Aircraft Structure - 1
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Lecture-11
Unit Load Analysis of Fuselage

Welcome back to aircraft structures one this is professor Anup Ghosh from aerospace engineering department, IIT Kharagpur. This is the last lecture of second week lecture 11, Unit Load Analysis of Fuselage.

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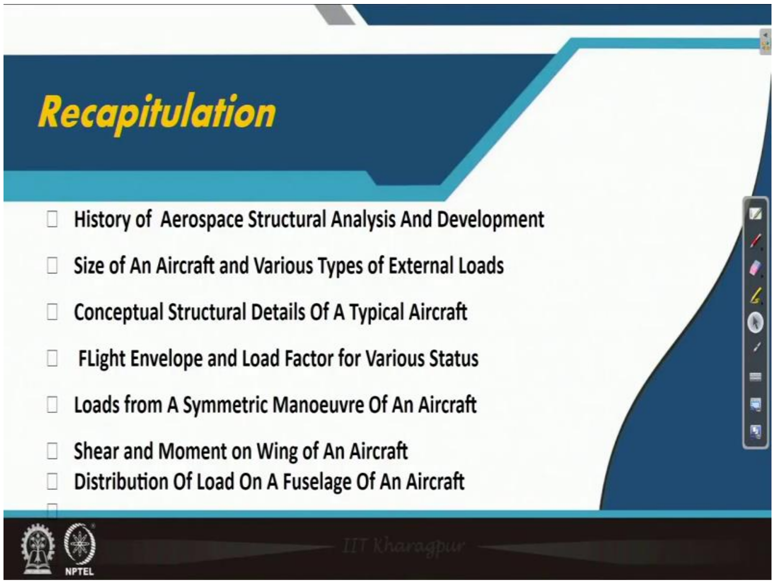

In the last lecture we have we have completed the load distribution and this lecture will continue from there before that as it is just now I have mentioned we have learned what we have learned that as a quick recapitulation. You can say we have learned some history from solid mechanics view or structural analysis view to the development of aircraft, conceptual detail of aircraft. How big small variation of wing positions all those we have done.

Flight envelope, please excuse me for that flight envelope and load factors for various status and then loads from symmetric maneuver of any aircraft. So, these load factor how does it vary where that is very important part how does it, where you; where it is taking; which value? Those things we have discussed. Then on an aircraft we have considered the wing load and then using the wing load we have found out the bending moment shear force acting on the wing.

And then in the last class we have started the fuselage bending moment shear force diagram and bending moment shear force analysis but since fuselage is a different type of structure than wing and it causes of different other category loads including loads coming from its own weight the fuselage weight that we have seen that how that own weight is distributed throughout the length of the fuselage.

And how that balance is maintained about an axis z axis the vertical axis or the first line axis or about the x axis then accordingly we have distributed the fuselage weight, total weight that is distributed along the length x as well as along the length z. So, maintaining the total moment of that. So, with that concept we have already come across a table and that table shows us the final distribution of the loads it is not only the loads coming from the fuselage.

It is also the loads coming from other payloads like the pilot like other radio equipments say or other passengers whoever it is those things are distributed on the fuselage various station points. Like the wing analysis here also we have considered station points and windows station points how it gets converted as a concentrated load or a moment that we have seen in our last lecture with figures with good explanation in the figures and for any kind of clarification I would suggest carefully you look at the figure and the description you will come to know how it is? Where it is?

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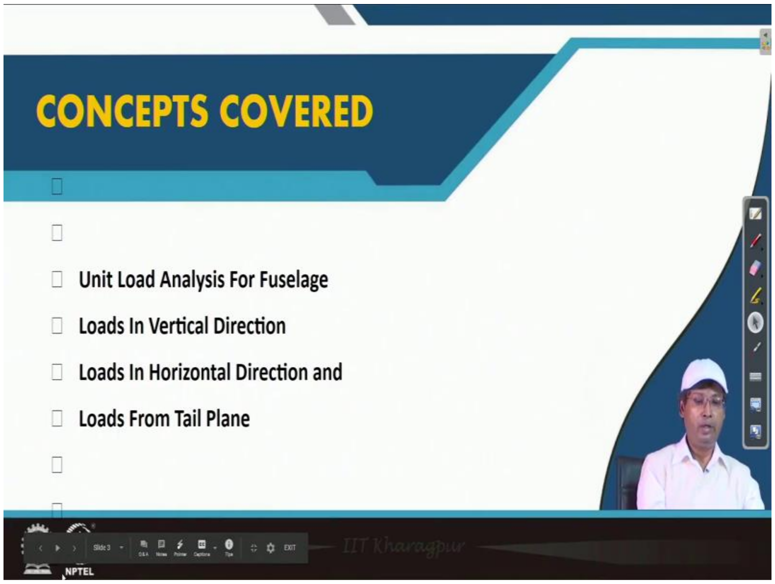

