NOC: Introduction to Airplane Performance
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Lecture - 25
Revision

Good morning dear friends, today is the session for Mann Ki Baat and you know, we have been discussing about range, endurance, gliding flight, then turning flight or accelerated flight or there is a pull up or that is a turn that is primarily the topic, what we covered in the last module. And, when I was getting tired giving lectures, recording lectures, after lectures and we hardly get some feedback from the blog. My TL will tell these are the basic questions, they have in the mind, settling among themselves.

It is very heartening that, you are participating, you are discussing and we are watching that and that is how I pick a few points, what should be the Mann Ki Baat topic is. One of the most important thing, which I need to mention here. Please understand, whatever power required, thrust required, range, endurance we have discussed, we have discussed them in an standard atmosphere, that is we have not assumed any wind blowing that is, suppose the aircraft is going like this, in actually atmosphere there could be wind following the aircraft, there could be wind from just opposite direction of the motion of the airplane.

So, if the airplane is going like this ((Refer Time: 01:39)), if wind is coming like this, the atmospheric wind, then we say it is a head wind, the aircraft is experiencing a head wind. If, the aircraft is going the going this direction ((Refer Time: 01:52)) and atmospheric wind is coming in this direction, then we call it tail wind. In fact, there will be atmospheric wind at any altitude, some altitude it is more some altitude it is less and they will have their own direction and generally, we define their direction in terms of north, south, east and west.

However, if I know, what is the direction of the wind and which is atmospheric wind, then I can always resolve those components along the aircraft x axis and one perpendicular to that. So, you can easily find out whether it is a head wind, whether it is a tail wind, whether it is a cross wind, cross wind means aircraft is going like this ((Refer Time: 02:37)) wind is coming like this, perpendicularly from right to left or left to right, that is how we characterize.

What is important to understand here, whenever we have talked about power required, thrust required or range or endurance, we have always spoken in terms of an atmosphere standard atmosphere, where there are no atmospheric wind; that means, I can assume that the atmosphere is stationary, that is why whatever air relative velocity of the aircraft was and that is exactly same as the ground relative speed.

Because, the atmosphere we have assumed to be having no speed no velocity, typical standard atmosphere. But, we will quickly see if there is a head wind or tail wind, what will happen and in the formulation fundamentally, where we should be careful. So, today this Mann Ki Baat one of the topic I have chosen is to give you a guideline, how to handle atmospheric wind, where it will affect, where it should not affect, this is one part.

Second, we will be talking and we, I perhaps might have mentioned about delta wing or a wing of this set of a shape, which is also called flying wing and today also, you will see that I will take you to our one of the very important room, where we actually make models, which are not aero models, which are actually designed on the black board and then, it is fabricated and that is a fun.

So, one clip will be there where you see, so many delta wings are lying, so many other type of configurations lying, the room is flooded with so many instruments and the whole truth that finally, we have been successful in designing a low altitude, long endurance, unmanned aerial vehicle autonomous, which you might have seen in the newspaper and there is lot of demand on us to meet the requirement of so many agencies.

That also, we are showing you, from classroom what you have understood, we have gone to a room where we can experiment. Once we are sure through initial flight, these design parameters are okay, because in that model, we have instrument it, we put the accelerometer we put angle of attack sensor.

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For example, if you see this model delta wing here, we have installed angle of attack sensor and beta sensor, the angle of attack sensor will be horizontal like this, it wll measure angle of attack and beta. Sometime, what we do for symmetry, we put beta sensor side slip angle or your angle sensor here and angle of attack sensor here. So, that there is a symmetry, symmetry is not lost. We put I M U inertial measurement unit inside this, which is gyro based, which tells you the attitude, accelerations and the orientation to the magnetometer based instrument.

These are extremely important; it is not matter of what you fly. Any area I can fly, you know George Cayley has told us that you have to give sufficient speed or velocity. And what is important for designer is, whether I am able to fly the machine, the way I have design the mission requirement. For example, I only should attain a height within this much of time, whether this model is doing or not.

If, I want it should turn at this particular rate, whether this model is doing or not and that is what is important that is how we get hands on experience and what are the problems. How one has to swift to convert do how to know how or know how to do how, it is a reversible process. Sometime you know something theoretically, then you try to implement it in a hardware and when you implement, you realize somewhere I am doing mistake come back.

