Design of Farm Machinery

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Lecture 32 : Design calculations for fluted roller metering unit and hopper

Hi everyone, this is Professor H. Raheman from the Agricultural and Food Engineering Department. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is Lecture 32, where I will try to cover some design calculations, as we have already completed the design part. Now, we will perform some calculations to determine the dimensions. The concepts covered or to be covered will include numericals related to seed metering, the design of flutes, and the design of hoppers.

Before that, I will start with a metering mechanism problem: a single-seed metering mechanism. So, the problem is: a horizontal plate planter with 72 cells on a 165-millimeter diameter circular plate. The effective radius of the drive wheel is 195 millimeters. A 16-tooth sprocket on the drive wheel drives an 18-tooth sprocket on the feed shaft, and a 12-tooth bevel gear on the feed shaft drives a 27-tooth gear on the plate shaft. So, there are gears through which the power is transmitted from the ground wheel to the feed roll shaft. Then, what is asked is to find out the seed spacing in the row for 100 per cent cell fill. That means all the cells are occupied with seeds; then we call it 100 per cent cell fill. If that is the case, how do we find out the seed spacing? That is number one. Number two is: if a plate with a speed of 15 meters per minute gives 100 per cent cell fill, what forward speed is required in kilometers per hour for 100 per cent fill? So, the first thing is you have to find out the ratio of the driving gear (that is, the ground wheel) to the driven shaft, that ratio. To find this out, what is given is the gears present on the drive wheel - a 16-tooth sprocket on the drive wheel drives an 18-tooth sprocket on the feed shaft. So, speed of, speed of ground wheel divided by speed of feed roll shaft or the plate, speed of plate this will be equal to 18 by 16 and then again there will be 12 teeth on the bevel gear on the feed shaft that drives 27-tooth gear on the plate shaft. Speed of ground wheel divided by speed of feed roll shaft or the plate, speed of plate this will be equal to 18 by 16 and then again there will be 12 teeth on the bevel gear which drives 27-tooth feed shaft. So, finally, it will be 27 by 12. Now, for 1 this this comes to 2.5.

Now for one revolution of the seed plate, the ground wheel has to rotate for 2.5 times that is the case. Now what is given is horizontal planter with 72 cells on a 165 millimeter diameter circular plate. So, now, you have to find out the spacing For one revolution of the ground wheel, what is the distance covered. Drive wheel radius is given. So, $2\pi rn$, n is 1 here.

So, in one revolution of the ground wheel the distance travelled will be $2\times \pi \times r$, radius is given as 195 millimeter. So, I can write 1.195 meter. Now, 2.5 revolution of ground wheel, the distance covered is equal to $2.5 \times 2 \times \pi \times 0.195$. for 2.5 revolution that will be 1 revolution of this plate. So, plate has 72 cells. So, in this distance this is to meter 72 seeds. So, this divided by 72 will give you the spacing in a row. if it is 100 per cent filled, if it is not then this number will change. That is the concept. Concept in the sense if it is 100 per cent fill the number of cells will be equal to number of seeds dropped. So, just divide the distance covered by the ground wheel with the number of seeds dropped. So that way, we are getting 4.30 centimeter with the spacing between two adjacent seed droppings.

Next question is asked to find out the forward speed, forward speed of the seed drill when the plate speed is given as 15 meter per minute. That means, we have to find out the ratio of ground wheel with plate that ratio. Speed of ground wheel by speed of plate is equal to 2.5. Now, plate speed is given. So, which is nothing, but, so speed of ground will be equal to $\pi \times d \times$rpm of the ground wheel - will be equal to $\pi \times d \times$rpm. So, r p m of the ground is denoted as n_g and the r p m of the plate is n_p then if you know the ratio then you can find out.

So, what exactly we will do is? Seed plate speed is given which is nothing, but $\pi \times$ the diameter, $0.165 \times n = 15$ meter per minute. So, now, n from here you can calculate and then ground wheel speed is 2.5 times this one.

