NOC: Introduction to Airplane Performance
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Lecture - 48
Revision

Hello and welcome, I am Vijay Shankar Dwivedi, TA in this course, with me our esteem Professor Dr. Ghosh, who has been teaching this course in previous sessions. He had covered a lot of materials, we expect that you have some questions; some of you have put them on the forum also. Due to technical limitations, it is not possible to have an interactive session with you.

So, I have prepared a list of questions, which we will be discussing in today's session. Welcome Professor Ghosh, let me welcome all of you and let me first confess very clearly that it was my friend Vijay Shankar Dwivedi, who is basically an electrical engineer and then, he did M. Tech here with me. It is the lifeline for this course, I have been getting lot many feedbacks, especially on the recording part and the board work.

You understand this first time we are trying and I have communicated this to the media centre, who does all these thing, I am sure on next course, we try to add whatever suggestions possible to include we will include thank you for suggestions. And talking about Mr. Dwivedi, you could by now you know that, he is one of the person passionater, very hard working.

And we have one thing common, very, very common man, he come from a common background, but he believes in hard work. My personal opinion is, do not unnecessarily give too much vertex to IQ, intelligence, all of you can be as intelligence has been I could as intelligence assume, it is finally, the hard work that matters. Rightly, so the suggestion came because Mr. Dwivedi and his one or two friend where interacting to the forum and there are some questions.

So, we try to discuss few questions, whatever possible, so that it helps you and as, we have promised that, this is our Maan Ki Baat session, this is the last session for this course. So, we will not keep anything remain unfulfilled, we try our best see that your concepts are clear. However, you are most welcome to contact as through our Email ID's and through the forum, we will still be able to communicate to you.

Let us start with these questions, a lot of students has been asking, they want to know,

when we already have the lift and drag, then why we need C L and C D. If you remember one of my lectures, where we were using Buckingham Pi theorem and that, if you go back to the lecture you will find, this question was answered. When, I talk about C L and C D, we are actually trying to take the advantage of geometric similarity and dynamic similarity.

That is, suppose it is a non dimensional, C L and C D are non-dimensional, they do not depend upon the dimensional parameters. Suppose, you have got aircraft, very huge aircraft, 30 meter span. Now, you want to generate it is lifting characteristics. So, what best you can do is, you can create a geometrically similar model, the scale down and ensure that, the dynamically they are similar. That is, if the Reynolds number or a Mach number you duplicate is add a tunnel, so then you can match the C L, non-dimensional coefficient you can match.

Because, C L is function of angle of attack, Reynolds number and Mach number, so that is why it is easier to work in C L or C D. If you want to match the lift let say, then you have to test same size, because lift is proportional to the area. We have to duplicate the area, same density, same speed, but here because in one dimensional coefficient, we know that C L is functional Reynolds number, Mach number, for a given angle of attack. So, you just bring down the internal models, scale down, smaller model.

But, ensure that, the Reynolds number and Mach number are duplicated and you will get accordingly the same value of C L, C D, which you can use for a designing of bigger aircraft. So, that is the primary advantage of using non-dimensional C L, C D instead of lift and drag. I hope it is clear; you go back to my lecture, which I have given on a dimensional analysis.

Thanks Professor Ghosh, I do not think, they are could be any better explanation to it and the next question is, why we need calibrated airspeed. I think you should answer this clear explain. Sure sir, let me try, this is the equivalent airspeed at the sea level for the similar lift. The advantage of this is, we know we have different stall speeds at different altitudes, because with the altitude our density decreases and to maintain the lift equal to weight, we will require different airspeeds.

But, for the calibrated airspeed, a respective of our altitude, we have common stall speed. At whatever altitude we are, our stall speed will not change, it will be same. Therefore, if we have the calibrated airspeed, the pilot need not worry to calculate his stall speed at

every time. And one more magical advantage of this calibrated airspeed is, for a given rate of time at whatever altitude we are, our calibrated airspeed will be unique.

