**Aircraft Structures - 1**
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**Module No - 02**
**Lecture No - 09**
**Shear and Moment on wing an Aircraft**

Welcome back to aircraft structures 1 this is Professor Anup Ghosh from aerospace engineering department IIT Kharagpur. We are in the second week lectures this is the fourth lecture of second week. So before we go into what we will be learning which is there in the first as a lecture topic shear and moment on wing of an aircraft.

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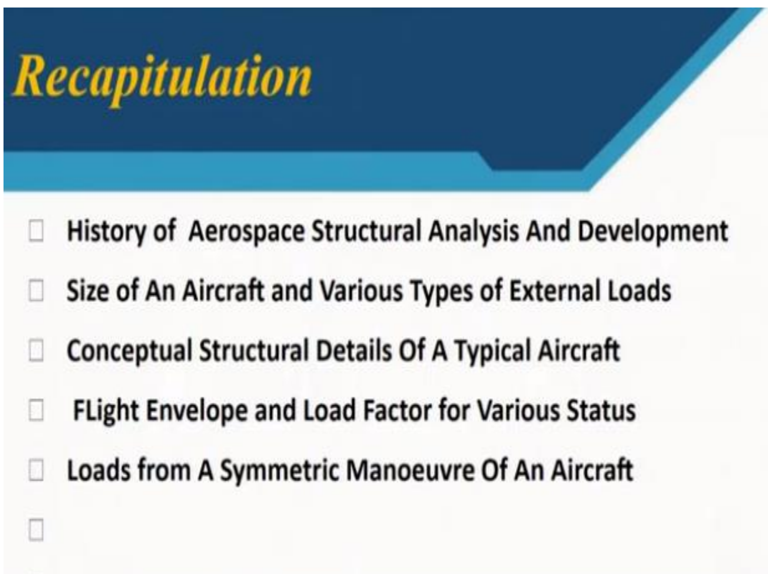


So recapitulation if you talk about history already you have done for structural analysis to some extent on aircraft development. Conceptual details of typical aircraft we have done flight envelopes and load factors what is load factor how from flight envelope a load factor is determined during design various parts of aircraft. How do we maintain a flight envelope? All those things we have learnt loads from symmetric maneuver in the last class we have learnt we have seen how can we calculate loads for a symmetric maneuver.

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And today what we will see that the shear and moment on wing how is it calculated how do, we find out due to the aerodynamic load and unit load analysis for wing, shear and moments. So we will better we go for the unit load analysis first and then we will solve one problem to understand how do, we find out shear and moments on wing?

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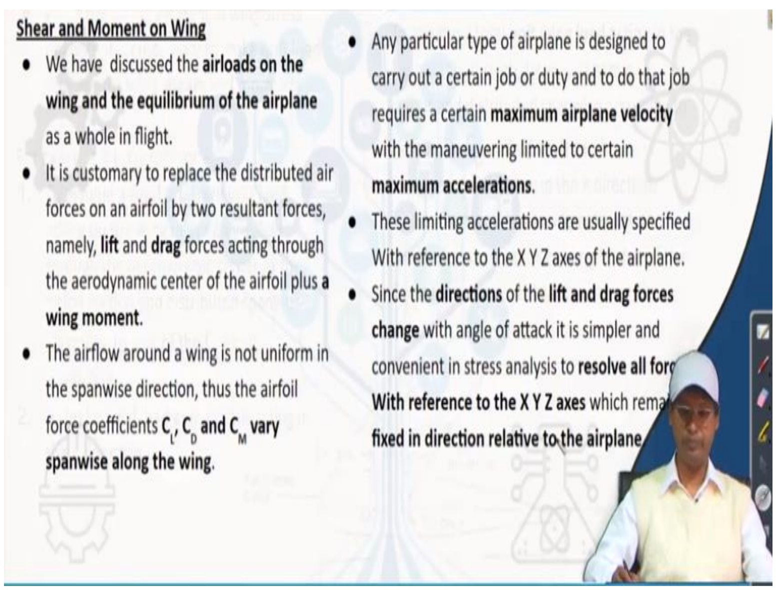


So as we have already seen that we have discussed the air load on the wing and the equilibrium of the airplane as a whole in flight. It is customary to replace the distributed air forces on an airfoil by 2 resultant forces lift and drag acting through the aerodynamic center of the airfoil plus a wing moment. So for a structural engineer what finally we get the 2 lift and drag forces and 1 moment and that we need to consider and we will have to find out a stresses build in component members and will have to design.