So with that load we will start today unit load analysis we will start today unit load analysis for fuselage will consider three load conditions Loads In Vertical Direction, Loads In Horizontal Direction, Loads From Tail Plane. So, in each and every case as a unit load analysis will be considering unit acceleration and then we will continue our study.

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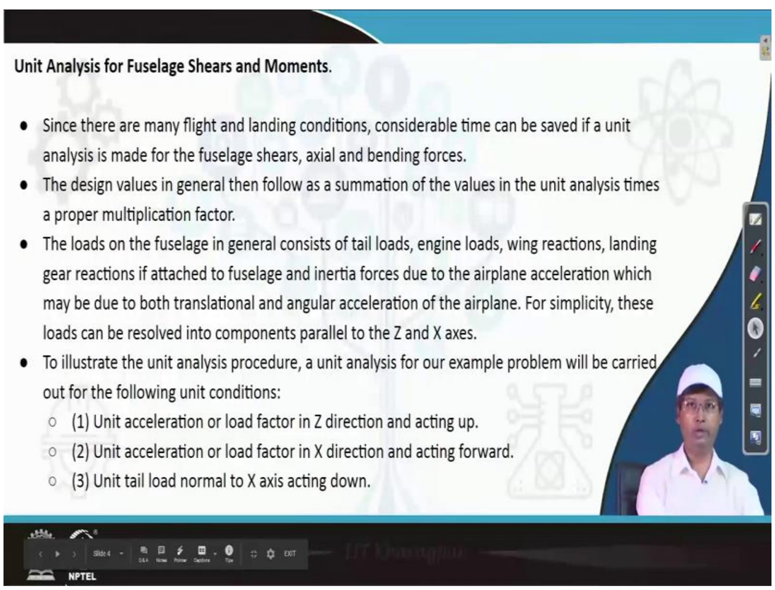

So, following that same line the unit analysis of fuselage shears and moments since there are many flight and landing conditions considerable time can be saved if a unit analysis is made for the fuselage shears, shears and bending forces. This is actually the purpose of unit analysis we have already discussed it is a repeat, no problem in that I guess the design values in general then follow as a summation of the values in the unit analysis times a proper multiplication factor that means if the direction Z is more that many times you need to multiply it with it and then you will have to add it.

The loads on the fuselage in general consists of tail loads, engine loads, wing reactions, landing gear reactions if attached to fuselage and inertia forces due to the airplane acceleration which may be due to do both translational angular acceleration of the airplane. For simplicity these loads can be resolved into components parallel to Z and X axis that we have already resolved in our previous class we will continue solving that same problem.

To illustrate the unit analysis procedure a unit analysis for our example problem will be carried out for the following in condition. Unit acceleration or load factor in Z direction as I mentioned already, unit acceleration or load factor in X Direction. Unit tail load normal to X-axis acting downward. So, these 3 conditions will be conspire we will be solving today. Let us see how do we proceed in the first case.

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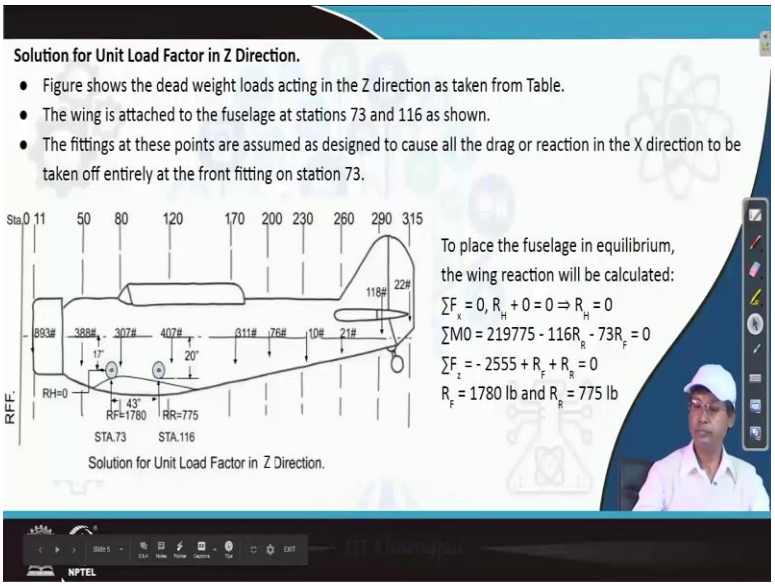

