Aircraft Design
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Lecture – 36
Conceptual Design

Good morning friends, we were discussing about how do I locate wing, where do I locate wing, should I give a setting angle the wing or not what should be the size of the tail, horizontal tail whether will give a tail setting angle or not for meeting two conditions one is the aircraft should be statically stable that is d C m by d alpha should be less than 0 and C m naught should be greater than 0 so that I can trim at positive angle of a diagram.

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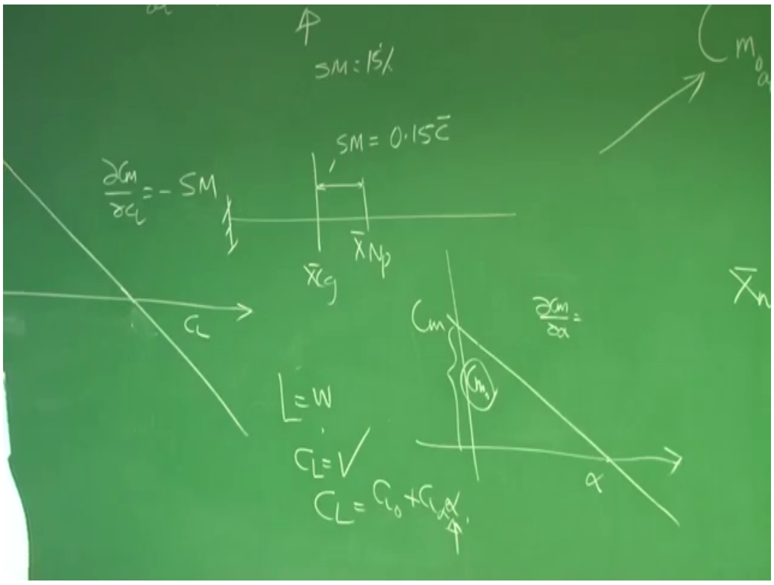

And how we started as for as conceptualizing the design, you said I know C m versus CL will be something like this and this slope d C m by d CL is nothing, but minus static margin; and static margin will define as if this is the neutral point and if this is the c g then this difference is static margin and it is expressed as some percentage of called if I say 15 percent static margin.

That means this gap is 0.15 C bar min a (Refer Time: 01:38) C bar is min a record of the wing. So, that is fine if we are designing it like this that I want 15 percent static margin, generally aircrafts will be design between 5 2 10 or around that percentage, but at a conceptual stage will take a conservative volume then we will find (Refer Time: 02:00) will apply we will have lot of difficulty in handling C g. Once I know C m versus CL, I can easily start visualizing it in terms of C m versus alpha where this slope now will be d C m by d alpha and this alpha I can easily get from lift equal to weight.

I know what is CL requirement is there, then I will CL I right equal to CL naught plus CL alpha into alpha. So, I can get alpha please understand in the during the conceptual stage we are assuming there all the lift is coming from the wing, but we know in actual practice some lift will come from fuselage some lift will come from tail, but at a conceptual stage because the wing is dominating as for a lift is concerned I do this approximation I translate this to C m versus alpha, and now I see that I need to have a particular value of C m naught here which needs to be generated through either wing how I am keeping a Cambered wing.

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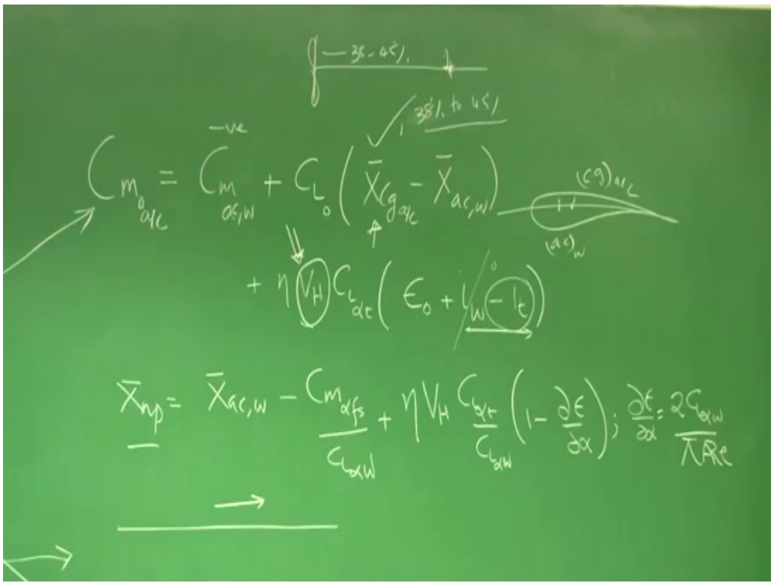

If I am keeping the a c of the wing ahead of little ahead of c g of the aircrafts, I know this gentleman becomes positive right, but this will always remain negative for cambered aerofoil, but it becomes positive for a reflex aerofoil. So, cambered as the positive cambered and negative cambered, but I am saying cambered aerofoil and he conventional says the C m a c of the wing always be negative.