The flow around the wing is not uniform in span wise direction thus the airfoil force coefficient CL, CD and CM vary span wise along the wing. This already we have seen with some diagram CL varies, lift varies, CD varies, drag varies and moment also varies from root to the tip along the span. Any particular type of airplane is design to carry out a certain job or duty and to do that job requires a certain maximum airplane velocity.

So from the flight envelope already we have introduced with this we are repeating just to keep in mind that is a major factor for an airplane design with the maneuvering limited to certain maximum acceleration. So that flight envelope gives us the maximum acceleration so if we why we are talking about? If we do unit analysis then from that unit analysis we can easily go for any acceleration level.

And the velocity from the velocity we can find out the acceleration from the, envelop these limiting accelerations are usually specified with reference to the XYZ axis of the airplane. Since the directions of the lift and drag forces change with angle of attack it is simpler and convenient in stress analysis to resolve all forces. So since it is changes as it is mentioned it is resolved and it reference to the XYZ axis which remain fixed in direction relative to the airplane. So it is generally kept fixed and it is resolved and that way we generally continue.

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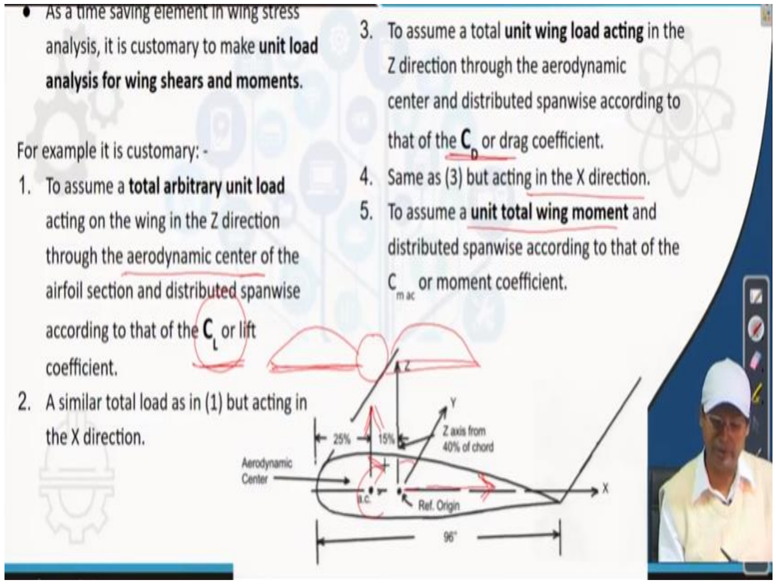


So as a time saving element in the wing stress analysis it is customary to make unit load analysis for wing shears and moments. So we are repeatedly saying we need to do usually do time saving for time saving unit loads but what is unit loads? These are the following steps by which we describe it to some extent but it is difficult to understand simply going through this texts that is the reason we will solve 1 problem in 1 direction here it is talked about many more direction more than 1 direction and we will see how that it is carried out?

So let us try to understand as far the text written here that as to assume a total arbitrary unit load acting on the wing in the Z direction. This arbitrary unit load please keep it mind it is not load 1 unit load does not mean that it is under unit magnitude 1 magnitude of load acting on the wing in the Z direction through the aerodynamic center of the airfoil section and distributed span wise according to the to that of CL or lift coefficient.

