Aircraft Design
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Lecture - 01
Introduction

Good morning friends. We are back here again after completing three courses namely airplane performance, stability and control and introduction to experiments in flight. Now we are here to start a course on aircraft design. Primarily we will be focusing on the conceptual design based on aerodynamic considerations, we will be mostly talking about performance related issues in designing an aircraft, yes, we will be talking more on civil aircrafts civil transport aircrafts. We will be also discussing how to design the aircrafts so that it is having right type of handling qualities, in turn we will talk about how to layout wing, tail, vertical tail, horizontal tail so that we have right amount of stability margins; its damping ratio, its natural frequency which already we have some exposure.

This is the time to synthesize whatever we have learnt in earlier three courses. Before I start this course let us understand our country has produced space vehicle or launch vehicle; satellite launch vehicle of various capacities. We recently had Mangalyaan; a wonderful venture, we have deployed 104 satellites particular orbit.

All these things talks about the synthesis of design, the same time you could see we have lot of success in designing missiles including air difference missile ballistic missiles we also have tremendous success on fighter airplane light combat aircraft this is LCA and country is also moving forward towards the next version with higher capacities and capabilities.

But you will see that we have not really done enough as far as designing of civil transport airplane and that is where this lecture is dedicated to can we through these courses make design a popular course so that younger generation can get inspired and empowered technically so that they can add values and convert this understanding do technologies and maybe in extend 20 years. We will have our own civil transport airplane with that understanding with that motivation I thought I will again interact with you and share with you whatever I understand in terms of aircraft design. Please understand that when I say we have not been able to produce really good civil transport airplane; I am

not undermining that we have already developed answer three at trainee aircraft of course, under NAL; national aerospace laboratory.

We had some success with (Refer Time: 03:56) airplane, but for an unfortunate incident which is a part of development and I am sure NAL will come up with new ventures, but a question comes are you ready are you really creating right type of manpower we will be able to take these challenges and this course will help in a smaller way to fulfil that requirement coming back to this courses. In particular aircraft design we need to understand ourselves what are the immediate thing that comes to our mind when I when we see an aircraft for example, if I am seeing this aircraft which is sinus 9 1 2 motor glider.

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If I see the; as a typically as a passenger, a joy rider, my first focus goes towards this propeller which is the engine side and the propeller rotates and creates enough power to take it out give a proper speed to the plane so that it can generate right type of lift.

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But, for a passenger what comes to his mind the moment it is a single propeller airplane it is oh my God. So, only a single propeller if something happens what will happen. So, that is the impression a passenger gets he does not get much bothered about seeing the wing or the vertical tail for him immediate psychological focus will be on the engine. For example, you will ask what is a single engine what will happen if the engine starts off, but now think same aircraft when viewed by an maintenance engineer he starts looking to every component for him yes he puts enough inspection to ensure that this engine is air worthy reliable.

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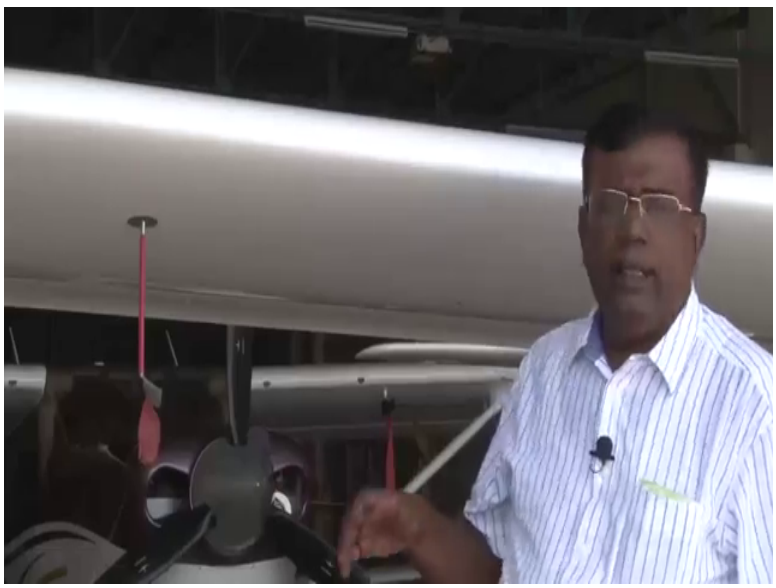

He also looks for the wing; he looks for this piteous tube because you know this piteous tube will tell you; what is the air relative speed the airplane is having. So, we will take extra care to see that the piteous tube is not blocked because of some for in particle and that is why some covering will be there the part of mandated regulation.