Since I want some positive value of C m naught I have to nullify this contribution. So, one way I can nullify this by making this gentleman positive that is I put a c of the wing ahead of c g of the aircraft, and second thing is I come here I try to see that you when if I put this 0 then I can manipulate or generate a positive moment by giving I t negative, and that is called tail setting of that horizontal tail negative.

But if you want to enhance its contribution then this gentleman V H tail volume ratio will play an important role, and that is why for a designer he operates through tail volume. First question he decide how much tail volume I should take right and he could see immediate effect of tail volume, the moment you increase tail volume ratio your neutral point moves backward and it becomes more and more stable because V H is here right. So, for a designer he will always try to use this information for different different similar aircraft what is the tail volume ratio he picks up that number right.

Before going to use historical data let us also see once I write this expression C m naught of the aircraft is C m a c of the wing, do I know it when I am doing conceptual design or not answer is yes, because at some stage you have chosen in aerofoil right. The moment I know the aerofoil I know what is C m a c of the wing, do I know CL naught? Yes I know CL naught because I have chosen an aerofoil maybe a 6 series aerofoil, maybe a laminar aerofoil, when the question comes do I know X c g of the aircraft, where is most difficult part? So, again we start taking the advantage of historical data and we know this will be between 40 percent or maybe 38 percent to 45 percent I do not that range from will leading h or from the say from the popular idea.

This distance will find roughly 38 to 45 percent of the total length will be the c g. These are numbers right and a good designer will see from different different configuration where exactly c g is located. I just to give you an example as I was talking about c g the c g of the aircraft will depend upon the type of payload you have a type of passenger configuration you have.

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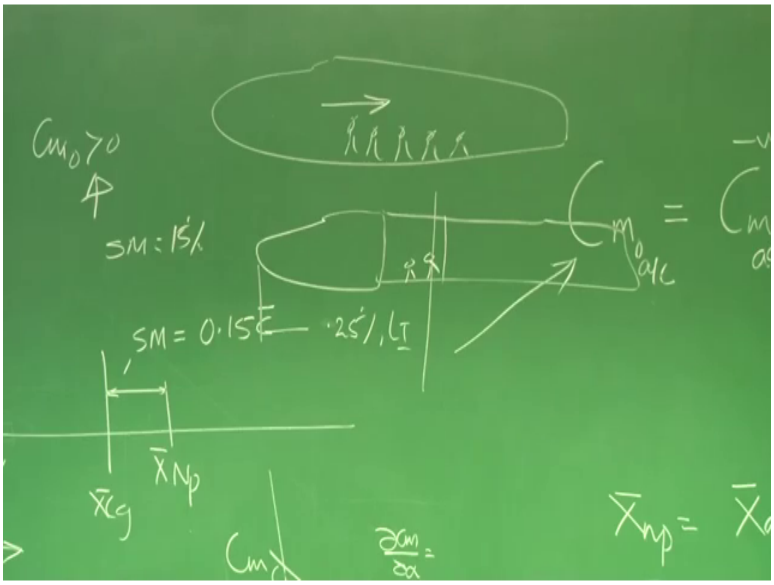

If you see aircraft where passengers are sitting here like your airbus going all those there is the tendency of c g going backward right. But if you see an aircraft like your Cessna 206 where most of the passengers are confine here. So, this portion is much empty here. So, there you would not be surprised if the c g is between around 25 percent of the total length. So, it is important to see what type of aircraft are doing. So, what I should do is instead of 38 percent right I can let me write 25 percent to let us say 40 percent which is it will have a side. Let me correct this, but this is a guideline my request is always you give lot of weightiest to a base line aeroplane right because every aircraft has got its different different mission requirements and accordingly we will find c g will play have a right unless you are careful about c g, you will have to change many things at a final moment.

Let us check for Cessna 206.