So what we are saying that it is distributed along the lift position just to remember if we think of we have learnt this is the fuselage generally this is the distribution along the wing followed. So accordingly CL is supposed to be distributed. Axial a similar total load; as in one but acting in the X direction that is the reason to understand this reason. So this is nothing but what we are talking about this CL is as we said that acts from the through the aerodynamics center so we can say this is the force acting okay this CL is acting here in this direction.

Then the next it says that the similar total load as in 1 but acting in X direction in this direction and then to assume a total unit wing load acting in the Z direction through the aerodynamic center and distributed span wise according to that of CD it was distributed according to CL next it is distributed along CD. So that same CD is acting here and we are supposed to do the analysis. Similarly it is also acting this way.

Then to assume unit wing moment which may be acting not this way acting this way and we have to solve that also. But it appears from this discussion that we need to solve 5 unit problems and will need to keep that solution for a particular set of wing. So for time we cannot solve all the 5 problems what we will have to solve we will solve only one type of problem we will see how do we solve the problem and we will the same process we can apply for others and solve it.

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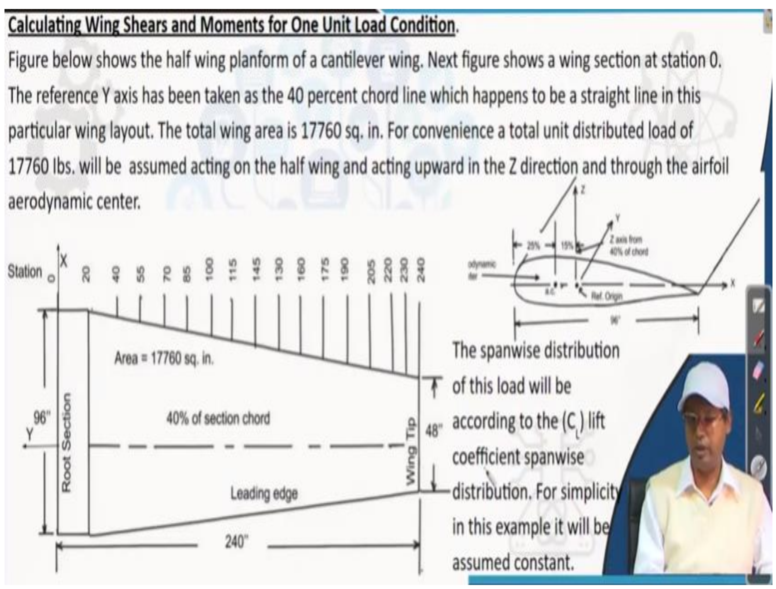


So here is the problem what we will be solving today figure below shows the half wing plan form this is this figure we are talking about plan form of a cantilever wing. Next figure shows a wing section at station 0 this is this figure makes a less next figure we are talking about it says at station 0 means we are talking saying that this is a station second station third, fourth and consecutive stations numbered in this according to this length from this axis.

So this is this way this is the leading edge this is the trailing edge. The reference Y axis has been taken as 40% chord line from here to here it is 40% chord line this and this are the same representation which happens to be a straight line in this particular case it is straight line. But usually it is not because of complicated geometry and requirement or various section types of aerodynamics files.

Airfoils used at different sections in normal modern days aircraft never this section airfoil is name same as this section airfoil section changes the shape also changes. So depending upon that it is not a straight line that is why emphasis is given on that it is a straight line in this particular wing layout. The total wing area is 11760 square inch for convenience a total unit distribution load of 17760 pound is taken. This is what we said I have mentioned while we were discuss in the last slide.

It is not 1 pound it is 17760 pound to keep the make the analysis convenient it is not 1 load will be assumed acting on the half wing and acting upward in the Z direction and through the airfoil aerodynamic center. So along this line it is acting upward okay so this is the simple problem what we have there is a aerodynamic load acting upward this way. We are supposed to find out shear and moment it is as simple as that we have some dimensions.