So, this sort of an iteration goes on and finally, you find which will be seeing keep you must be watching now on our unmanned aerial vehicle. That is a grand success story of us, the student ourselves and one of the few start up members who joined us, so that is also one of the aspects you will see.

Student: Welcome to the flight laboratory IIT Kanpur, I am Vijayshankar Devedhi, Student and TA in this course. This is the place where we fabricate our designs.

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Here, you can see I am surrounded by a lot of instruments and equipments, which are required to make initial design of an aircraft. You can also see many airplane models, which we have developed to meet some specific requirements.

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This is the flat plate, which was developed to compare the aerodynamic characteristics with the flying wing. The flying wing and to more other configuration of the flying wing ((Refer Time: 08:09)) glider, which has very good gliding ratio about 45.

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This is the power parafoil, the parafoil attached to the trachea, here are cells and if fills with the air and it is cross section takes the shape of a airfoil and this is attached to the suspensions, when the suspensions are pulled in a symmetrical manner. The cambered changes and it works as an elevator and at the same time, if we increase our throttle it climbs for the steering, the suspensions are pulled in a differential manner.

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And now, this is our state of art, low altitude, high endurance, unmanned aerial vehicle, which is fully autonomous. This is fabricated with glass fibre, carbon fibre and other sandwiched materials, it has wingspan of 3.3 metres. For tail, we have three options, the one you are seeing here, inverted C tail, the maximum takeoff weight is 25 kilograms. It can carry payload up to 5 kilograms, which can be increased by decreasing the fuel weight currently as a payload.

A high resolution camera is mounted, which can be operated from the ground station. The required takeoff distance is 50 to 100 metres depending upon runway and runway location. It is climb rate at sea level is 2.5 metre per seconds. The operational attitude is 5000 feet from the takeoff point, it is endurance is 6 to 8 hours, which is remarkable in itself, it has operational range of 200 kilometres from the ground station.

The best part of this place is these facilities are not limited for the IIT Kanpur Students only. Any student or researcher from anywhere in India can take advantage of these. If you want to use this facility, simply mail to us, we are available all the year; however, it is preferable in October and November.

Thank you.

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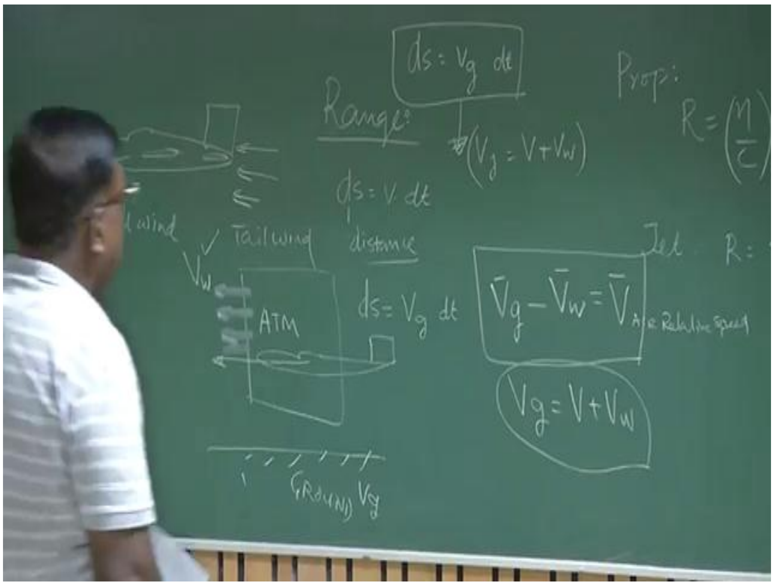

I come back to the effect of atmospheric wind primarily in this session. Remember, when we are calculating range, what was our understanding that we say d s small distance travelled is V with a constant speed it is going into d t for the small duration time. But, what is this? This is distance, this is distance which distance, how do you measure that distance; I have mentioned it with respect to the ground, so this is actually when I am thinking of d s, it is V g dot d t.

Since, so far we have assumed that they are the atmospheric wind, so air relative speed of the vehicle or the ground relative speed of the vehicle were same. But now, the moment you say there is an atmospheric wind, that is suppose this is an airplane and this is the wind may follow the tail like this, this is called tailwind and there could be a case, where wind is approaching the aircraft like this, which is called headwind.