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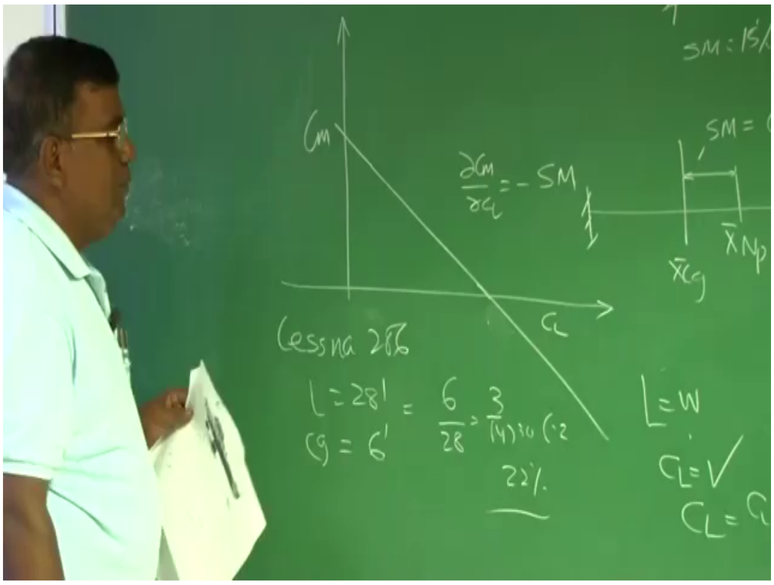

We have Cessna 2 0 6, where I could see total length is around 28 feet and your c g is roughly around 6 feet. So, how much it comes 6 by 28 that is 3 by 14. So, 3.02 around 22 percent right this is a most forward c g most f g is little aft. So, around the, that is why when I write 25 40 do not take me to court keeps are it is 22 percent there right. So, you are responsible to see what type of configuration you are doing, because final m means you want to carry a cargo right carry passenger carry cargo. So, that is more important we have to first see the layout, how we are going to put all those things and then you start taking of wing etcetera etcetera right.

So, there is a always the conflict between a layout engineer and a aerodynamics or a flight mechanics or designer engineer. So, it is a part of life. So, let us say in a simplistic manner we only could tell at this stage, but you have to very very careful about c g it is better you see lot of statistical data for different tax of aircraft should put one should put lot of clear here right. Now I were discussing how many things we are having at our hand during conceptual stage, since we have decided aerofoil roughly. So, you know these value, you know these value, you know X a c of the wing and also CL alpha tail that is you select some symmetrical aerofoil will discuss that, we generally it is that use a symmetrical aerofoil tail.

But its aspect ratio should be less than the wing aspect ratio just to ensure that tail stalls later than the wing right this things we know I also have got a fairly idea about this number right. So, what is important who will save us is V H and what is V H? The tail volume ratio, why I am giving so much weighted to V H let us see that. V H is tail volume ratio.

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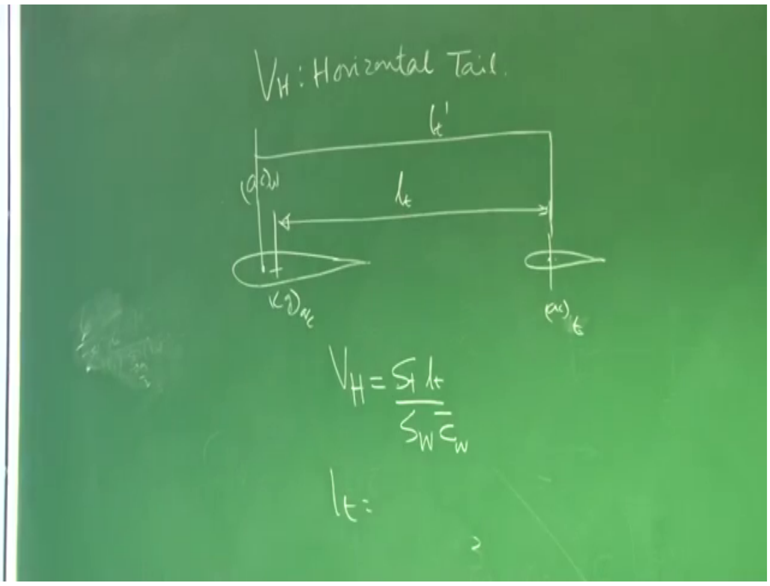

I am talking about horizontal tail, ideally if this is the wing, this is the tail, this is the a c of the tail right and let us say this is the c g of the aeroplane. So, l t the tail moment term is defined by the distance between c g of the aircraft and the a c of the tail right.