So, for an engineer he sees from purely from maintenance angle he is not bothered about whether this design or this angle of the landing gear is or not for him he believes he starts from that point that design has been done properly.

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He looks from the maintenance point of view he will be checking whether when the aircraft lands whether the landing was proper or not there are many occasions were landing maybe heavy landing. So, he will immediately come and check as per the maintenance schedule what the landing gear is or not.

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He will be also checking if we see here checking this ailerons this control surfaces similarly elevators rudder you will see whether when the pilot moves it with a stick, whether these things are being deflected proportionately or not as per the manual. But the question comes the basic question which comes to our mind in this course is how much it should be deflected for a particular mission and how much stick force the pilots to apply to deflect this up and down on elevator up and down that should be properly designed and before you design you do a proper evaluation. And once you say this much of area I need of the wing to be aileron.

Then come that comes the next the design, I will see whether stand alone aileron size, but when I fly the machine when this aileron deflection also gets coupled with yaw in motion the ailerons are primarily for roll motion right, but as it rolls it yaws also. So, it will also create some yaw motion on the airplane and then you have to correct it through rudder.

So, designer will see the effect of each individual not only separately, but also as a cumulative performance and that is a good design when you take the advantage of each component effectively and make the whole airplane worthy as per the handling requirements dictated by design parameters please do not forget whatever airplane to design finally, the pilot will be flying. So, when the pilot flies the machine when he touched down he should tell so wonderful machine lovely to fly you should not say oh

my God what is this aircraft I am have to pull do you. So, many of forces to deflect the elevator or aileron I am getting tired.

So, all those inputs are to be taken to finally, design an airplane if it is from that angle the second angle you understand that I will like to go the particular speed I like to fly at a particular angle the question comes whether the structurally it is good enough to withstand that much of a dynamic load or not it should not happen that as I deflect the aileron the aileron starts deforming right then the aileron will not be effective. So, that part is taken care by the structural designer you could understand this is typically like a cantilever wing and if there is a load here and if there will be bending moment at the root there may be a torque acting on the on the wing. So, the wing should not deflate unnecessarily or whatever deflections are there we should be able to estimate it and apply appropriate corrections right in the design.

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If you further see from a designer point of view this portion the huge large span you know it is the wing and the question comes to our mind the wing is primarily to produce enough lift to balance the weight of the airplane the moment, we think of wing producing lift first thing comes to our mind what will be the area of the wing we should be able to produce the lift at a particular speed.

So, when you see the wing yes it first impression how much will be the area of the wing, but then we also know that it is just not the area we have to also see what is the aspect

ratio of the wing because we know that as I increase the aspect ratio they induce the component reduces, right so that impression comes from the area part, but same time you know that I want to ensure that the lift to drag ratio for the wing is comfortable the way we want it and there we go for aerofoil. If I take a cross section like this there are we will discuss and you know that the whole art of selecting aerofoil becomes very very important in designing the wing and when you try to see an aerofoil or selected aerofoil we primarily see how effective it is in terms of lifting and what are the penalties you have if you want to increasing is lifting characteristics.

What sort of CL by CD the wing is supposed to give another important thing is what is the stall angle right there at what angle the wing is supposed to stall and how do I design or customize the aerofoil so that either few of this parameters are optimized or some time will give more weightage to the stall angle. So, all these combinations will decide what sort of aerofoil you will be using will be talking in detail in our design exercise in the classroom, but before you design is important that you try to appreciate things without using a formula, it should come from your heart, yes I want this and looking for this,.