Let us see how do we do how do we find out those the span wise distribution of this load will be according to the CL lift coefficient span wise distribution for simplicity in this example it is it will be assumed constant. So CL is assumed to be constant along the length of the wing.

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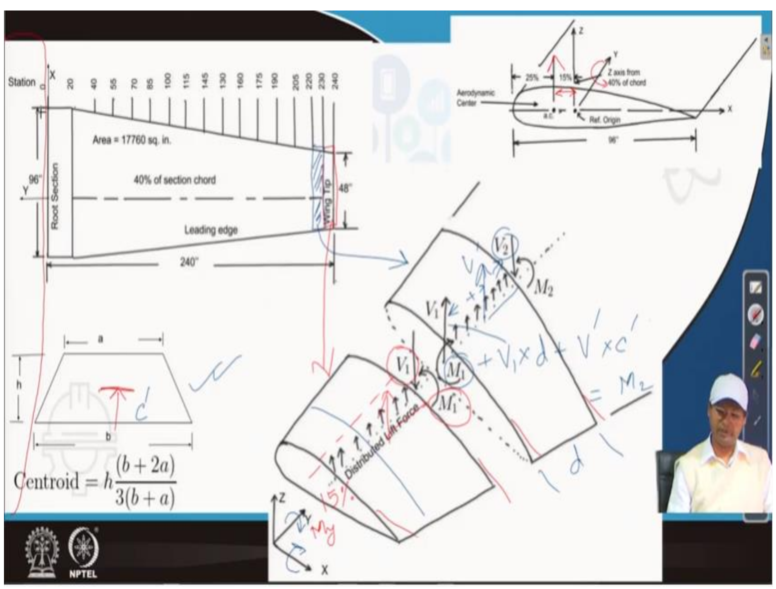

So here we come with some additional figure just to understand the problem first and then the modern tools computer tools with excel sheet we will solve the problem. So let us see look at the problem first how it is already we have understood how what is this problem is this is a half wing this is this portion is fuselage, this is the wing, this is root section, this is leading edge, this is trailing edge. Already we know 17760 equals to the area of the wing force is acting we are assumed element on the aerodynamic center line and this figure will help us in understanding let us see how it is acting.

We will also assume that the distribution of lift along chord is also unity so it is only one set of arrow is shown here it is not like that we are assuming that the distribution is uniform on this section. And for understanding we can start with this section actually this is this section we are trying to understand so this total force is acting upward this is a trapezoidal portion that is why this trapezoidal is drawn here.

We need the centroid how much far it is from this because we need to find out the moment so that distance and multiply it by the sum of resultant of the force acting there we will give us the moment equals to M1. The sum of all those forces will give us the shear V1 once we have shear and moment in this section we are considering the next section here this is this section if we understand the calculation up to this it is very simple we are assuming distribution in this direction also uniform this direction also you have considered already uniform.

So that load calculation point of view it has become easy in this section for equilibrium consideration this V should act upward and this M1 should act in the opposite direction. So what do we need to consider that similar way we are calculating one more resultant here we are again finding out the distance as at which the resultant is acting from this figure. So along with that to find out shear we need to add this also along with plus this will give us the V2.

Similarly this M1 plus this V1 multiplied by this distance say d plus say this is V prime + V prime multiplied this say centroid distance C prime will give us the M2. So this is what we need t consider to find out M2 because M1 remains this also will act and then all 3 component will give us the M2. So once we understand this properly we can easily understand the remain table so this calculation will carry out for moment about X.

So this in case this is the moment we are talking about we need to calculate the other moment also in the Y direction that how can we calculate? We have assumed that the force is acting along this direction. So this lever arm will act for moment around this Y axis so this force multiplied by this lever arm will give us the section wise this section, wise moments and then we will add up all those moments.

So actually it is acting on this aerodynamic center so this is the 15% and that 15% is here that will be acting and giving us the My moment. So keeping mind all this data we will go to the next slide or if possible if it supports will go to the axial set and will try to find out we will try to check the calculation how do we carry out? The basic understanding should be clear here.