But a whole problem is a at this stage we have not pretty sure about the c g, c g narration could be there and sometime it is difficult to really get what is the l t we are talking about, but at a conceptual stage what we do? One a define V H which is actually S t l t by S w c bar, which is got at a conceptual stage we take l t as distance between a c of the wing and a c of the tail right at a conceptual stage. But you should not forget that ideally moment you will come about c g because of tail. So, this distance l t distance the c g and the a c of tail is important, but we use this length.

The same time you also know the difference between c g of the aircraft and a c of the wing will not be much right. So, it is not a bad assumption it simplifies your approach because you are going to fuse statistical data. When I am saying so many things, let me erase this I need to know roughly what is the fuselage length is after all you are going to install the tail wing that will be on the fuselage.

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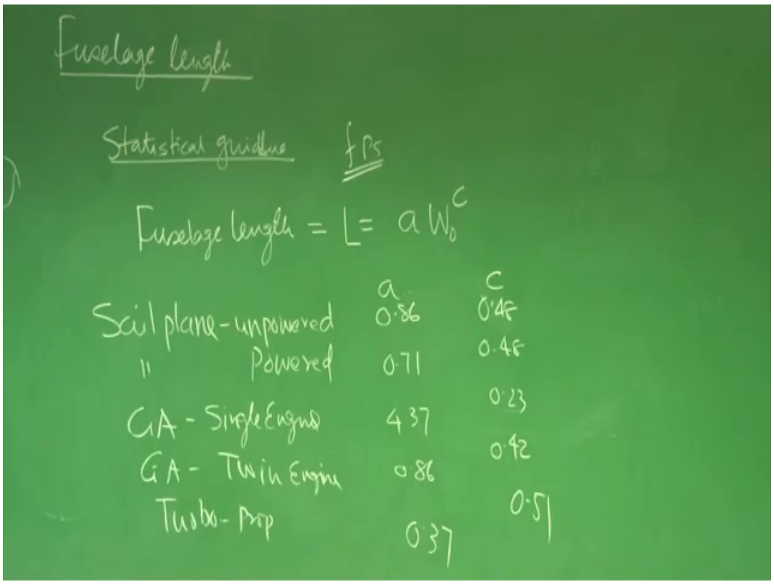

I need to know where do I locate it depending upon the fuselage length. How do I get what should be the fuselage length and the diameter.

Again you understand that is decided by the purpose if it is a full flagged passenger large aircraft in the length will be predominantly decided by how many passenger you are going to carry and then you have to ensure that they can walk through the oil. So, that will decide the diameter, but if it is the general aviation time Cessna 2 0 6 you know hardly 4 or 6 people will be setting and then need not walk through the oil they can go scrolling and sit.

So, all this things will decide the type of aircraft fuselage you are going to design. This is a excellent statistical data statistical guideline, which is purely estimated using the gross weight of the aeroplane and that is fuselage length given as L equal to a W naught to the power c, just I will give you example for sail plane some number you can refer rammer this is unpowered a and c if I write, and there is a sail plane powered then general aviation single engine then general aviation, twin engine and you can have a turbo prop and typical the values are for a sail plane unpowered it a is 0.86 and c is 0.48 for power it is 0.71, 0.48. For general aviation single engine it is 4.37 and 0.23 and then you are twin engine it is 0.86 0.42 and for turbo prop it is 0.37, 0.51. These are statistical number and this gives excellent correlation and please understand whenever using this, this is in FPS right that is very important see you in FPS system and maybe new books and everything they are giving in S i unit, but I am giving you in FPS let us check how does it look like.

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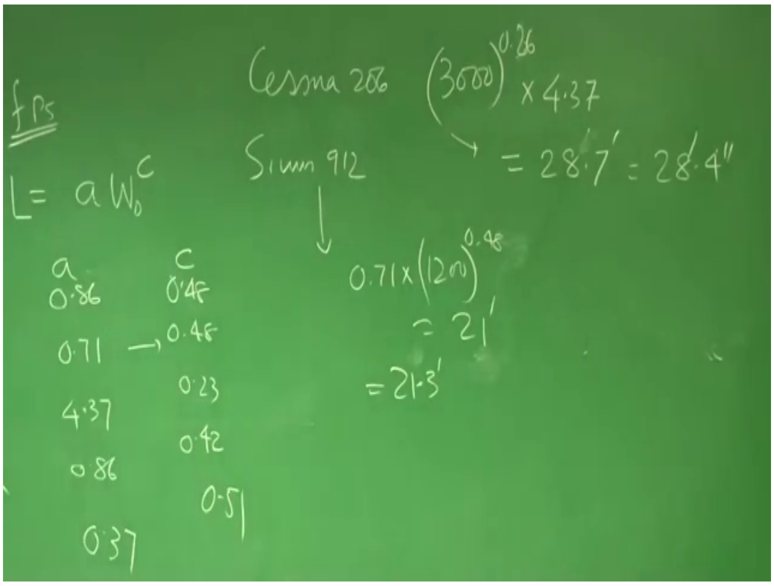