So, this was not incorporated because we are all working in standard atmosphere, where we assume that the atmosphere is still, there is no atmospheric wind. So, what is the implication? Implication is very simple, that I can write the air relative speed minus V w will be the… So, what is the difference? Difference is, if this is the atmosphere, say this is atmosphere, this is the ground and this is the vehicle, this is the vehicle has a speed with respect to the ground, which I say V g.

The atmosphere is also having a speed now, or velocity, because there is a atmospheric wind I say V w. So, then what is the speed of this aircraft with relative to the air medium on the atmosphere, that is a question that is responsible for giving lift and drag is not it. Since, V w is also a reference to the ground and V g is also refer to the ground, I can easily write V g minus V w will be air relative speed of the vehicle. This is the air relative speed, there is no doubt. So, what is V g? So, V g is actually is V plus V w correct.

So, when I again come back to this equation d s equal to V into d t and I know that V has to be V ground or V with respect to the ground and it was equal to the air relative speed, when they are on the atmospheric wind. But, now if there is an atmospheric wind I have to write d s as V g dot d t. This is the correction, correction means this is the, you have to modify your things, where V g is v plus V w. This is clear; this is at a fundamental level. Now, we again go back to our formulation of power required, let us see where we have to modify if there is an atmospheric wind.

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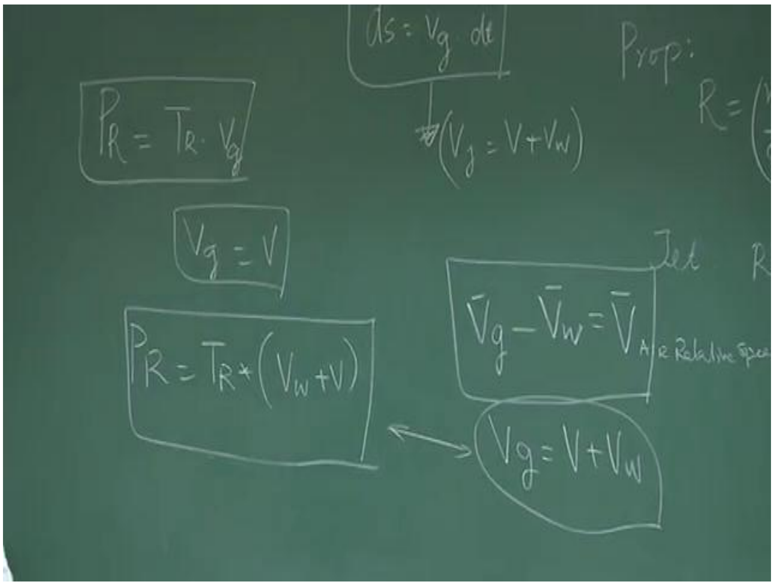

How, did we calculate power required we said power required is nothing but, thrust required into V, which V something that is to be moved some work has to be done unless there is a displacement, there is no work done and the rate of change of that work done is power. So, this V has to be, V with respect to the ground V g. Is it clear? The vehicle is moving with respect to the ground. Now, the question is when there was no atmospheric wind, then V g and air relative speed V were same.

So, we calculated like this for a standard atmosphere very fine, because in standard atmosphere there is no atmospheric wind. But, now atmospheric wind is there, so what happens P R is what thrust required into V g is V w plus V, where V is the air relative speed from this. Just to give you more insight about V relative air relative speed imagine first of all we understand that the lift and drag they are generated, because of relative air speed.

So, even if theoretically an aircraft is stationary if I have atmospheric wind coming like this, so there is a air relative speed. So, it should produce lift and it should produce drag depending upon what is the orientation, so theoretically it is possible the airplane is not having any motion with respect to the ground, but still because of atmospheric wind there is a lift and that is sufficient enough to balance the weight theoretically it is possible.

So, in that case what is a power consumed nothing, because there are no motions of the airplane with respect to the ground. So, when you are doing formulation, which wind or atmospheric wind, we have to be careful that here, it should be V g and V g, we know is V plus V w. Now, let us see revisit this range this is a propeller driven range, because range estimation formulation uses V g that is V to respect to the ground for a endurance nothing is the air relative speed, so fine no issues.