Let us move to the next question, why we need infinite wing. To the concept of infinite wing is very simple that, you know for a finite wing, after all when you are generating lift, if finite wing you know the pressure is here more, pressure top is less, there will be what is this. So, lot of kinetic energy you gets into a typically rotational kinetic energy is extracted out of the airplane and this is, deduction in the speed or you said drag has increased.

Theoretically, if I have been in finite span, first of all this lose of drag will be 0 theoretically, because there are no pressure difference as an infinite. Second thing is, when you talk about infinite span for our analysis, we actually mean that, there are no cross flows, the flow is moving around the chord, normal to the chord. So, our analysis become simpler and we can postulate, all our coefficient etcetera with this assumption.

With the moment we have a cross flow, whole the analysis will have to be modified and that is one of the advantage of when you talk about infinite span, which is also very clear for you that, if it is infinite span, there is aspect is also infinite, so the induced drag will be 0. Rather designer use, many times you try to fly an aircraft, a designer aircraft have been a larger span, larger span means, high aspect ratio lesser induced drag.

But, please remember as you are making the wing, span larger and larger or the aspect larger and larger, there is the possibility that, you can increase the area of the wing. If you increase the area of the wing; the skin friction drag will become more, so you need to balance it out. Yes and this is like an ideal case, when there is no side flow of the air, as a result, no induced drag. Whereas, in our finite wing, we have the side flow of the air as a result, we have what is at the tip, which result into the induced drag.

In an axial, when you say infinite span, we are actually talking about a situation, where the induced drag is 0 and the flow is two dimensional. Flow is going like this, no flow is going like this or coming like this. Let us continue our discussion with next question, next question reads, how lift is generated, is it due to the stacking of due to the wing or due to the pressure difference. I think you should be able to answer this, you will tell, what are you understood.

I think both regions are valid, because first is the cost and second is the effect. Yes, due to the striking of the fluid, there is pressure difference and due to the pressure difference,

you have lift. After all the lift has to come from somewhere, it cannot come out of nothing. So, it is the basically moment of exchange, whatever momentum the fluid has, part of that gets rid into lift, part of that get into drag. Some of our viewers are confused, why the time taken by the fluid to reach from leading edge to the trailing edge, either from of the top surface or bottom surface is same.

If you, I understand the question correctly, what you are asking me, if I draw an aerofoil, the time taken by the fluid over top surface and bottom surface has to be same. It is obviously true, because we understand with the continuity of flow; that mass or fluid particle cannot get stagnated, whatever is coming in they should go out at same instant. That is part of our continuity of flow, which is a natural justice or a natural law, whatever goes in has to come out.

Take a pipe, whatever mass flow is entering that has to come out, if they are not coming or that, there is a stagnation, in this case, we have sure that, there is no question of any stagnation. So, fluid is covered or fluid is coming at the time T, same amount of fluid has to go out at the other time T. So, that is why we say that because of the continuity of the flow to be maintained, they have to come on same time.

Anything more you want to add? And mass is not generated in the path, because and there is no mass is generated or no mass is consumed in the process. And sir, what is the physical meaning of k and e, see k when I talk about k, if you see the expression also, it is a 1 by pi aspect ratio e. As we understand that if aspect ratio is in finite, the induced drag will be 0. So, k in somewhere try to model the variation of induced drag with aspect ratio, also we know that induced drag is minimum for elliptic distribution.

So, e is there to model for e equal to 1, it is an elliptic distribution where downwards will be same all through, so that is the time, where it has minimum induced drag. So, e equal to 1 corresponds to elliptic distribution and e less than 1 is non elliptic, for which is 0.8, 0.8, 0.9. Mostly for the wings, we generally fly with taper ratio between 0.4 to 0.5. Also, understand; obvious which I am not discussed, your C D equal to C D naught plus K C L squared.