So, $2.5 \times \pi \times 0.165\times n$. So, this n you have got now, now putting the n value. So, we will find out what is the speed of ground wheel, but speed of the ground wheel divided by first you have to calculate the rpm of the ground wheel, then knowing the radius – radius is given. So, just multiply with 2 that will give speed, will be equal to somewhere around 89.70 meter per minute. So, $2.5 \times 15/(2 \times \pi \times 0.165)$ that will give you the rpm. Now, speed will be equal to $2 \times \pi \times$ r is given. $2.5 \times 15 \times 2/(2\times \pi\times 0.165)$. So that we will get around 89.70. So, now you convert it, if it is meters per minute, then convert into kilometers per hour by dividing 60 by 1000. So, that will be the speed corresponding to the plate speed of 15 meters per minute. So, that will get 100 per cent cell fill.

Next, for this seed drill, this is a tractor-drawn fluted roller seed drill, which is used for metering wheat. So, what we have to calculate is: from this information, we have to calculate the size of the flute.

So, for calculating the size of the flute, as I said, this metering mechanism is a fluted roller. So, there will be a feed roll; this square shape is for passing the shaft. That shaft will rotate this in an anticlockwise direction, and the bottom part is fixed. So, because of this rotation, there will be movement of grains, and grains will be discharged. Grains here will be seeds - wheat seeds. So, we have to find out how much is the volume of seed that is displaced. So, for finding this out, let us say the forward speed is 4 kilometers per hour.

So, that means, and the width is 9×200, that will be the total width. So, $4000 \times 9 \times 200$. So, 200 is in millimeters. So, I have converted it into 1000. So, divided by 60. So, that will give you this much area which is covered per minute. Now, then we find out what will be the mass of seed which will be dropped in that area. So, this area if the seed rate is 100 kg per hectare. So, 100 divided by 10000. So, that way you are getting 6.133 kg.

Now assuming the diameter of the ground wheel as 60 centimeter. So, what will be the number of revolutions required to cover a distance in 1 minute at a forward speed of 4 kilometer per hour. So, forward speed 4000/60 that will give you the distance covered in 1 minute divided by π D. So, that will give you the revolutions required to cover, this distance. Then we have already calculated the mass of seeds which has to be dropped.

So, from there, we will find out what will be the mass of seed because this is 9-row. So, what will be the mass of seed which will be dropped in one revolution of the ground wheel. So, $6.133/(35.36 \times 9)$ that will give you the mass of seed to be dropped in each row. Now, if the transmission ratio because power is transmitted from the ground wheel to the feed roll shaft. So, what is the transmission ratio, if you fix as 1 is to 1. So, then the calculation becomes simpler, and then you can directly calculate the volume of seed dropped per revolution, which will be equal to the mass (which will remain the same) divided by the bulk density. The bulk density of wheat seed is taken as 750 kg per meter cube. And I have converted it into centimeter cube. So, that is why I multiplied with this. So, that way, you are getting 25.73 centimeter cube as the volume of seed which will be dropped in one revolution.

Let us now see what is the volume actually - theoretically, you have calculated for a fluted roller. If you look at this figure, when the feed shaft roll rotates, these flutes will rotate. So, along with this flute at the bottom side, where the bottom is present, some seeds will be available. A small thickness of seed will also move along with this feed roll.

So, the total volume will be equal to the volume of the flutes plus this thickness of seed which is discharged. So, we will try to find out what that thickness is. So, here I have denoted the thickness as S and the gap between the bottom and the feed roll as S1. So, the simple relations which we have taken from the last to last class: $S = S_1/(m+1)$. S is the active layer, which means this is the thickness of the layer of grains which will be displaced along with the rotation of the feed roll. The active layer means this is the thickness of the layer of grains which will be displaced along with the rotation of the feed roll. So, that will be equal to $S_1/(m+1)$, S_1 will be the gap between feed roll and ah the bottom plate. So, S_1 usually 1 centimeter one has to keep. So that seeds will be available. So, $S_1/(m+1)$, the value of m for wheat seed is 2.6. So, that way the value of S can be calculated that is nothing, but 1 upon 3.6.

So, roughly it comes to 0.28. Now, the volume of seed which is displaced will be equal to: if the outer diameter is D, outer diameter of the feed roll is D and the inner diameter, d - inner diameter means this is the inner diameter. This is the inner diameter. So, this circle. So, that distance, I have denoted as small d. So, $\frac{\pi(D^2 - d^2)}{2}$. So, that distance have denoted as small d.