Solution for unit load factor in Z direction, figure shows the deadweight loads acting in the Z direction as taken from table. This values it is talking about all these values 893 pound at station 11, 388 pound at station 50, 307 pound at station 80, 120 at station 120, 407 at station 170, 311 at station 200, 176 pound at 230 station 230 it is 10 pound 260, 21 pound at station 290 it is 118 pound at station 315 it is 22 pound.

The wing is attached to the fuselage at station 73 and 116 as shown. So, here the wing is attached the fittings at these points are assumed as designed to cause all the drag or reaction in the X direction to be taken off entirely at the front fitting of 73, at station 73. Let us repeat the fittings at this point are assumed as designed to cause all the drag or reaction in the X direction to taken off entirely at the front fitting that means whatever coming the horizontal force that is taken by this one at station 73 that is what is mentioned here.

Let us try to find out the reaction components at the wing fitting? To place the fuselage in equilibrium the wing reaction will be calculated that is the weighing reaction is a very small easy calculation we need to do summation of x equals to 0 that is R H gives us the R H equals to 0 summation of MO about point O about this point it is 0 and this has to be subscript and that we considered a 219775 - 116 or this 116 this data 116 is coming from the distance here it is 73 station 73 and this is station 116.

This O is about this point that is the reason 116 is coming here and 73 is also coming there, so that gives us one equation the other Z because two in vertical direction if we consider equals to 0 that gives us the moment sorry that gives us -255 plus this is from the table this is also from the table the total moment and then R F and R R this total moment we know that is the reason the movement is considered about this point, about O.

And then it is it goes to 0 and then we solve these two equations and we get that R F is equal to 1780, R R equals to 775 pound. Here I would like to mention that because calculations may not match exactly digit by digit because in the table if you look at there; because of the rearrangement of the loads there are small changes and to accommodate those small changes sometimes the digit may not match digit by digits, results may not match digit by digit.

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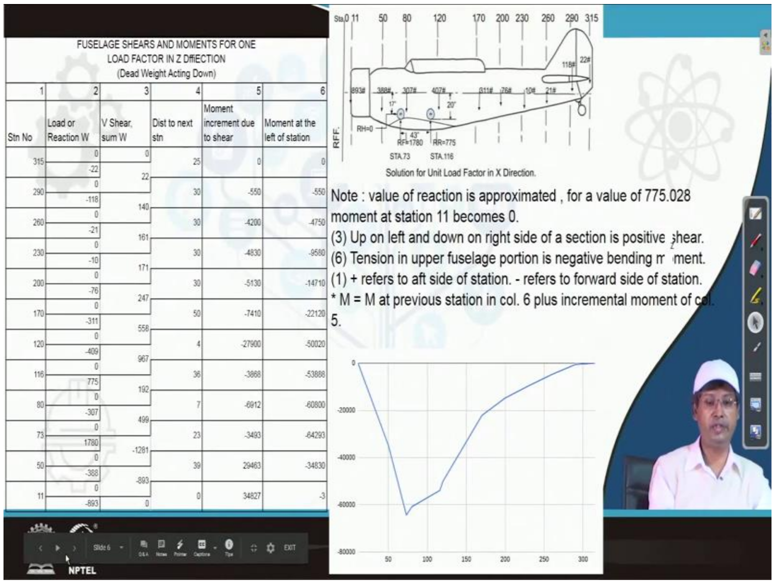

So what we are doing in the next slide? In the next slide we are doing we are bringing in those stations and the left side column and on that station what do we bring at 315 this is that when load 22, -22 before why it is -22? Let us have a value of reaction is approximated for a value of 77 this is this note will come need later we will do it this is with relation to this. So, minus is because we are considering Z up.

Up on lift and down on right side of a section is positive shear. This is please ignore this Z a positive shear actually this is Z axis that jade has come here, please consider this as a Z axis that mistake and then tension in upper fuselage portion is negative bending moment positive refers to the half side of station negative side refers to forward side of station. So, M is equals to M star this one at previous section this column we are talking about at previous station in column 6 plus the incremental moment of column 5 it is talking about M star is this column.

