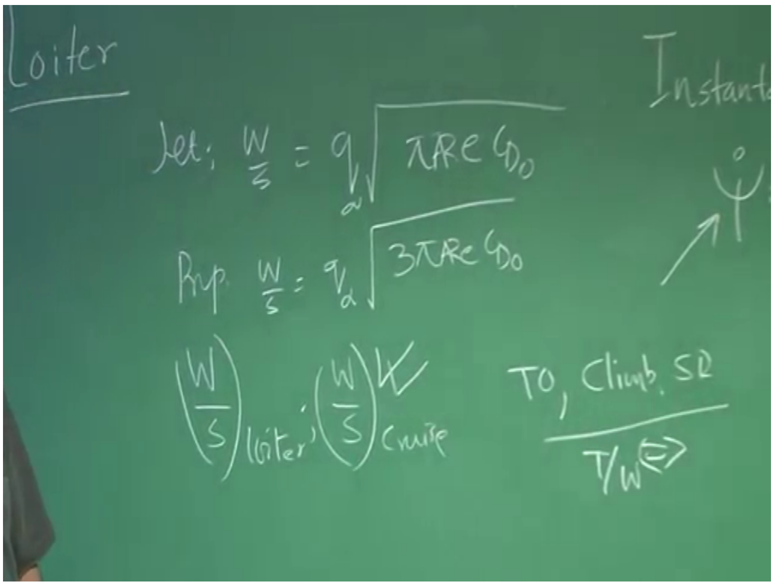

This condition; this is important and you could understand in takeoff in climb and you sustained turn rate it is indeed T by W we will play important role. So, when I select T by W I will give this as I write segment based on which I should look for T by W.

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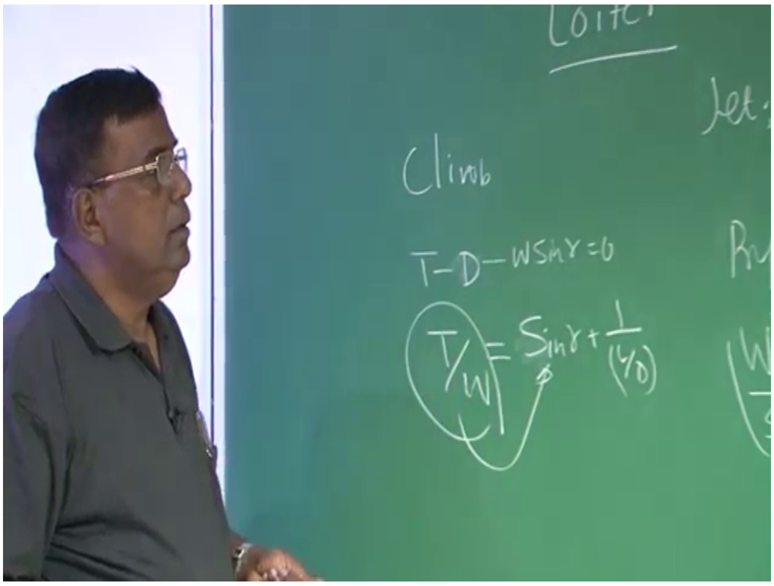

When I am saying climb you know that for climb T minus W minus or T minus drag minus W sin gamma will be equal to 0 if it is going for a 20 climb and this is sin gamma plus 1 by roughly L by D.

So, T by W requirement is dictated by what is the fly path angle or climb angle you are planning to climb and one by roughly L by d. So, for climb midding climb performance I will give more weightage to T by W right and for this I will give more to the W by S I thought I must also add something on balance feed length you know what is the balance feed length the requirement is very simple if I have a multi engine aero plane let us say 2 engines are there and its starts taking off from here.