I was checking with Cessna 2 0 6 and sinus 912 Cessna 2 0 6 like a general aviation single engine aircraft and the weight is 3000 pound. So, 3000 to the power c, c is how much? C is 0.23, 0.23 into 4.37 and you will find this is coming around 28 feet 28.7feet.

Actual measurement I have seen we have done it roughly this is of 28. 28 feet 4 inches this is for Cessna 2 0 6, then I was checking correlation for sinus 912 which is a motor glider. So, it is sail plane power and its weight is around let me check around 1200 pound. So, it was what is that 1200 if it is sail plane powered 0.71 for this 0.71 into 1200 pounds to the power 0.48 right and that was coming around 21 feet and actual measurement is 21 feet, 21.3 feet. So, you see this correlation work very well and in the Rammers book the author also claims this gives the excellent correlation.

The message is you can easily use this relationship this correlation in FPS unit and quickly get what is the fuselage length. Once we have a fuselage length now where do I locate horizontal tail wing that becomes easier right. You will also appreciate when some bodies moving in air especially fuselage you take of cylinder moving in air, it is important to decide what should be length to diameter ratio so, the drag is as well as possible further some guideline is there for.

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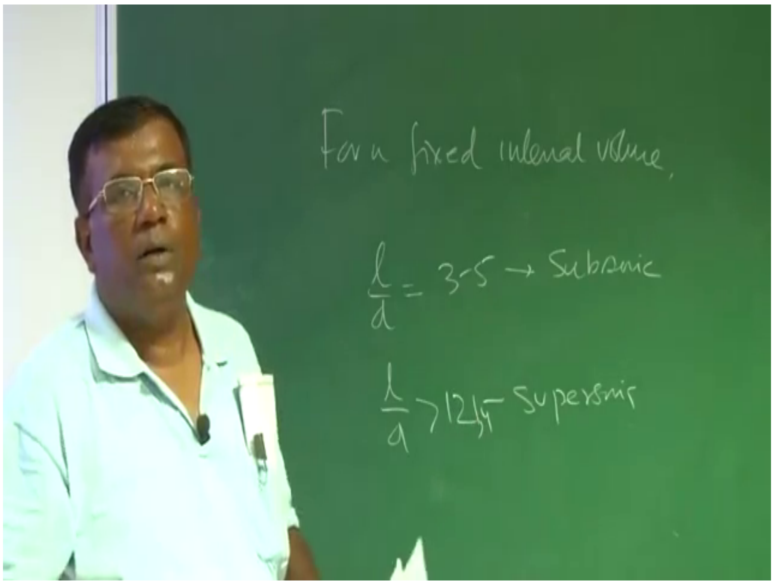

A fixed internal volume l by d it 3 to 5 is good enough for subsonic, and l by d greater than 12 for supersonic.

Twelve by 14 these are numbers right. So, this may help you in getting what should be the slenderness of the fuselage, but do not forget one thing. If you are designing a Cessna 2 0 6 the requirement is different the then though requirement of passenger moving through the oil. So, in you do not require height. If you such that (Refer Time: 19:36) up to just go inside and sit. So, the diameter automatically goes down right all those things playing important role when will be actually designing a fuselage, will try to incorporate those things.

But this are the conceptual stage this important that you know how to get rough idea how much length will be there correct. We had just come out of the class room I thought you have spend enough time drawing diagrams equations on black board let us check our self with whatever you have learnt, how our mind get excited when I see an aeroplane.

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For example, if I see the aeroplane from this angle what is the span of this wing should be the first question that will come to my mind, and this is I am standing near Cessna 2 0 6 aircraft and the span is around whatever record I have got around 36 feet.