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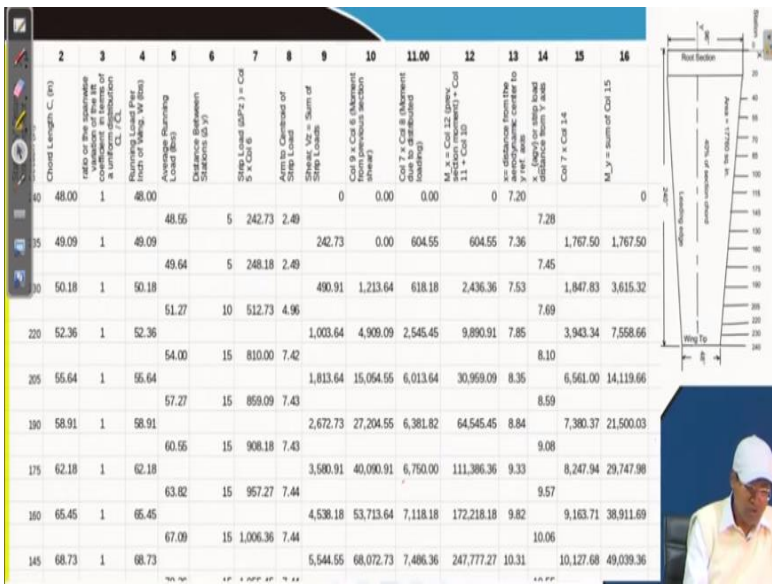

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11.00 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chord Length C, (in) | ratio or the spanwise variation of the lift coefficient in terms of a uniform distribution CL / CL | Running Load Per Inch of Wing, W (lbs) | Average Running Load (lbs) | Distance Between Stations (Δy) | Step Load (ΔPz) = Col 5 x Col 6 | Arm to Centroid of Step Load | Shear, Vz = Sum of Step Loads | Col 9 x Col 6 (Moment from previous section shear) | Col 7 x Col 8 (Moment due to distributed loading) | M_x = Col 12 (prev. section moment) + Col 11 + Col 10 | x = distance from the aerodynamic center to y ref. axis | x_(agv) or step load distance from Y axis | Col 7 x Col 14 | M_y = sum of Col 15 |
| 40 | 48.00 | 1 | 48.00 | | | | | 0 | 0.00 | 0.00 | 0 | 7.20 | | | 0 |
| | | | | 48.56 | 5 | 242.73 | 2.49 | | | | | | 7.28 | | |
| 35 | 49.09 | 1 | 49.09 | | | | | 242.73 | 0.00 | 604.55 | 604.55 | 7.36 | | 1,767.50 | 1,767.50 |
| | | | | 49.64 | 5 | 248.18 | 2.49 | | | | | | 7.45 | | |
| 30 | 50.18 | 1 | 50.18 | | | | | 490.91 | 1,213.64 | 618.18 | 2,436.36 | 7.53 | | 1,847.83 | 3,615.32 |
| | | | | 51.27 | 10 | 512.73 | 4.96 | | | | | | 7.69 | | |
| 220 | 52.36 | 1 | 52.36 | | | | | 1,003.64 | 4,909.09 | 2,545.45 | 9,890.91 | 7.85 | | 3,943.34 | 7,558.66 |
| | | | | 54.00 | 15 | 810.00 | 7.42 | | | | | | 8.10 | | |
| 205 | 55.64 | 1 | 55.64 | | | | | 1,813.64 | 15,064.55 | 6,013.64 | 30,959.09 | 8.35 | | 6,561.00 | 14,119.66 |
| | | | | 57.27 | 15 | 859.09 | 7.43 | | | | | | 8.59 | | |
| 190 | 58.91 | 1 | 58.91 | | | | | 2,672.73 | 27,204.55 | 6,381.82 | 64,545.45 | 8.84 | | 7,380.37 | 21,500.03 |
| | | | | 60.55 | 15 | 908.18 | 7.43 | | | | | | 9.08 | | |
| 175 | 62.18 | 1 | 62.18 | | | | | 3,580.91 | 40,090.91 | 6,750.00 | 111,386.36 | 9.33 | | 8,247.94 | 29,747.98 |
| | | | | 63.82 | 15 | 957.27 | 7.44 | | | | | | 9.57 | | |
| 160 | 65.45 | 1 | 65.45 | | | | | 4,538.18 | 53,713.64 | 7,118.18 | 172,218.18 | 9.82 | | 9,163.71 | 38,911.69 |
| | | | | 67.09 | 15 | 1,006.36 | 7.44 | | | | | | 10.06 | | |
| 145 | 68.73 | 1 | 68.73 | | | | | 5,544.55 | 68,072.73 | 7,486.36 | 247,777.27 | 10.31 | | 10,127.68 | 49,039.36 |