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Now, from wing if I come here this is the horizontal tail and you know this is elevator and this is a vertical tail and this is rudder. So, it is also important to find out what should be the horizontal tail area how much of this horizontal tail should I use the area as an elevator or should I use complete horizontal tail as an elevator you know when I

complete horizontal tail is use we call it a all movable tail right same as similar thing is here for rudder this vertical tail the 40 percent of vertical tail will be rudder 50 percent 60 percent or all of this area these are the primary decision you take before you start conceptualizing a design of an aircraft.

Now, this whatever I have told you is from the configuration point of view, but what is the role of the wing is it only to give lift and drag ratio the way you want it, the way we want it is only the role to give enough area to get enough lift.

Let us understand this we will go to another aircraft and try to address this question. So, you are discussing about wing and primarily we are talking about the area required to the aspect ratio of the aerofoil from aerodynamic consideration.

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But you see that if this is an engine which is driven by fuel combustion engine then I need to have fuel carried in this airplane. So, I need to have a fuel tank please see here this is one of the combination.

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So, design combinational refine people are putting fuel tank inside the wing right; that means it is just not selecting an aerofoil we need to see that when I translate that into a wing I should have enough volume to accommodate this tank.

So, that also decides what will be the thickness of the wing and what sort of a aerofoil I will be taking all right, because each aerofoil has got thickness to called distribution specified distribution and we talk about the fuel tank you will understand I cannot locate this fuel tank anywhere randomly because this has a weight almost 30 percent of the weight of the airplane is the fuel.

So, if location will determine the location of centre of gravity of the airplane and more importantly as we fly the fuel get consumed; so if we are not clever enough then what will happen as the fuel consumed there will large variation in the centre of gravity of the airplane and which will directly affect the stability of the airplane you know that stability and centre of gravity locations are related.

So, lot of effort will go in designing and wing aerofoil combination keeping the housing of fuel tank. So, what by this I am trying to stress is this is real synthesis what is important you should know each alone stand alone characteristics, but is also should know there are to do multiple things and study try to satisfy everybody which generally is not possible. So, there is a something called we try to optimize some time we call

optimization in truces may not be feasible, but we say it is adequate adequately optimized.

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Now, beyond aerofoil and fuel tank if we said these are one this ribs they actually maintain the contour of the wing and the question comes how many of such ribs should be there how many of load bearing member longer on (Refer Time: 17:04) will be there we after all, it will always having a bending load or torsional load how do I distribute those load across the member through this sort of a structure and ensure that they are plenty safe structurally.

That is why it is extremely important that I not only designed a wing through aerofoil and aspect ratio I need to go inside the wing and see the volume available for accommodating fuel tank I need to know how do I place the stiffener inside the wing how do I put the longerons inside the wing so that it is structurally enough strengthened right. And again you could see aerodynamic structure and fuel tank all these three things have to be integrated synthesized keeping a one mission that my airplane should have particular mission requirement what are the mission requirements how do you decide will be discussing inside a classroom.

This is important thing as far as a wing is concerned, but if I ask you a question if this is an airplane out of this airplane you will see the engine part engine part we do not make any engine right so in fact, not very large number of company produces engine. So,

engine will be use as a standalone as if it is available in the shelf and what are the power required what are the trust required you will pick up the engine and fit in the aeroplane if you see other sensors which are there in this aircraft most of them are not produced here of course, of fleet things are changing. But since you are not making your own such subsystems some time optimization becomes a constrained situation you wanted something, but you are getting little different than that, but you have no option.

So, you have to integrate them and compromise accept the compromise on your mission requirement I am sure our country also will produce senses sooner or later lot of efforts are being made.

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So, from wing to engine and if you see this part this is another type of landing here which you know we have to also see what should be the width of this base of this landing here how much their separation is required all this thing will come into the conceptual design right you could have imagine if the base length is shortened then it will be underground it will be; it will not be struble, it will just topple right all those minor-minor things will take into consideration, but we will not overload ourselves.

Because, finally it has to be something which we should enjoy right and relaxed manner we should be able to do synthesis and that will be the USP of this course the pace of this course will be very very optimally slow to ensure that you enjoy every moment of it we

will go back and forth check with existing design the concept validate it. So, there after the end of this course you are confidently yes, I at least I know this much.

So, we will be having next class in the classroom wish you all the best and again welcome to this course on aircraft design.

Thank you very much.