You can easily converted into meter 36 divided by 3.28 it will be around 11 meters, 11 to 12 meters around that. So, that gives even idea about what is the span because I need to know that information, when I next question would be if this is the span what is the area of this wing because we have been talking about wing loading. So, I need to know what is the wing loading of this aircraft because that we have being talking for last few lectures. Once I do this span I will look for what is the area and for this aeroplane area is around 174 square feet, which is equivalent to around 16 meter square and since I now need to know what is the wing loading.

So, I am taking the gross weight of this aeroplanes Cessna 2 0 6 and the gross weight is around 1 6 3 6 kg. So, then gross weight is 1 6 3 6 kg and wing area is 16.17 meter square. So, for me it is very easy to get wing loading, wing loading will be around 100, 105, 110 kg per meter square and then you can check from the statistical data for general aviation single engine aircraft, the wing loading will be around hundred kg per meter square.

Once I see this immediately I cannot avoid looking at the propeller, one thing I see first that this propeller there is a 3 propellers like that there are aeroplane which two propellers it has his own stories in terms of efficiencies is empower being delivered and if you see as a conceptual designer, I would like to know how much is this each propeller length. Propeller length is around 3 feet and also you know that this is a variable pitch propeller which you know also that if I want to maximize the power at different flight condition. So, I have to fly at a different different pitch angle, I need to ensure that the propeller is highly efficient at that point. Now again recall you what we have we have talking in the classroom we have talking about thrust loading then power loading see this is a I c engine backup propeller driven aircraft will not talking about thrust loading. So, will I to know what is the power loading for this aircraft and the power loading for this aircraft is twelve pounds per horsepower.

Again you can check statistical data the this will fitting to whatever have been reported in the literature. So, I repeat the power loading is 12 pounds per horsepower. Now from here I need to see also the landing wheel, if you see these are the real landing wheel. So, I would like to know what is the wheel base as a conceptual person I am now doing conceptual design and the wheel basis as per my record is around 5.77 feet you can understand the wheel basis less than a threshold the aircraft can topple like this right. Have it is more it is also not going to help you. So, there is an optimal value at the designer you find out again you use some statistical data which was evolved for different weight class different types of wing.

Once you know what are this basic dimensions you can easily start conceptualizing a sketch, then you add the law physics and make the aeroplane the way you wanted to fly. See once I am trying to draw a sketch in my mind about aeroplane, these are not only important that you know how much will be wing area or how much will be the fuselage area fuselage volume, but you also should know how they are located relative to each other. Like if I ask you draw a figure of a human sketch you always try to find out what is the proportion of this size to the total size and accordingly you make a proportion a diagram so, that you should look like a human figure.

Similarly whatever theory you have conventionally you should look like a conventional aeroplane right. So, first thing also should come to our mind that this is my propeller they how much from cockpit to this distance, I should keep in relation to the total length of this aeroplane generally for a general. Emission aircraft just to take an example for this the total length of this aeroplane from here to the extreme that is the tip of the radar it is around 28 feet 3 inches. How much? 28 feet 3 inches and from here to this cockpit here it is roughly 3 feet 9 inches.

So, if this is the ratio 20 feet is 20 feet 28 feet edit a total length is 28 feet 3 inches and from here to the cockpit it is around three feet 9 inches. So, ratio is around 22, 25 percent 22 percent a motor size. So, when I am drawing a sketch I know that I should keep this much of percentage for cockpit start point and then depending upon passenger I mean layout to the dimension this is important for a high wing for a conventional layer plane the high wing will start somewhere from here.

So, this is a very important formation for drawing a conceptual sketch, also if I try to know from if I try to find the reference from here to where do I put my horizontal stabilizer total length was 28 feet 3 inches, and from tip to this point it is around 21 feet 6 inches.

So, it is around 75, 70 percent right this is very important formation when you were trying to conceptualize and you will realize that these dimensions have important effect on the overall stability of the aeroplane how we are going to design, the stability of the aeroplane and stability you will be directly connected to handling qualities it is also important to see what will be the c g location, we will show you where are the c g location when you cover the stability part of it. Again coming back to the wing this is another important thing we should realize that whether the wing is parallel to the fuselage reference line or wing has a setting angle. That is the wing if this is the wing how this wing is mounted parallel to the fuselage line or it has been given a setting angle which we call wing setting angle right.

So, once I trying to see this wing you will realize why I am also looking for wing setting angle during our stability analysis, will see that wing setting angle will play an important role in generating lift and control characteristics. So, generally if you are doing a conceptual sketch it is better to keep honor to degree wing setting angle, and then finally, is an you may wing setting angle may not give me setting angle depending upon your requirements right. Now let us come back we know the wing loading you know stall speediest square root of 2 into w by s divide by rho into CL max and wing loading is around 100 kg per meter square.