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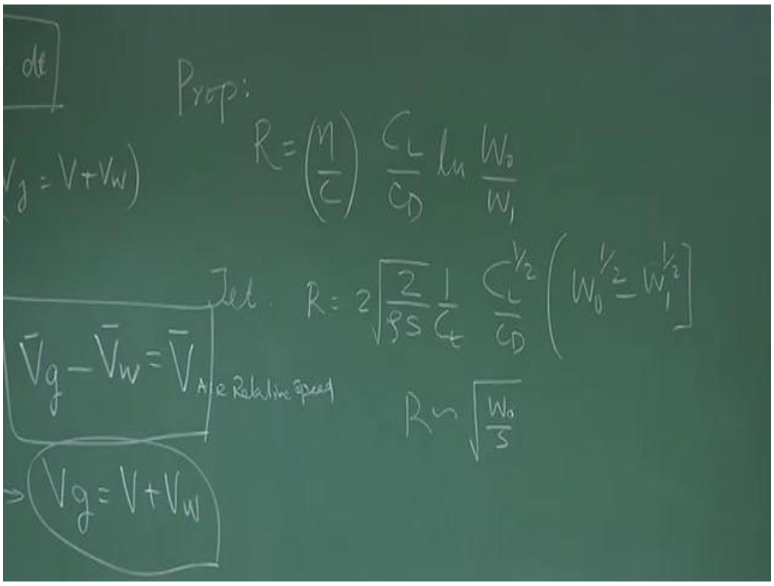

Now, see if you come to the range, what I see range is maximum when C L by C D is maximum. So, there is a corresponding speed for that corresponding air relative speed for that, but if there is an atmospheric wind, how should I change this formulation that is the question.

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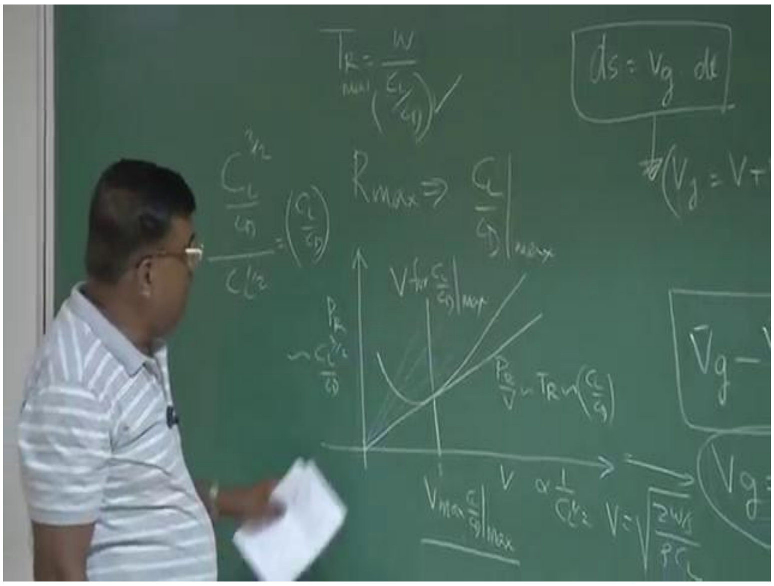

So, range maximum from that I am finding it, when C L by C D is maximum this was propeller driven I C engine aircraft. Now, let us go a little bit into it, if this is power required versus speed let us say it is something like this you are now aware now watch out this power required is proportional to C L 3 by 2 by C D, you can check your notes and V is proportional to 1 by C L to the power half, because V is under root 2 w by S rho C L.

So, if I divide C L 3 by 2 by C D divided by C L to the power half what I get C L by C D, typically I am talking through these dimensions its variations. So, what is the interpretation is if I draw a line, which is tangent to this power required versus V and the tangent starts from V equal to zero this point is basically, which we have done V for C L by C D maximum, where the slope is giving C L by C D from this ratio.

I have tried to explain, but also you understand what is this slope this slope is P R by V that is thrust required and you know thrust required is proportional to C l by C D I have tried to interpret this slope through C L 3 by 2 by C D and C L to the power half and I have shown that this is nothing, but C L by C D. Now, try to see what is this slope actually for us this slope is nothing, but P R by V P R by V is nothing, but thrust required and this is the minimum slope any other line, if you draw we have seen that this slope will increase.

So, this is the velocity at which P R by V is minimum or thrust required is minimum which implies C L by C D is maximum, so this is the V max for C L by C D max. I repeat this is the point, where this slope P R by V is minimum that is thrust required minimum and that thrust required minimum means, you have to apply at C l by C D maximum, that you know thrust required with w C L by C D if thrust required is minimum you know C L by C D has to be maximum.