So this is this loads all are considered negative because it is coming down only if we look at that R F 1780 and 775 at 116 station at and at 73 station where wings are at us those are on the acting vertically upward. So, all those loads are put in this column then the shear; shear between these two is definitely the 22 and between these two it is increases on the left of 29 to 90 station here it will come this plus this is coming here and that gives us 140.

And if we go across after the 260 definitely these three gets added up so after 260 sorry after 260 so that gets added up and that becomes 100 161 this plus this plus this so accordingly we add it and we find it that immediately after 50th station 50 if we look at immediately after station 50 it is -388 because this is acting upward these two are acting upward and here it is sorry I should say here at station 73 you see it changes sign at station 73 what is happening this one seven eight zero is acting upward that's get added up and then it is on the other direction.

This sign convention is described here as we have said up on the left and down on the right side of the section is positive shear following that this sign convention is given. Distance to the next station this is simply a subtraction of these two point this is 25 and definitely moment we are getting from there this multiplied by this we are getting this value this multiplied by this we are getting this value and this multiplied by this we are getting this value.

What is happening here the moment is equals to this 22 multiplied by the difference between this station here it comes that moment. But again the other moment is this concentrated force multiplied by this distance this distance is multiplied by this and that gives us this value this, this while get multiplied gives this value. And similarly if we look at other points also we get the moments accordingly and that gets increased increases the value depends on the on the shear acting and the distance between those.

And what we get on the on the sixth column this is fifth column on the sixth column what do we get we get it added that means the moment produced here that plus the moment produced by these two is getting added. So, that is the reason this plus this is this value and then this plus this is getting this value and accordingly we are getting the moment on the fuselage. So, if this moments will have got and we plot it I have again used some spreadsheet utility to plot it.

It is not advisable to plot with spreadsheet you may use some other utility since it is negative in sign that that is not it has plotted on the bottom side. So, it is showing that it at the free ends this is also free and this is also free end that moment 0 is maintained. And the first line as I was telling you that 775.028 it makes this value 0 but we have considered here is that if this is 775 this value is 775.

But if you look at the table third table in the previous lecture you will see that we have made adjustment while we have iterated values and distributed these loads that these loads have has a little bit adjustment and that may increase or decrease little bit in the reaction force being reaction force and considering those things it may be considered that this is also a negligible value or 0 value.

And then following that the moment on the fuselage in the vertical direction unit load in the vertical direction takes this type of form. So, the second part we are will have come across so I would like to go back once to as we were discussing; it is better to note that this are F and R R this to this is say because of Z direction unit load and what we will get later is that that for X Direction unit load as well as for unit load at tail assembly, tail plane.

So we need to add these three while all the three are acting together to give you that concept but I am just trying to differentiate it with R F and R R because later it will be difficult to come back and see it.

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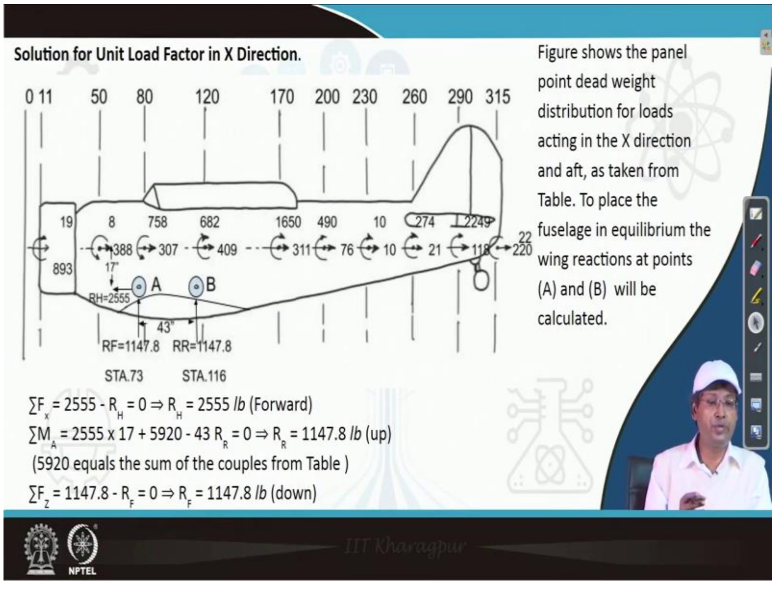

So, we have come to the X direction for solution of unit load factor in X direction this is again taken from that same table where load distribution is considered and the moments are shown here. What do we do in this, similar way as we have done in the last case we need to find out the values of R F and R R. Figure shows the panel point dead weight distribution for loads acting in X direction at different station it is acting in the X direction in association to moments.