Even, the C D naught changes with angle of attack or C L, but because as going for different, different angle, the C D naught may also change and part of that is also observed through e, the modified e. You can read Anderson, Introduction to Flight by Anderson on the chapter of elliptic distribution, he has talked about it in small manner,

but let us good enough. So, what I understand, this is the proportionality constant for the induced drag, as aspect ratio increases, k decreases and for the infinite aspect ratio, the k becomes 0 as a result induced drag become 0, now our wing is 2 D.

The induced drag also depend upon the pattern of the lift distribution, which is taken care by e, which is maximum for the elliptical distribution. That means, the k if it become, if aspect ratio become infinite, the k becomes very small. So, the wing will behave more like a 2 D wing or more like a, it is aerodynamic characteristic will be more governed by just the characteristic of aerofoil.

So, when we apply an aspect ratio correction, the correction required will be very, very less. And next question for you, what is winglet and what is it is usefulness. As you understand that, if this is the wing, finite wing, there are vertices here, because of high pressure or low pressure. So, one way to discourage this generation of what you say, physically make sure that, they are no space for the lower pressure, the particle to go the higher pressure of the top.

So, physically if we put some surfaces like this, which are basically constant behind the winglet. By putting winglet, actually you are reducing the induced drag or theoretically speaking, you are actually increasing the aspect ratio of the wing, because we know as the aspect ratio increases, the induced drag reduces. Although, the geometrically aspect ratio is not increasing, how about by putting a winglet seeing this, what is the generation will be discouraged.

So, induced drag will reduce that is equivalently saying, I am increase the aspect ratio, I will reduce the induced drag. However, once you put a winglet, make sure that, the winglet itself will give some C D naught, because it will have friction or skin friction drag, you have to do optimization what you put. And next for you, that C D naught vary with Reynolds number. You know C D naught has a major component of the skin friction and you know as Reynolds number increases, the skin friction coefficient reduces.

So, if it is, the flow having high Reynolds number, high speed flows, your skin friction coefficient will reduce, so your C D naught will start reducing. If the Reynolds number reduces, then the skin friction coefficient will go on increasing. That is why, when your rocket is fired, when it goes very high altitude, let say 1520 kilometers, where density of it is very small, the Reynolds number is very small, the skin friction drag increases in all language C D naught increases.

Yes, C D naught has indeed strong function of Reynolds number; that is why; when you are going for a scale level testing, we need to duplicate for a low speed airplane, which is mandatory that will duplicate that Reynolds number to get an idea about the lift coefficient. I am asked, what is stall angle? You know the many ways are looking into the stall angle, you understand that as I increase the angle of attack, the lift increases, the C L increases not the lift, what the C L increases.

At some point beyond that angle, the flow starts separating and there, if no increase in C L, you state there is an increase in the drag. So, the stall angle is defined at the angle, where the flow starts separating or stall angle is there, write as a definition if the stall angle is an angle, where you get the maximum C L or C L max. Another way of interpreting is this, stall angle is the angle at which you can fly with the minimum speed and still maintain lift equal to weight.

So, it is corresponding speed I will call it stall speed. Is it clear? V equal to 2 W by S by rho C L. So, if I am at a stall angle alpha; that means C L is C L max and so, V is the V stall. So, it is the minimum speed at which the airplane can be maintained lift equal to weight at a given altitude. There are many ways of interpreting this. Do you want to add anything on this? From your answer, I got the answer of my next question, the question is, how we decide whether the given angle is advisable or not.

And what I interpret from your answer, if my given angle is less than the stall angle, then this is advisable, otherwise it is not. One question with some of our viewer have asked, the viscosity which we discussed is it dynamic viscosity or the kinematic viscosity. See, this is the question of definition, when you are defining the last number as rho u l by mu, the mu is the normal viscosity and you know, it is dynamic viscosity is mu by rho. Am I correct? Absolutely.