So, I write 2 into 100 into 9.8 divided by rho let us say 1.2 into CL max I take around 1.2. So, that will give you around 25 27 meter per second. So, this stall speed will be around 22 23 and take off will be around 27 28 depending upon what is the flab orientation right. So, you could see that all this numbers are making sense based on whatever we have studied there. See this is very important part of the aeroplane this is called stabilizer you all know.

So, as a designer if you want to conceptualize this configuration, I should look for if this is the whole is horizontal stabilizer and this much portion is the elevator then I should try to know what is the percentage of area being used as elevator. And from this you could see that this is around 30 to 35 percent of the whole stabilizer area. So, when I am conceptualizing a design I will keep around 30 percent, all though by through analysis will also find out that and whatever number he get through analysis I cross check whether I am really get making sense or not whether this numbers are coming are conformed into the conventional tail or not right.

Will also find their some portion of the tail elevator is somewhere here, and why this is given many aeroplane may not have this. So, will talk about this portion also how is going to help in the handling qualities of the aeroplane. Since we are talking about elevator it is important to know that where is the c g location of this whole aeroplane, that is also very important observation or need to have this location of c g somewhere should be closer to this landing here and you understand the c g should be little ahead of this real landing here, if the c g is behind your landing here there would tendency of aeroplane to hit like this and if you see the dimension here this c g is roughly around 8.5 feet for most forward and the landing, here is around 9 feet right they are rough numbers. So, what is being convey these you ensure that the c g is first of all near here where the people are sitting cockpit etcetera this there, and the c g location should be little aft of the real landing here ok.

So, that also make sense for us and if you see now here another question always comes to our mind when you see an aircraft, we try to know what is the ration of length in span and the length right. If this is the span what is the length what is the ratio typically for this example aeroplane total length is around 28 feet 3 inches, and if you see the span is around 36 feet. So, 36 divided by 28 feet. So, around 70 75 percent that is the ratio of that length two span, that is you can keep the length around 75 percent of the span two start initial conceptual design right. And you will find mostly that you will confirm to conventional aeroplane that is the total length is around 75 percent of the total span this is an important observation the must keep backup your mind, and also another question you come to your mind what is the diameter maximum diameter of the fuselage you very well understand that depends upon what sort of a passenger number of passenger is will going to carry.

But for this away 6 setters for this aeroplane the width is around 50 inches. 50 inches means around 4 feet and the height is around 43 inches which is around 3 point some feet. So, 50 inch and 30 inch that is the cross section width and height of the fuselage. So, for such aeroplane you do not walk through the fuselage you go crumble and then sit, but for a airbus or going or big aeroplane you need to walk through the fuselage. So, there diameters are more. So, that sort of a requirements are different.

But as long as you produce appropriate lift it does not make much of a difference from aero dynamics model. Remember we start they talking about this length because we are looking for how to locate horizontal tail, what should be size and we decided the best way to visualize that conceptual stage it should look for we a tail volume ratio right. So, statistical some value I will be giving for tail volume ratio.

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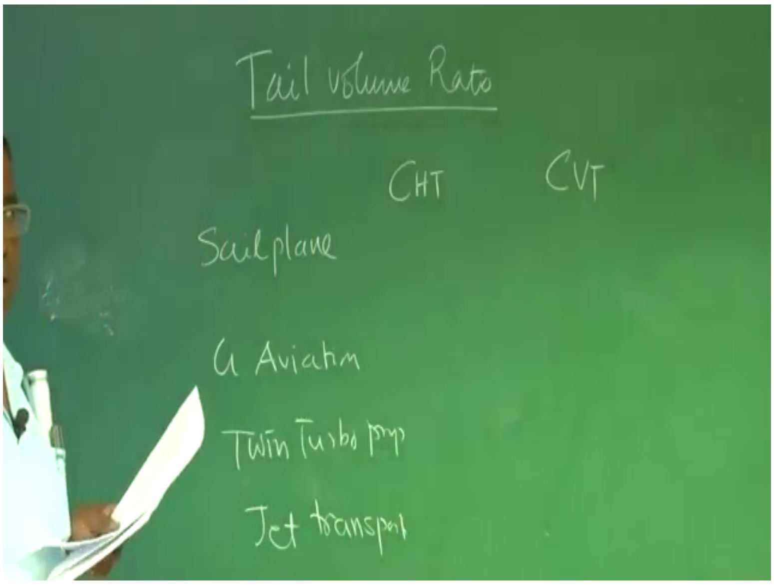

And you know what its importance of tail volume ratio. So, again for sail plane then general aviation, then twin turbo prop then jet transport, will just give some represarative number or CHT the tail volume ratio if a horizontal tail, and CVT tail volume ratio for vertical tail and we define CHT.