Okay so as we have seen we are starting with this station 240 we are starting with station 240 that is what 240 is given here. Chord length C is 48 inch as it is shown here and here lies as we assume that ratio of the span wise variation to the lift coefficient in terms of a unit distribution along the chord that is C bar L. So that we are assuming to be unity we are not considering any variation.

So with respect to that there is no modification of running load per inch of wing that remains same 48. Now average running load from this section and this section we are simply taking an arithmetic average and finding out the load. Distance of station between these 2 station 240 and

235 is 5 and here all if you see this is 220 and 205 which is 15 accordingly we have noted down all those points.

Before we go to distance of average load for all the station also calculated strip load is as it is mentioned column 5 multiplied by column 6 that is column 5 multiplied by column 6. So average running load is this distance is this so the strip load acting on that particular strip is total this much 242 in this particular segment it is this segment if you talk about this segment it is 242.73.

Now amount of centroid sorry arm to centroid of strip load here comes the trapezoidal centroid formula because as you look into it the chord is changing 48 49. We use that formula and we find out that arm length as 2.49. We have the load strip load we have the amount of arm length and accordingly we see that this shear remains same this will require to calculate the moment. So this is the moment from previous section means as we were talking about this is similar to that M1 from if well why we are calculating for M2.

So for M2 while we are calculating this is moment from previous session is that moment due to the distributed load this is multiplication of this arm and this so this we are talking about this is column 9 and column 6 that is strip load and distance between stations so this is it says moment from the previous section it is actually the multiplication at the junction of previous section the shear multiplied by the distance.

So this is this shear multiplied by this distance so that is what we get here while will see the excel sheet will again understand it properly. And this is the moment due to the strip load so this is as I mentioned this arm length multiplied by the strip load we are getting and column 12 this is the Mx that is previous one the previous M, M1 or the previous section load moment due to the shear this one that is the column 10, and then the column 11 this one.

So all this 4 are making it to here it is column 12 the previous one section and then column 10 that is column 10 is because of the previous section shear and the distance and this is from the strip load and the centroid whatever we multiplied that is yes this 2 we are summing up and we are getting the moment. So this is what we get for the Mx and then if we look for the Y axis the X distance from the aerodynamics center to the Y reference axis.

So this is nothing but the 15% of that particular chord always this is 15% of that particular chord and then average is considered and then once we have the average then it is simply the strip load as we have in column 7 this is the strict and that average of distance is multiplied we get the moment Y and this is the sum with respect to the pervious one and this one. So some column some of this so accordingly we if we continue calculation following this process it become easy.

Now a days with help of excel sheet we can easily modify we can easily carry out this type of calculation and one check is better to note here is that the shear or the sum of the strip load is coming equals to 17760 which is exactly the amount of load applied and that is the result unit load per unit square inch is applied on the wing and the calculation is carried out.