If you take the rho in denominator, then you can change it to kinematic viscosity, otherwise as per definition, the Reynolds number when you are using rho u l by mu, mu is the kinematic viscosity. One very pragmatic question, what is the importance of the cruise speed and why we need service ceiling. So, cruise speed is the generally, when you are designing an airplane and if it is for cruse machine, you want to select a cruise speed, so that your range is maximum or endurance, whatever you want and also the maximum speed, you also have while comfortable.

Sometime, it happens to fly at the maximum endurance, the speed is very low and if you

are flying all the time with that speed, then you will be reaching a target in a very, very longer time. So, you do not like that. So, cruise speed is basically the speed, the design speed for a transport airplane, where you want to select and check that your range is maximum and you are flying, such that time taken is also not that large.

And what is the second one there? The next part is service ceiling, service ceiling is see as I am going higher and higher, you understand that, the engine power and the power required, the gap goes on reducing. So, there is an altitude at which theoretically speaking you fine the rate of maximum will be 0, when they two gap will match at one point. But, service ceiling which say then the particular altitude, where the rate of claim maximum could 100 feet for minute, but that is the concept of service ceiling.

And cruise speed of for what is speed I can comfortably and favorably design to cruise and service ceiling is at what height up to what height I have power to claim. Because, that also decides, what is the combination of power, available in power required or what is the characteristic of the airplane to have excess power. So, you know I can have a rate claim maximum at different altitude by different, different amount; that also we were additional dimension to an airplane.

So, the cruise speed is that optimum speed to travel from one point to another point, I said if you are either transport airplane. Thanks, this was very precise and to the point here is one more question for you, why do we still have the option of the fix landing gear, when we already have the relatable landing gears. This is practical see theoretically speaking you always you should have retractable landing gear to minimize the drag, improve C L C D all will agree.

But, when you make an airplane, the cost not only goes in making landing gear, but also maintaining them. So, total optimization if I do, whereas to see for the operation for smaller airplane, where we have a different above operation, it may not be advisable to put it retracting landing gear or you can put it, the cost will go up. The maintenance headache will go up, but for bigger airplane for longer duration airplane, high speed airplane, not very low speed airplane, their definitely you they have no other option.

But, to go for retractable landing gear, because high speed, all for longer duration, it will amount to loss of lot of loss of fuel, because of drag experience by the landing gear. The next is, why flaps are deployed only during the takeoff and landing, why not during cruise? The flaps are primarily deployed during the landing and takeoff to increase the C

L max. So, that you do not reply very large land road distance that takeoff or is to land.

So, both you are using this flaps in the cruise, while I am putting the flap down lot of drag increases. So, unnecessarily lot of energy will wasted and the engine will be using unnecessary power and fluid will consume and you do not get anything; that is why it is primarily landing and takeoff. So, that we are flying at this speed lower, much lower, very close to V stall and we want larger lift.

So, that takeoff distance landing distance or the landing distance or bear minimum, this thing you are to add in this. Yes, when we cruise, we have enough speed to look get sufficient lift, even without using the hide lift devices. And that is speed, if you used flaps, it will increase our drag unnecessarily. Let us proceed with the next question, how ground effect X on the aircraft and how it affects that takeoff and landing? At this stage is primarily understand that, because of ground effect, the induced drag reduces.

But, we are given an expression, when the aircraft is close to the ground in takeoff, during landing, once should lands, I would always like to have very minimal lift, in fact 0 lift, I do not want any lift that time, all will be the breaking. So, at this point other going to detail, the ground effect for us is basically reduce the induced drag, because the deflection of what is from ground to back to the airplane. It is also change the lift craft slope, but let us not discuss about it.

If you read you will find the downwards also exchange. So, some trimming of the tail also need to be require to be change to the counter for the change in the downwards. Whereas the performance is of course, is good enough to understand, during the ground effect, the induce drag compound and reduces. This K C L square little bit of 5 into the K C L square or 5 less than 1.