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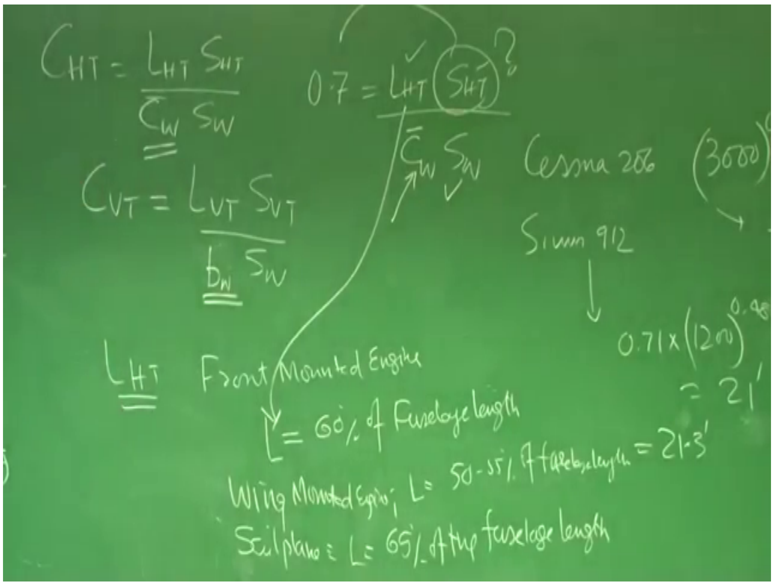

As LHT SHT by C wing S wing and CVT vertical tail volume ratio as LVT SVT by t the span of the wing S w please note this.

Vertical tail volume ratio is non dimensionalised with span, in contrast to horizontal tail volume ratio we will try to non dimensionalised using cord (Refer Time: 35:54) aerodynamic cord or precisely right.

So, this values are is around 0.5 for sail plane, 0.7 for general aviation twin turbo prop 0.9 1.0 and this is 0.02 0.04 0.08 0.09 these are conservative numbers specially here these are conservative side, but at a conceptual stage you use that. There will be a question how much LHT I should take historically there are some guidelines you understand this LHT means that l t which was ideally it is distance between a c of the tail and c g of the aircraft, but we are since we do not why is the c g we take from a c of the wing to a c of the tail, also silently we know that a c of the wing and c g there will be close right.

For a guideline for LHT, but a front mounted engine L you can take as 60 percent of fuselage length. So, that is why before coming to this we said let us see what will be the fuselage length, if the engine is at the wing, wing mounted engine then L you take around 50 to 55 percent of fuselage length and for a sail plane we take L as 65 percent of the fuselage length.

So, this is typically the number, why this is important you see suppose I am designing a sail or let say general aviation right. So, I know CHT is 0.7. So, immediately I write point seven is equal to LHT, LHT I get from this. So, this is known I want to find out what is SHT, this is what I want to know divided by c bar already I know wing we have design at least conceptualize wing area I know. So, you can easily find out how much tail area he has required at a simple conceptual state.

Then what a design under whatever number it comes he checks what is this percentage of this tail area in compare to the whole wing area. So, there are statistical data also will be there is it 15 percent, 20 percent or is in only 4 percent 2 percent. So, that also give the designer a fail whether he is right direction or not right will be talking about that as well, but this is just telling you how do I get first number then there is a process of checking whether at a intermediate stage, am I going right or not. They are the statistical data gives a lots of fail and that is again and again I am telling you need to have a base line aircraft all base beside you to check whether you are in right direction or not right.

With this background now will become more specific on how much will be the elevator area, how much will be the eleven area, how to decide at a conceptual level, how much will I take a radar area. So, that with a pen and pencil and a small small this information I should be able to sketch my first conceptual aircraft where sizes are proportionate right then we go for final analysis and do refinement right. So, maybe another one or two lecture I will take on how to get into all this numbers, and when at least draw a good sketch of an aeroplane which looks proportionate.

Thank you very much.