So, from this slope also you get a interpretation that this is the velocity where if I fly I will be flying at C l by C D maximum and that will correspond to from here ((Refer Time: 20:21)), C L is maximum means I will get range maximum. Now the question comes, what happens if there is a wind that is the question we are trying to address.

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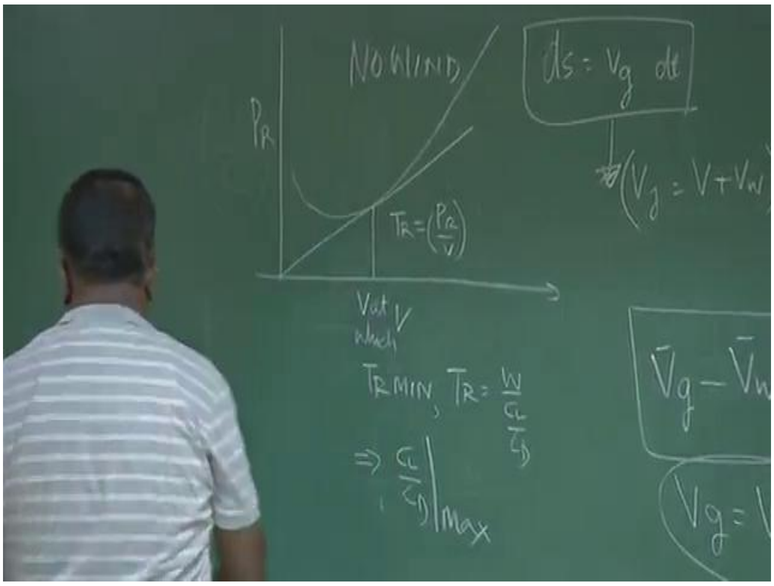

So, there is a very simpler way also there to interpret required versus velocity and when I draw a this tangent and the slope is T R equal to P R by V. So, this is the speed or velocity, at which thrust required is minimum and you know thrust required equal to w by C L by C D, so this implies C L by C D maximum.

So, this gives you V for C L by C D maximum and the moment I said it is a V for C L by C D maximum, I know this is also the speed for a propeller driven aircraft for ((Refer Time: 21:42)), which range is also maximum that is this is also the V for range maximum this is, when we talk about no wind condition. But, what we are trying to discuss today in our Mann Ki Baat session is, what happens if there is a wind.

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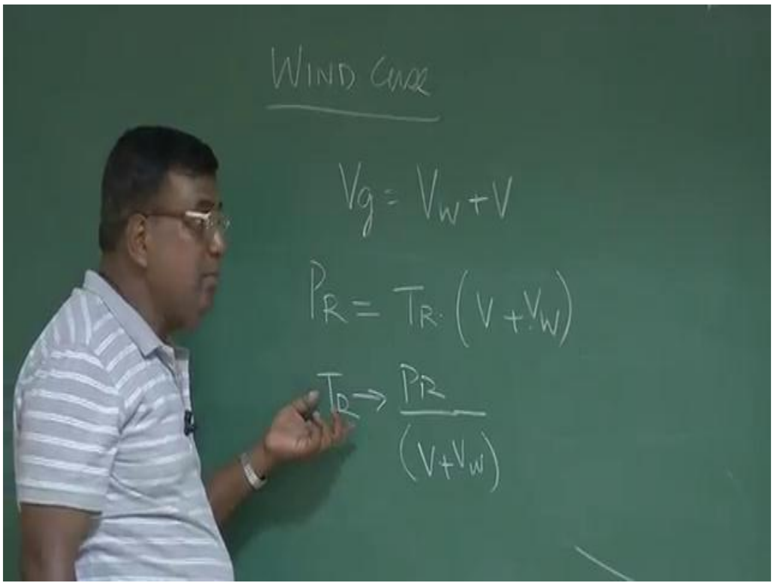

So, now, we are smart we know for our wind case that is atmospheric wind case no more we are assuming the atmosphere is stationary, then you know V g is nothing but V w plus V, where V is the air relative speed and your power required is thrust required into V plus V w. So, in this case thrust required is power required divided by V plus V w and now this T R, which is P R by V plus V w has to be minimum.