So, the words are reflected and induce drag is reduced and the next question is, when we touchdown, why our real wheels touch the ground first? That is primarily for some reason that when you are landing, you still on the maintenance of large angular of attack. So, that lift is equal to weight, it does not fall like a stone. So, that is that makes us compulsory does ensure that the rear wheel that this first and then the nose wheel to have their angle of attack.

There were playing were, now one can land with nose wheel also their older plane, but then the length will be different. But, a point is you cannot compromise on the fact that, when I am landing and it will high at 7 to 8 degrees of angle of attack. So, there lift is

balancing the weight. Yes, it is a quite obvious, when you touchdown, we need larger angle of attack, so that our touch speed will be minimum and lesser landing distance.

Some of our viewers one to know, why the jet engines at described by the thrust required and reciprocating engine by power required? You know, it is actually the question is not very correct, when you talk about jet, how do I benchmark a jet, jet is benchmark by thrust. That is small mass of fluid, it throughout a higher speed, a little moment of exchange, but when I come for the popular driven airplane we will understand larger marks is thrown back with a smaller speed.

However, when you want to the basic principle, if you see from the energy point of with they are not very, very different, we not very, very different. Though, they are not same definitely; however, what one think you can understand for characterize an airplane with jet engine, it is easy to say this plane is producing this much of thrust. Now, if I talk about the propeller driven engine and if I say do you also producing some thrust, it is in this producing some thrust.

But, if going to benchmark it, how can you benchmark you know one shaft is rotating is energy is being, it gets the energy from bending of the fuel and so we say there is a power available at the brake and then, you attach different type of propeller and extract the power from it. From that angle, we will talk about power rating, when you talk about the propeller driven engine.

And next, I was does the wind effect, the range and endurance? There if till you explain, the endurance has nothing to do the wind at all, because it is all about the consumption of fuel and the duration of flight. But, the range will certainly fatted by the wind, if the wind is had wind, it will reduce our ground speed and you will get less arrange and similarly, if our wind is tail wind, it will increase our ground speed and we will get higher range for the similar fuel conception.

Very good next, what is glide? So, when you say glide is suppose throw the stone, it was a go would like this falls like this, I do not called it glide, glide means the weight of the body as to be balance by somebody. In case of glide, it is balance by a lift. So, instead of falling like this, it goes like this. So, that is we call gliding; that is the glide angle is very minimal. So, instead of falling like a stone of like a projectile, it actually flies like part port of the weight is balance by the lift produce by the wing.

So, there no thrust in this absolutely, there no thrust in convectional way of talking about

gliding or glide flight. In addition to that, we tradeoff our potential energy, which is because of attitude and we get forward speed to maintain our lift and next question is for you, why we ignore buoyancy force, force on aircraft, what happens, if you consider it? That is very good, he is you are right, there will be balance force, but no if I planning to work on airship, aerostat or balloon, where the weight of the body material usage is very small.

Then, there is a point in talking about buoyancy, buoyancy is nothing but, it is the weight of the displace fluid, but for aircraft or where materially is so metallic material weight is so large we find the advance component, it is very, very negligible. So, we neglect it, thanks, that was very precise, the next is, why tail is also called stabilizer? Why tail is also called stabilizer, you should be able to explain better than me, please explain, sure sir.

We have already seen, whenever there is changing angle of attack, due to the tail, the aircraft has a tendency to nullify this change. And from the control and the stability point of view, we can say, the tail is providing of a negative feedback and whenever, there is negative feedback; that would be contributed to the stability. That is why; we can say the tail is stabilizer. Actually, this is the probability, in this man is an electrical man is a control man to be explain things in his own knowledge and as we understand, I try to understand a language of an electrical person is what any control.

I understand, if there is the disturbance at the positive angle of attack, it will the aftail, the stabilizer will generated negative moment. What you call from it feedback and you know, it causes an initial tendency to come back to the equilibrium. So, you call it is providing static stability. See, how wonderful this merging of electrical and other spacer have been ending with Mr. Dwivedi, who is now, what you know solar part.