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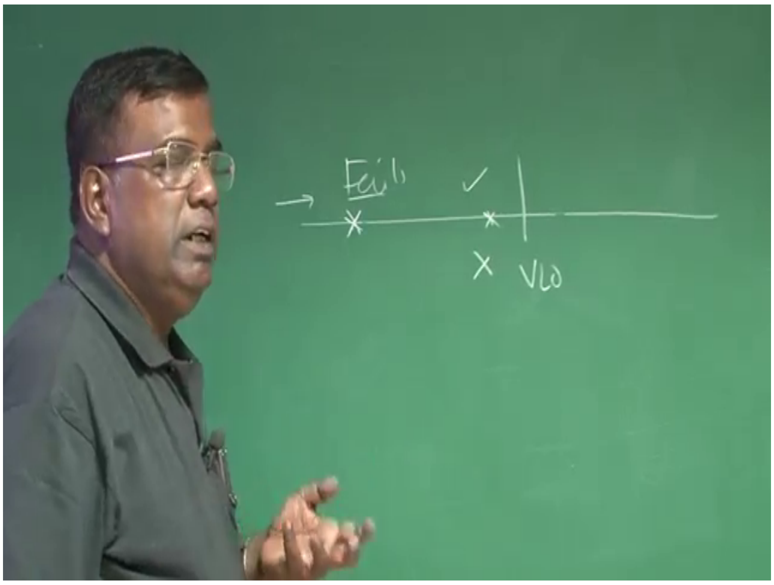

And this close by if one engine fails then the answer is obvious if at very early stage if it fails and then I can apply break, because I have go sufficient lengths to all the aero plane and let us say this is the V lift off and some where here it is failing.

So, now one engine is operative one engine is not operative now the question is if it fails very close to V lift off it is possible that I may not have sufficient length available to the apply break instead I should ensure that even after one engine has failed I should be able to do a prescribe rate of climb that may not be high as rate of climb with the 2 engine.

But fairly a good enough a rate of climb and then go for a circuit and then again land back right. So, then the question is what is that speed at which if the engine fails I should rather apply break or I continue take off with a lower rate of climb go for a circuit and come back the question is what is that speed. So, to address this question the regulation wise they something called balance feed length has been defined you see I have written here.

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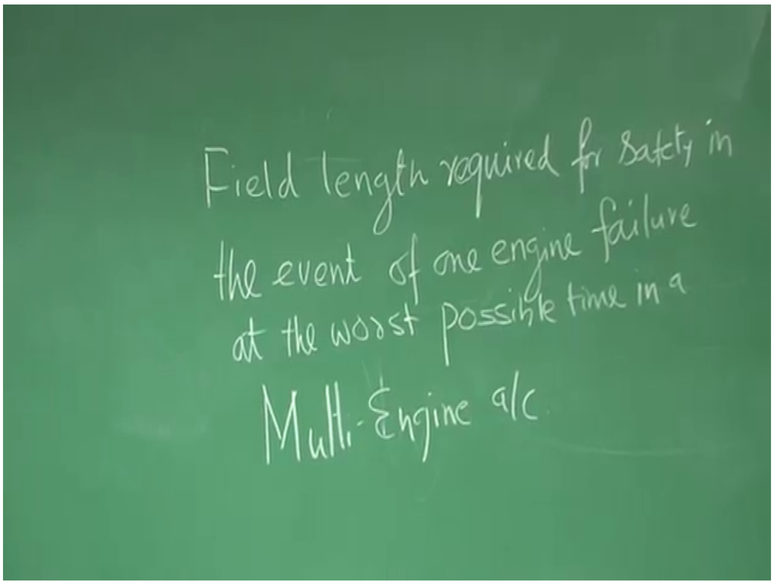

Field length required for safety in the event of one engine failure at the worst possible time what is the worst possible time worst possible time if it is fairly earning, it is not the worst possible time.

In mere V lift off it is failing that is the worst possible time right. So, that is called that is worst possible time in a multi engine aircraft. So, this balance field length or this philosophy you relevant for aircraft has been more than one engine right and this discussion we talked about decision a speed.