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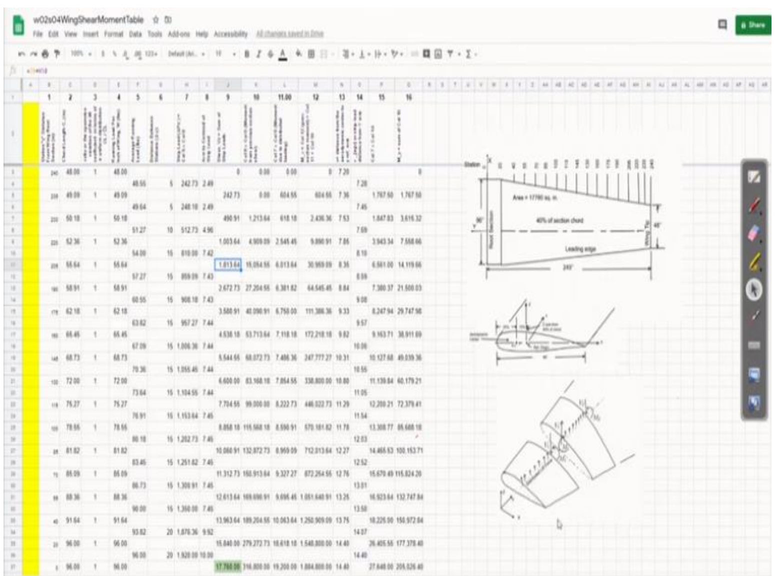


So with respect to this let us before we finish let us look at the excel sheet what we have learned how can we carry out with help of the excel sheet. Here in this diagram we see assisting figures are also there complete table is also there. So as were mentioning this is simple average so that excel sheet formula is used here it is divided by 2 and if we see this multiplication is carried simple way.

And we also carry out the other operation as described this is the sum of previous and this new one and then we are getting the sum value. Like that we calculate the Mx moment we calculate the My moment as well as the shear acting on the section.

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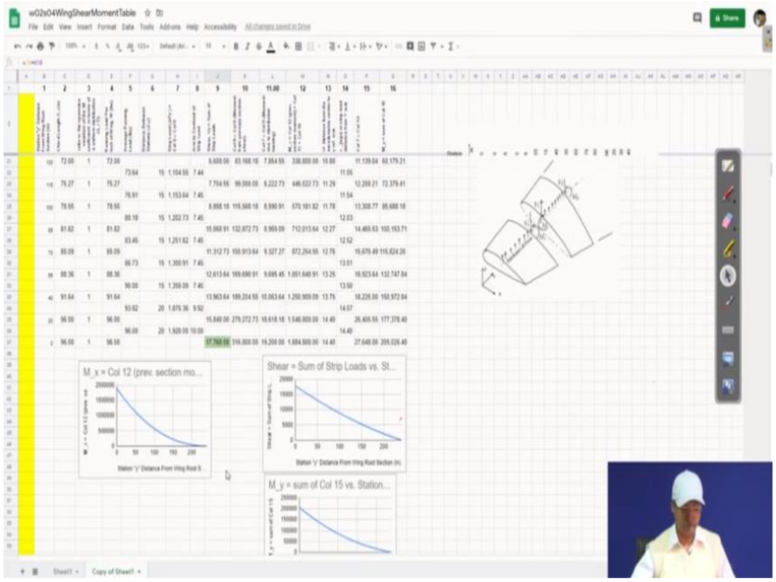

So this diagram helps a lot for understanding and if we plot this excel is generally not used for plotting this type of diagram but in this particular presentation it is easier to show using excel that is why excuse me. Column values are Mx value is plotted with respect to the root section to the tip section. Here the shear force is plotted which is not a straight line if you look it carefully and this is the moment y which is also a curve and we can have a feeling how the moment various along the span for only lift we consider.

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So with conclusion of today’s lecture the reference is a standard reference is taken.

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And what we have learnt this week is that shear and moment on wing unit load analysis for wing shears and moments. And similarly for other 4 components as we have discussed in the unit load case we can have some analysis we can keep the solution and we can use those solutions for in future design purpose thank you for attending this lecture with that let us conclude today's lecture we will meet again in the next lecture.