We will soon see that in 1 year was solar part, IIT, Kanpur will launching and the main person whose what the electrical research scientist, principle scientist on the solar part is Mr. Dwivedi, Vijay Shankar Dwivedi here. Our many view are confused sometimes you C Lock C m versus alpha and sometime C m versus C L here. That is see for symmetric aerofoil or any cambered aerofoil, whether the air plots C m versus alpha or C m versus C L, actually C L and alpha related, C L equal to C L alpha into alpha plus C L naught.

So, that is the scale only get change; however, there is the very good question, you know if it is the symmetric aerofoil, there what are you put C m versus alpha if C m versus C

L. You know at alpha equal to 0 it will be C m naught, C m naught will be there. However, if you are plotting C m versus C L, then C m naught is basically C m at C L equal to 0.

Now, think of an cambered aerofoil, cambered aerofoil C L is 0, when at alpha equal to 0 C L is not 0, it is C L is 0 at some alpha positive angle, alpha negative angle. See, for cambered aerofoil this at alpha equal to 0, C m is not 0, we are alpha equal to 0, there will be some C L naught. So, for cambered and for symmetric when I am plotting C m versus C L, we have to careful at C L equal to 0, what is the C m naught? This is the mathematics part, but physical part, one I put C m versus C L, I know the d C m by d C L is related to the static margin.

So, if I there d C m by d alpha, I cannot write equal to minus of static margin, but if I write d C m by d C L, then I can write d C m by d C L, you going to minus static margin roughly speaking. So, that helps me let explain many thing are helps be a designer, how much static margin should a keep, what should the slope of that line, what should the intersect? But, you should very careful that if I bearding C m versus alpha at alpha equal to 0 whatever C m is there at I call C m naught and I need a positive C m naught to dream the airplane at in positive angle of attack.

For same C m naught if I define at C m at C L equal to 0, the value will be different, the alpha remain the same. So, have to careful about it. We are approaching to the limit of the time. So, let us wrap of with this final question which many our viewers want to know, what is the procedure to which it is pipeline? As for gas pipeline is concerned, you by now you know Mr. Dwivedi's Email ID, they know your ID, I will give my contact details in the end of the session.

You have to simply a send an E-mail request, it that to his E-mail ID or to my E-mail ID note down my E-mail ID, it is akg at the rate IIT dot ac dot in. You send me a mail, it will be good or better if look and plan you are visit in a group by 5 to 10 in a group. So, there I can plan it that does not mean, if you want to come alone, I will not entertain you, we are most welcome, this flight level created by tax payers money.

And you part of the citizen; you have equal rights as my shoulder is have. So, most welcome to flight lab and I am looking forward to see sometime a flight lab and exchange one to one in person I hope you have enjoy it, it was our initial experimental effort, you were aware of that, there is a need to proof the recording, the need to improve

use a virtual board. And those things are simple things, first of most important thing was, whether our young community needs us, let say medium or not.

And once you get a positive feedback, other things upgrading it a higher scaling technically is a trivial thing. Most important thing is, whether how our young people have that enough passion to learn aerospace, if you have that, you are always with you.

Thank you very much.

Thank you Professor Ghosh for your valuable time, it was really the very informative session for our viewers as well as for me. So, friends this was our final session of this series, we try to cover as many as topics and portions as we could, what we own know, questions never end. If you have any query, please feel free to direct them to us, we will try our best to address them.

You can reach to us by our web forum, which is hosted at NPTEL website or you can drop the mail to Professor Ghosh or me, my email address is Vijay D at IITK dot ac dot in. I hope you enjoyed from the session and benefited from this apart from technical queries, please let us know about you are views on the session. Your feedback is valuable for us, it helps us to improve that is all, I have for now, thanks for hearing with us, keep watching keep learning.

Thank you.