And as taken from the table to place the fuselage in equilibrium the wing reaction at point A and B will be calculated this is point A and B as we have done in the last case here also we will do and solving that what the forward as mentioned in the previous and assumption that R H is equal to 2555 pound this horizontal force it is balancing all the force in the this direction. And the vertical two forces R F and R R again it is better to mention that these two are this R R is because of X and this R F is because of X.

So better to note these two that this is not to confuse with the previous case while both say for Z and X both unit load is acting then we need to add up these two and all other moments also. So, let us go forward this equations I am not describing again because these are simple moment equations about A the moment is considered here and all those things are quite easy you can easily get if you look at it carefully.

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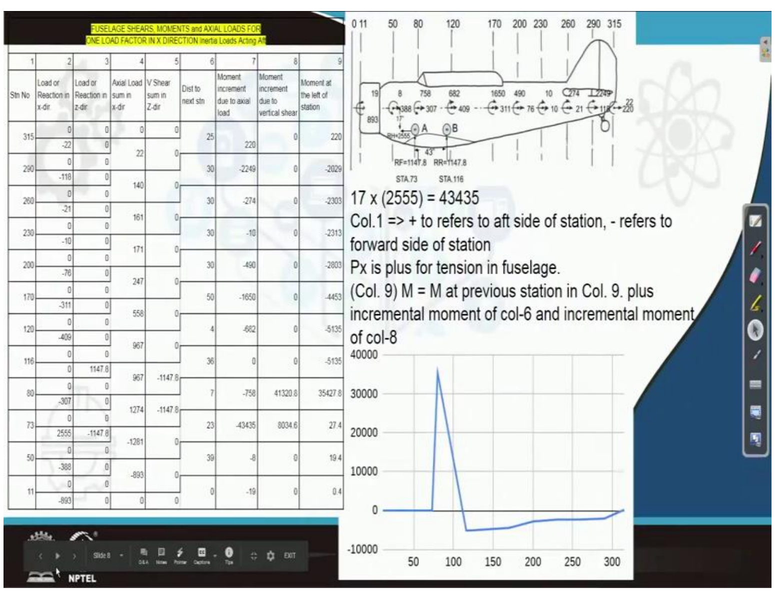

And this table also is there is not much things to explain because already we have explained one table. Only difference is that here we have one more moment component that we need to see moment increase due to axial load, moment increment due to vertical shear, moment at the left of station. So, two things we are we have this vertical shear we are well we are talking about these two you say all other components are 0.

Only this component and this component is having some value and that is because of this shear excitation 73 this is acting this one vertical Z shear this is acting with a x-axis distance of 36 these two gets multiplied and we get this value. Similarly this two gets multiplied and we get this value. So, the vertical shear these two values we have got from their R F and R R are equal values we have, so that is the reason we have these two is here and these two getting multiplied and having this value.

And this is as we have seen this is addition of this plus this plus this and we are getting this value and this is this plus this plus this and we are getting this value. So, the other things are similar if we follow carefully a similar way we have put the loads in X direction and we have put the load in the Z direction as it is mentioned the reactions we have at 116 station and at 73 station and because of that there is a shear force in some in the Z direction.

In the X Direction also axial load increases that gives us this moment component this, moment component we get from this two is getting this moment component this two is getting this 220 is this is the 220 moment; this is the direct moment we are getting that moment is added up this 220 is added up with this to 2249 these components are from directly from there 274 this is X component moments are plotted from the station whatever we have from the station it is plotted here.

And this is the for the vertical shear it is getting multiplied this way we are getting this value. This moment's as we have already found out from there we have put it so accordingly we get the moment on the fuselage because of the X unit load and we plot that X in net load and the bending moment diagram is something like this here we have a negative bending moment up to this station and then again we have a sharp increase in the opposite direction because of these two shear forces through wing reactions and then it goes down from here almost 0, it goes.

You see 19, 20, 27,19 these are very small values and from there it is 0. So, for the x-direction load it is almost clear how do we carry out the analysis and if we move forward.