So, that will give you this area this band we can say. So, this band. but in this area there are portions which are not occupied by seeds. So, that part is taken care by $(1-\alpha)$. So, α I have taken as 0.2. So, that means, 80 per cent of the outer diameter minus inner diameter will be the area which will be displacing the seeds. So, if I take that then multiply it with the length of the flute which is perpendicular to the screen. So, that is denoted as L_f. So, that becomes the volume which is displaced by the flutes plus this is the volume of seed which will be displaced because of the friction between the feed roll and the grains present at the bottom. So, π D S L_f, L_f is the length of the flute, perpendicular to the screen. Now, the summation of these two components will be equal to the volume which you have calculated in the last slide, 25.73. Now, some of the assumptions which you have to make are the α value which you have taken as 0.2, the length of the flute we have taken as 1 centimeter, and the outer diameter, we limit that outer diameter to 8 centimeters. You can go up to 10 centimeters, not beyond that.

So, now if you limit the outer diameter, now you substitute. So, the S value is 0.278. Now, V will be equal to if you substitute in this equation, you will find out there is only one unknown, this small d, and the small d value comes to 5.84 centimeters. That means the diameter of the inner - inner diameter is 5.84 centimeters, outer diameter is 8 centimeters. So, that will decide the diameter so that you can know this depth. Depth will be D minus d, that means 8 minus 5.84 divided by 2, that will be the depth of the flute. 1.08 centimeters.

You have to find out the dimensions that in the total area of the flute, each flute - what area it covers. So, volume again if you go by the flute side $A_1 + A_2$, that is the component because of this curvature, because of this curvature. So, the summation is $A_1 + A_2$, which is denoted as $A \times L_f$. Now, cross-sectional area into length of the flute that will give you the volume of each flute, volume of flute. Now, the volume of seed fed by 1 turn of the ground wheel is given. From there, we will try to find out the total volume of discharge will be $A \times L_f$, that is volume of each flute, and N t is the number of flutes. So, that will give the total volume of flutes assuming that all the volume is occupied by seeds. Then this portion is the seed volume, the volume of seed which is displaced because of the friction. Now, N_t is the number of flutes. So, now you multiply that, and it will give you the total volume. Now, you assume that the number of flutes is 7.

There are 7 number of flutes. So, that way, from here we will find out because this part we have already calculated the total volume to be displaced in one revolution, which is 25.73 centimeter cube, and the number of flutes is assumed as 7, and the length of flute as 1 cm. Now, the outer diameter we have taken as 8 cm, and the S value has been calculated as 0.278 cm, and the L_f value has been taken as 1 cm. So, that way, we are getting the area, the area of each flute to be equal to 2.678 centimeter square.

Now, we have to find out the width of the flute, which is equal to b. So, if you look at the expression here, b is equal to $D \sin\frac{\pi}{N_t} - \Delta b$. That means, if you look at the angle, the angle subtended by each flute is α1. Now, α1/2 will be equal to, sin (α1/2) will be equal to A F by O A. Now, O A is nothing, but D/2, and A F is nothing, but D/2 sin (α1/2). So, you substitute here, then we will find out distance b will be equal to twice of AF. So, which is nothing, but $D \sin\frac{\pi}{N_t} - \Delta b$. Now, what is the delta b?

Δb is the spacing between two adjacent flutes that means, it has some spacing on this side, it has some spacing in this side. It is not necessary that spacing should be provided, we can make it 0 also. Once you provide the spacing, the seed should be dropped like this. Once it will drop again there is a gap no seeds again there will be dropping some gap like that. So, if you want that there should not be any gap between 2 droppings then you can remove this Δb, you can assume that Δb will be equal to 0. Then we will have continuous dropping of seeds, which is required for wheat and paddy.