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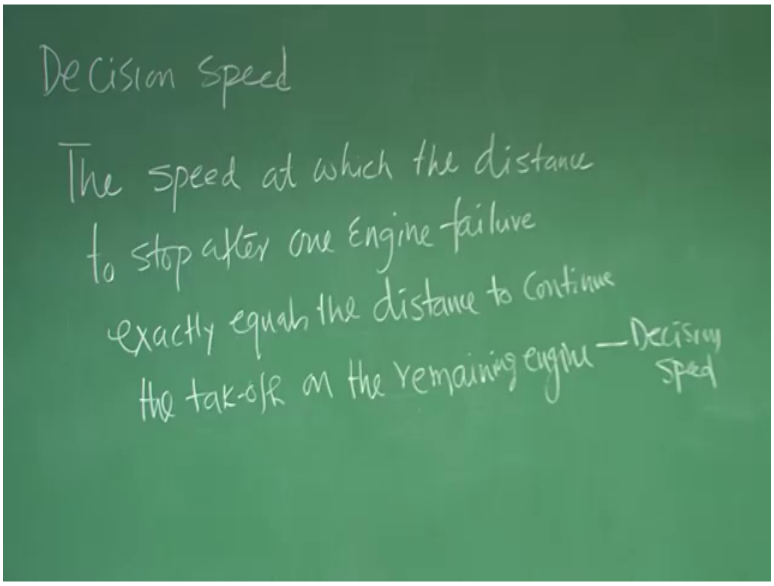

And let me write if these are very very strict definition which is approved by the regulatory body. So, either decision is speed the speed at which the distance to stop after one engine failure exactly equals the distance to continue the takeoff on the remaining engine which is decision speed.

So, what is the decision speed the speed at which the distance to stop after one engine failure exactly equal the distance to continue takeoff on the remaining engine right if I can identify what is the decision is speed then what I will do the pilot if the engine has failed below the decision is speed I will apply the break if it is more than that is the speed I should be able to takeoff right clear.

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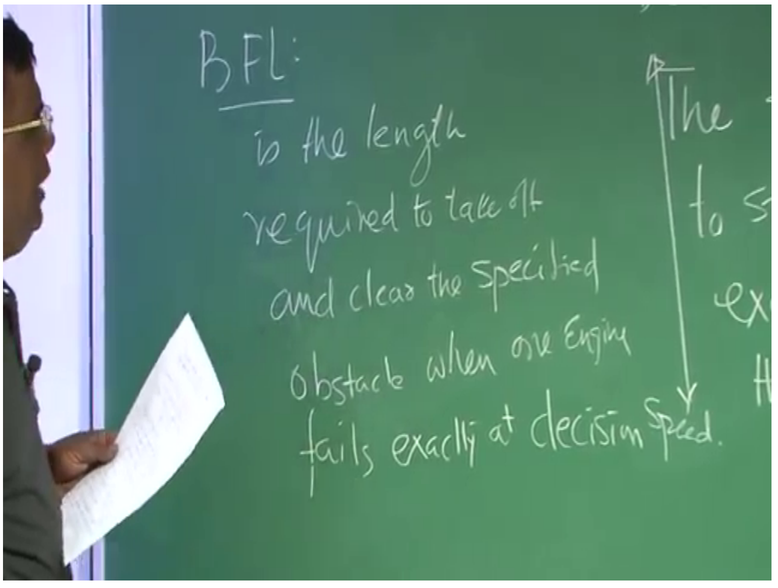

So, based on that; this balanced feed length is defined as is the length required to takeoff and clear the as specified obstacle when one engine fails exactly at decision some speed right.

Balance feet length is the length required to takeoff and clear a specified obstacle that is fifty feet or thirty five feet with one engine operative exactly at decision speed. So, this is the balance field length definition. If you see my earlier lecture, where we have given those parameter correlation even for popular aero plane and also we have given how to get the balance feed length from those chart right; however, my advice always would be because safety has a non-linear requirement right.

So, it is better you take data from similar type off aircraft in engineer craft what sort of balance feed length is prescribed in their manual more and more such data and take a decision at a conceptual stage.

Thank you.