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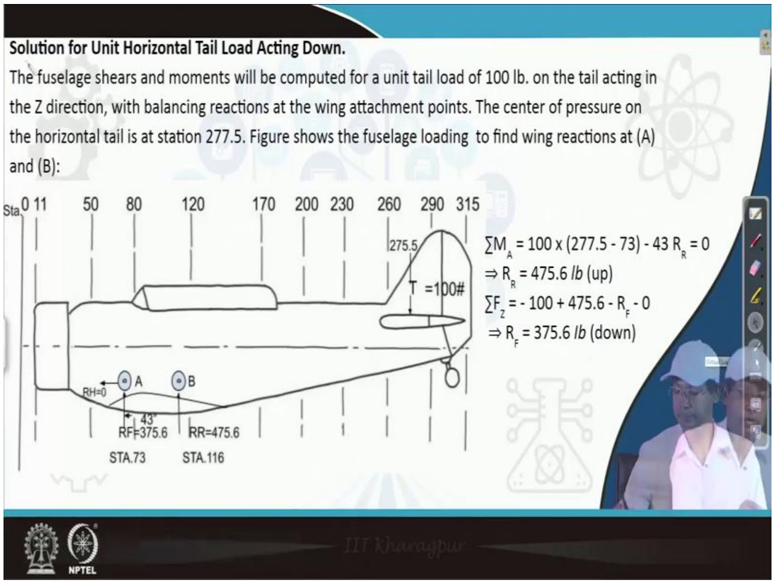

This is for the unit tail plane solution for unit horizontal tail load acting downward 275.5 is the station value that is there is in 100 277 -73 this about this point when the moment is considered as the reason this is the station point value how far it is from this section and load is 100 the fuselage shears and moments will be computed for a unit even a tail load of 100 pound.

Here the unit load is considered as 100 pound on the tail acting in Z direction with balancing reactions at the wing attachment points the center of pressure on the horizontal tail is at Station 277.5 figure shows the fuselage length loading to find wing reactions at A and B. So, if we see it is a simple equation solving with respect to point A, the moment acting this way is considered and with 43 R because the distance between these two stations are 43 it is acting the other way that is the reason it is considered like that and accordingly we get the R R value.

R R value as 475.6 pound upward and summation of loads in the Z direction gives us that the R F value is 375.6 pound. Again it is better to mention that this is because of the tail plane load and while all the three loads are acting we need to sum it up with proportion depending on how much load is acting in which direction. Here whether the tail plane load is more than 100 if it is 200 we need to multiply it by 2 even the moments also we need to multiply it by 2 if the acceleration in

X direction is 2Z and then we need to multiply it by 2 and if in a vertical direction it is 3Z we need to multiply all the components by 3.

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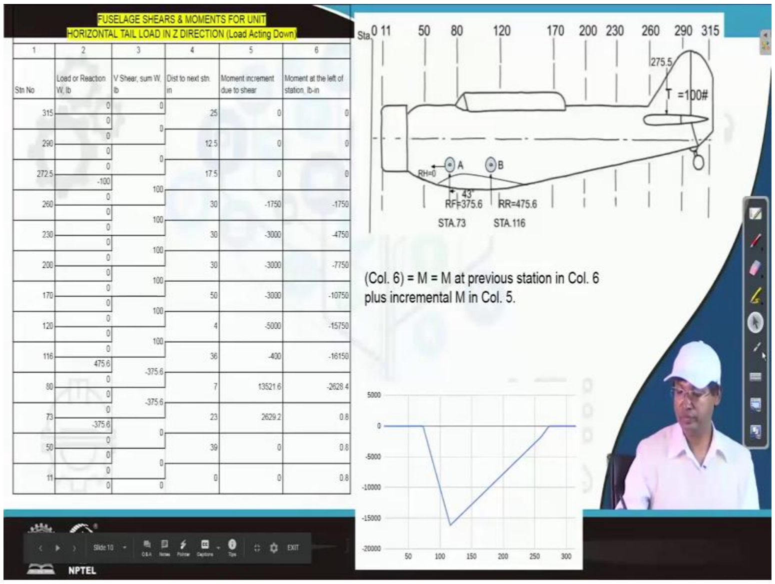