So, if you assume Δb as 0, then the expression for the width b will be equal to $D \sin \frac{\pi}{N_t}$. So, we know the number of cells you have taken as 7. So, from there you find out what will be the value of $\frac{\pi}{N_t}$, then D outer diameter. So, that way you will find out the width of flute as 3.47 centimeter. So, we know the area of the flute, it is not volume this is area. So, area of the flute and we know the width of the flute and then volume of the flute.

So, these dimensions are known and this is related to the design of hopper for a seed drill. So, for designing a hopper for a 9 × 200 millimeters that means, 9 row seed drill used for sowing wheat, wheat seeds at a forward speed of 4 kilometer per hour with a field efficiency of 80 per cent. The number of fillings, we have taken as two , bulk density of wheat seeds as 750 kg per meter cube. To calculate, first you have to calculate the field capacity. So field capacity will be equal to width, width is nothing, but 9 × 200 and S is the forward speed. So, that will give you the theoretical field capacity. Now, if you multiply with efficiency, field efficiency which is denoted as η_f. So, this η_f will take care of the field efficiency then we will find out what is the actual area covered. So, per unit time because we are multiplying width and speed, speed is per unit time. So, that is why you are getting per unit time this much is the area covered. If you know the seed rate which is denoted as Q. So, $Q \times FC_A$ that will give you the weight of seed. So, weight of a seed which has to be dropped in that area per unit time. So, now H is nothing, but for how many hours you want to operate. So, for 1 hour, 2 hour so, that way, we are going to decide the total weight. So, if you are taking H as 1 then you just take as 1, if you take 2 that means, you are continuing for 2 hours. So, corresponding to that weight if you want to find out the volume so, just divide by the bulk density. So, that will give you the total volume of seeds to be accommodated per unit time depending on H value. Now, FC_A that we have discussed FC_A is the actual field capacity, eta f is the field efficiency, W s is the weight of seed, Q is the seed rate, H is the number of hours, W is the width of coverage of seed drill. In this case it is 9 × 200 that will give you 1800 millimeter or 1.8 meter. Then speed, forward speed per kilometer per hour is given just multiply and then find out what will be the field capacity and then knowing the seed rate which is given as if it is wheat seed 100 kg per hectare. So, you can find out. So, we have found out the field capacity as this much then for every 1.4 hours the hopper is refilled. So, that means, H we have taken as 1.4 hours. So, we just multiply with that that will give you the weight of seeds to be handled in one time. So, then we find out the volume V_s dividing by the bulk density.

So, then considering 10 per cent extra volume to avoid spillage. So, we just take 1.1 times. So, that will be the actual volume of the hopper. Now this is the volume of the hopper or the seed box. Now we have to fix the width of the seed box that is length of the seed box. Then it is a trapezoidal section, what will be the size at the bottom, what will be the size at the top, then we find out what is the volume?

The length of the seed box will be W − 2 b that means, W is the total width − 2 b is the clearance between either and either side which is taken as 150 millimeter. So, that way L_b comes to 150 cm that means, 1.5 meter that is the length of the box. Now, the volume will be equal to volume of the seed box will be or the hopper will be equal to $((a + b)/2)\times h\times L_b$. So, now, if this is angle θ, I have expressed b in terms of h cotθ. So, this will be the final expression. Now, what you have to do is: you have to assume a value of h. So, let the h be 20, 20-25 centimeter height.

So, if height is fixed what will be the angle? Angle is more than the angle of repose we have taken as 55 degree though it is 32 degree we have taken little higher. So, that all the seeds will be always available at the bottom. So, that way we got the value of h cot θ L_b h. So, a is nothing, but the bottom width should be such that it should accommodate the flute. So, flute diameter outer diameter you have taken as 8 centimeter and the bottom gap is 1 centimeter.

So, that way 9 centimeter and another 3 centimeter this side 3 centimeter this side. So, that way if you put this value here a is coming to 15 centimeter and b is coming to this this is 15, this is 50 centimeter and the length of the box is 1.5 meter and that will give the total volume to accommodate the volume of seeds up to 80 kg. That means, you can run the tractor continuously for 1.4 hour. This is all about how to calculate the volume of hopper and the dimensions of the flute. These are the references.

So, in brief I can say we have calculated the flute dimensions and then hopper dimensions and we also solved a numerical related to single seed dropping.

Thank you.