So, that the C L by C D will be maximum and hence the range will be maximum is the statement clear now it is V plus V w. So, now, in this case the thrust required should be minimum and thrust required minimum means C L by C D is maximum and C L by C D maximum means the range is maximum.

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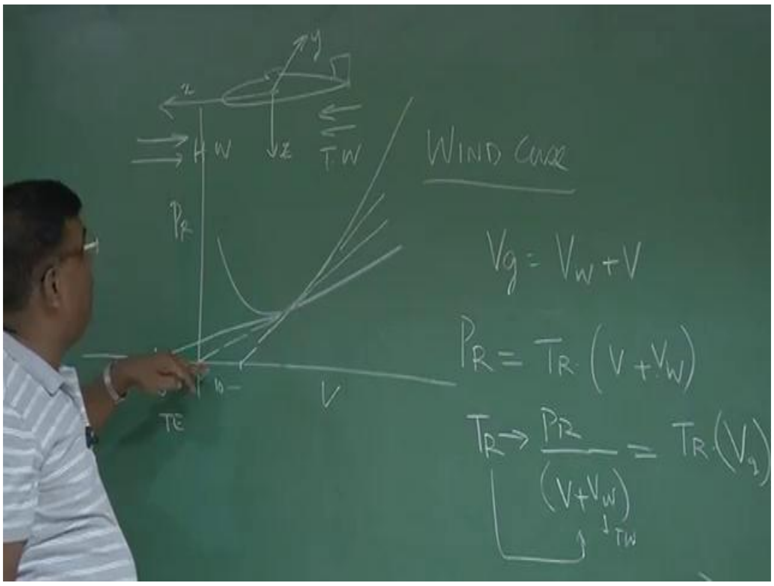

So, how do I use same graph, what I do this is power required versus V, now suppose if it is a tailwind as far the convention if this is a aircraft, this is x, this is y, this is z tailwind means like this that is along T W is tailwind along x direction and H W is headwind the opposite direction. So, as far as this convention tailwind is positive, so what we will do if it is positive means the power required has to be divided by a number larger than V relative, which is in stationary air it was earlier we are doing that.

So, very simple if this power required versus V graph is available with us, what I will do I also further understand, what is power required is thrust required into air relative speed V, which V this is V g that is how this thrust required has come this same thing here, which I have written in a other notation.

So, now since there is a V w what I will do if it is a tailwind; that means, this is positive tailwind this is positive let us say 5 metre per second or 10 metre per second tailwind is there. So, what I will do I will come to this x axis and cut 10 here in the negative side and then I will draw the slope from here, and for zero wind it was slope was drawn from here this is for tailwind. Now, you could see the power required divided by whatever V from here plus this of much of tailwind has come.

So, you will get different speed and suppose if it is a head wind, then you take here let say 10 metre you cut 10 and then, you try to find out the slope, though it is indistinguishable in the scale of this diagram, but you can guess one thing that as I am going off from no wind condition the slope of this line is reducing as I am going towards headwind slope is increasing correct, what is the meaning of that.

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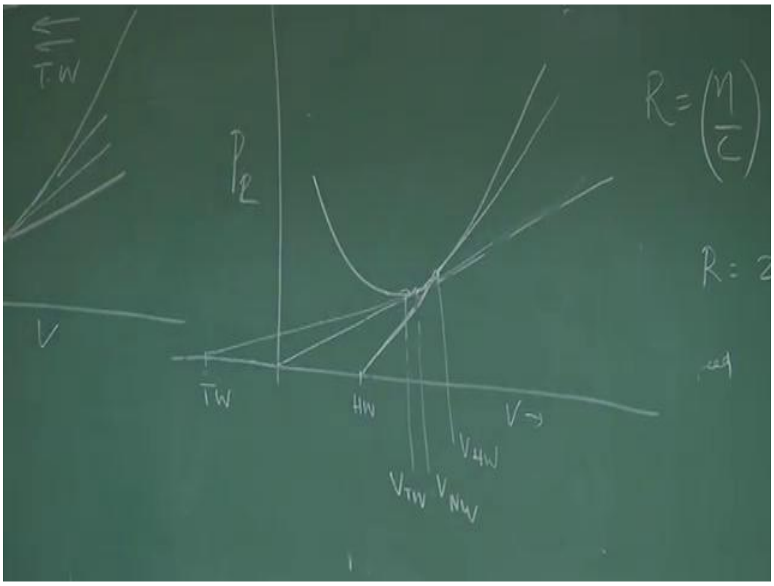