1	2	3	4	5	6
Stn No	Load or Reaction W, lb	V Shear, sum W, lb	Dist to next stn. in	Moment increment due to shear	Moment at the left of station, lb-in
315	0 / 0	0 / 0	25	0	0
290	0 / 0	0	12.5	0	0
272.5	0 / -100	100	17.5	0	0
260	0 / 0	100	30	-1750	-1750
230	0 / 0	100	30	-3000	-4750
200	0 / 0	100	30	-3000	-7750
170	0 / 0	100	50	-3000	-10750
120	0 / 0	100	4	-5000	-15750
116	0 / 475.6	-375.6	36	-400	-16150
80	0 / 0	-375.6	7	13521.6	-2628.4
73	0 / -375.6	0	23	2629.2	0.8
50	0 / 0	0	39	0	0.8
11	0 / 0	0	0	0	0.8

So we come to the table as usual table; table does not have much more difference between the previous and this so I would not spend much time you please look at it with your spare time how is it done all these station points the shear forces load reactions are given there. Then shear forces as it is it is in starting from here and that remains constant that remains constant from this point up to this point because there is no other load at 116 that the shear force from the wing reaction coming.

And from the wing reaction we get this value and again the other is there and that we get this value; okay this gets balanced here becomes shear force becomes 0 because of this, this remains constant in this section from here to here and then becomes 0 and moments as we have seen already accordingly moment is calculated this multiplied by this is this one because this is the distance between the station points and this is the shear force acting.

And accordingly as we have done in previous tables this is this plus this is this, this plus this is this and accordingly we continue finding out moments again there is some amount of movement that is because of the approximation we have already carried out and this gives us a straight line as it is expected. So, with this we have we have covered the unit load analysis of a whole aircraft we have covered previous to previous in the previous to previous lecture the bending moment and shear force experienced by cantilever wing.

And then in the last lecture we have covered how the loads should be distributed that is very, very important we have seen how loads should be found out by the experienced engineer. And then we have seen how that load must be distributed at station points of a fuselage to keep the moment balance. And then in this lecture what we have learnt we have learnt that how in for 3 different cases we can continue we can carry out the unit load analysis.

In Z direction per unit acceleration in X direction per unit acceleration and for tail plane load horizontal tail plane load of 100 pound we have carried out the unit load analysis. But it is the it is it is not a case that only one of the unit load acts on the aircraft at a time it is a combination of all those things. So, we are supposed to add up all those things considering linear combination of the cases and we can find out the combined bending moment shear force diagram.

In all these cases in case of wing structure wing as well as in fuselage I have concentrated mostly on the bending moment diagram. As an home assignment what you can do you can easily draw the shear force diagram and check with your diagram and the values whether it is matching properly or not the basic shear force diagram properties are satisfied or not and accordingly you may continue your home assignment.

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So with this we go forward for the reference; light in different slides remain same because it is all the books generally considered.

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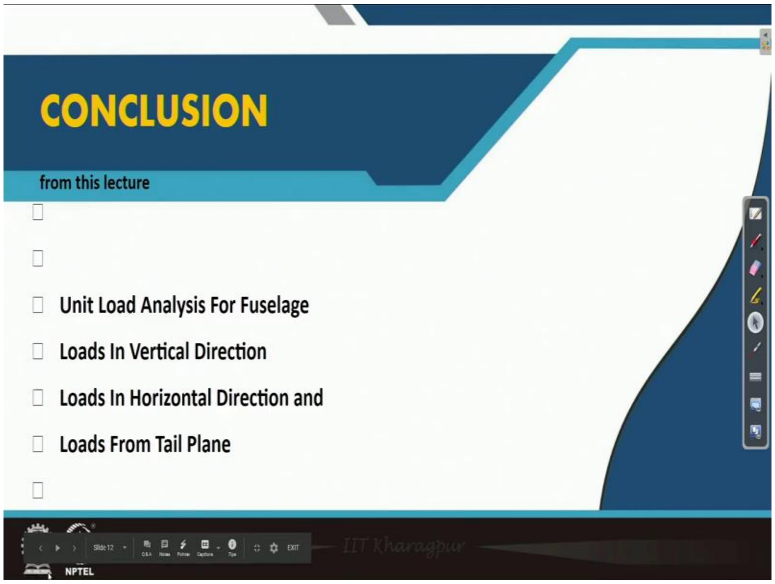

And this slight conclusion already I have told you just to note it down; you please keep a note what are the points we have learnt today. And with that I thank you for attending this lecture we will meet again in our next lecture.