Let me, draw a better diagram, so that you understand if it is like this, let say this is your no wind and let say your actually ((Refer Time: 26:09)) if you see very carefully there are three points one is definitely there is the no wind. So, this is a V for V for no wind N W as there is a tailwind the slope changes and this speed is less than the speed for no wind that is a speed for C L by C D max for with a tailwind it will be less than V N W and with the headwind this V for C L by C D max with headwind will be more than V no wind case this is the graphical you could see that, because this is power required and this speed.

So, what is the message, message is simple if I am going from here to here the that point and suppose I am going like this there is the no atmospheric wind, let say take some fifty minutes now second time, when I am travelling from Kanpur to luck now, let us say Kanpur and luck now. Then, again when I am travelling I find a tailwind, what will happen the moment there is a tailwind the air relative speed will reduce is not it as it reduce because we are talking about air relative speed with respect to the atmospheric atmosphere that is reducing, so lift will reduce.

So, you have to increase the ground speed to ensure that you have got same air relative speed to balance the lift in the process, what will happen you will reach luck now faster right in a contrast. If you see, when I am going from Kanpur to luck now, there is a headwind now, what this headwind will do since there is a headwind I need lesser ground relative speed to have the same air relative speed to help the lift, because lift depends upon air relative speed, so my ground speed will be reduce.

So, I have to longer time i may even loose a trajectory I may even lift up, so what is done you have to go little faster. So, we give a throttle, but if I only increase the ground relative speed, then air relative speed will increase. So, it will lift up like this, so we nose down the aircraft we reduce the angle of attack and try to compensate for time this one, but if I am a passenger I will always love to have a tailwind, so I can go fast faster and reach earlier.

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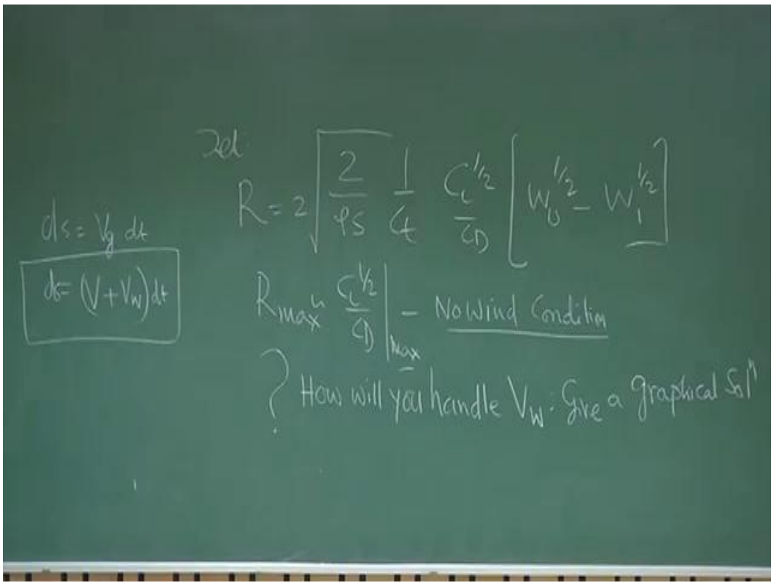

So, this is one of the concept I thought I must discuss with you, now natural second question will come what happens to the jet engine aircraft a range if you see it is two under root 2 by rho S 1 by C T, C L half by C D w naught half minus W 1 half here you see the range is maximum for other condition remaining same if C L half C half by C D is maximum again the same situation will arise that this is for no wind condition I am leaving a question for you how will you handle V w presence or atmospheric wind and give a graphical solution as you have done for range in case of propeller driven aircraft.

Because, I just give you a hint, when you start thinking like this you will know that d s is nothing but V dot d t, but now as there is a atmospheric wind I have to be more careful I write V g speed with respect to the ground dot d t and V g is nothing, but V air relative V W d t this should be kept in mind to find out what is the effect on range and how do i interpret C L half by C D and its corresponding speed what is the speed I should fly to have range maximum.

I hope you, will be able to answer this let us see if you get an answer fine I we are watching your blog, if you do not get an answer, we will come back in next Mann Ki Baat.