Design of Farm Machinery

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Lecture 37 : Deciding the dimensions of a multi-crop dryland drum seeder

Hello everyone, this is Professor H. Raheman from IIT Kharagpur. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture 37, where I will try to cover how to decide the dimensions of a multi-crop dryland drum seeder. The concepts which will be covered: how to decide the dimensions of the major components of a multi-crop dryland drum seeder. Why am I interested in deciding the dimensions? The reason is, we have already decided the dimensions for sowing mustard seeds in lecture number 35, then we decided the dimensions for sowing wheat seeds in lecture 36. Now, which dimensions we should take has to be decided, and in this class, I will emphasize that only. Then, it will be followed by a few numerical problems which will give some more clarity to the design aspects of sowing seeds.

So, as usual, you need to know the unit draft, the unit draft for the seed bed, which is 0.15 to 0.2 kg per centimeter square. Then, if you know the furrow opener width, furrow, and the depth of operation, we can find out the draft value. Once you know the draft value, then you can find out the vertical force acting, knowing the load angle. So, these are the procedures we have already discussed.

Then, the design of the shaft, as the shaft is subjected to both bending and torsion. Bending is due to the vertical forces. Vertical forces are nothing but the weight of the cage wheel, the weight of the seed, plus the weight of the drum. So, once you know the position of these vertical forces, then taking the bending moment about the central line—the center of the drum then we can find out the total bending moment which is acting. And as I said, the shaft is subjected to both bending and torsion. So, torsion is due to the rolling resistance or the motion resistance, and we have assumed the motion resistance to be 8 percent of the total weight. So, depending on the weight, we will try to find out what will be the rolling resistance, and then, knowing the cage wheel radius, we can find out what is the torsional moment acting. So, this is what we discussed in the previous classes.

Once you know the torsional moment and bending moment, then you find out the equivalent moment. Knowing the section modulus - polar section modulus, assuming the shaft to be solid circular or hollow circular, we can utilize this equation or this equation to find out the dimension of the shaft.

Then, for deciding the frame, the frame is again subjected to bending as well as torsion. The bending is due to the horizontal and vertical forces, which are nothing but the Kv. That means, the vertical soil reaction, which is acting at the tip of the working element—the soil working element, which is nothing but the shovel and the weight of the frame. So, from there, we will find out what the bending moment will be, and then we try to find out the torsional moment.

So, in the case of a drum seeder with mustard, the bending moment comes to - we have utilized this equation, which I discussed in Lecture 35. So, we are getting a value of 30.71 Newton meter. Whereas, in the case of a drum seeder for sowing wheat seeds, we are getting a value of 36.63 Newton meter. That means we are getting a higher value. This is because the number of furrow openers is more compared to the number of furrow openers in the case of mustard sowing. Then, the torsional moment is nothing but the draft into the throat clearance. The throat clearance in both cases is the same. So, the only difference here is the draft value. Here, the draft value is for 2 rows - 6 × 2. Here, the draft value is for 3 rows - 3 × 4.5. So, that is why we are getting a higher torsional moment in the case of the frame of the drum seeder used for sowing wheat. So, once you know the bending moment and torsional moment, then you try to find out the values of b and h. Here, b is the thickness of the frame, h is the width of the frame, and the ratio you have to assume is 1 to 3. This is in millimeters; this is in centimeters. So, the ratio is b to h as 1 to 3.

Now, similarly we got the value for b and h. b is 8.34 millimeter, h is 2.5 centimeter in case of wheat and this b and h you are getting utilizing the maximum stress theory, which procedure I have already discussed in lecture 35 and lecture 36.

Next is your design of shaft, shaft of the drum. So, there the shaft is subjected to bending moment. So, bending moment is due to weight and the torsional moment is due to the torsion of the, that means, the torque requirement to rotate and it is coming from the motion resistance, motion resistance of the cage wheel. So, that way we are getting bending moment for drum seeder, for sowing mustard we are getting 8.65 Newton meter, torsional moment we are getting 3.72 Newton meter whereas, in case of wheat we are getting a bending moment of 13.24 and torsional moment of 4.47 Newton meter. Now, once you know the bending moment, torsional moment, then you find out the T equivalent and then find out the dimensions. Dimensions come to - here the shaft dimension for mustard seed is 1.13 centimeter, shaft dimension for wheat seed is 1.28 centimeter. This higher dimension for wheat seed is because of the higher torsional moment and bending moment. So, that is the reason. So, now if you compare, if you compare these two what are the values which you got for the frame, which you got for the shaft, which you got for the shank.

So, for wheat R_A and R_B corresponding to frame design, we are getting a value of 15.73 kg whereas in mustard we are getting 14.12 kg. Whereas, the bending moment is 36.63 Newton meter and torsional moment is 25.16 Newton meter. So, b and h values are 8.34 and 25.02, these are in millimeter. Now corresponding values for mustard are 14.12, 30.71 and the torsional moment is 22.36 Newton meter. And the b value and h value are 7.96 and 23.88 millimeter. Now, we have a set of values for wheat, we have a set of values for mustard. So, which one you should select if you are going to design a multi-crop drum seeder.

Now, obviously, the answer is higher dimensions - that higher dimensions are to be selected because the number of rows is more. So, you have to go for higher dimensions. So that the frame can withstand the bending, stress due to bending, and stress due to torsion. So, we select this one - these sets of values: 8.34 millimeters - the b value, which means thickness, and the h value - the width value is 25.02 millimeters. Now, coming to the shaft, if you compare, the total weight supported by the shaft is - I am talking about the seed and the drum weight. For wheat, it is 12 kg, and for mustard, it is 7 kg. The reason for the difference is we are putting 5 kg of seed in the case of mustard, whereas we are putting 10 kg of seed in the case of wheat. So, that difference is there here. So, because of that difference, we are getting a total weight of the equipment of the seeder as 30 kg in the case of wheat, whereas in the case of mustard, it is 25 kg. So, because of this weight, we are getting higher reactions here - you can see 9 kg, whereas in the case of mustard seed, we are getting 6.5 kg.

Now, corresponding to the bending moment - because the shaft is subjected to both bending and torsion. Bending is due to the vertical force, and torsion is due to the torque -torque due to motion resistance - the moment due to motion resistance. So, the bending moment we are getting is 13.24 Newton meters, and the torsional moment we are getting is 4.47 Newton meters, whereas in the case of mustard, we are getting 8.65 Newton meters. 3.72 Newton meters. This difference is due to the weight only, nothing else. Because the cage wheel is the same - the weight of the cage wheel remains the same. The weight of the drum remains the same, and the weight of the seed, which is extra here, is 5 kg. So, that is creating this higher bending moment as well as torsional moment. The rolling resistance is dependent on the total weight. So, as the total weight increased, the rolling resistance is increased. So, the torque or the torsional moment increased. So, because of that, the T equivalent is higher for wheat and lesser for mustard. So, D, which is the diameter of the shaft, was calculated by taking into consideration the bending moment and the torsional moment. So, that way, we are getting 1.28 centimeters, whereas in the case of mustard, we are getting 1.13 millimeters. So, out of these two values, again, we have to select the 1.28-centimeter value as it is higher and it has to handle a higher bending moment or torsional moment.

So, the selected values for the shaft are 1.28, which is a solid circular, and the frame is 8.34 and 25.02 millimeters. Now, the third important component is the shank, to which these working elements are attached, and the shape of the shank. The cross-section of the shank is a solid square. So, that way, the shank is subjected to bending only. Since the working elements are symmetrical - that is, the shovels are attached to the shank. So, the shank, which is supporting the symmetrical tool, will only be subjected to bending, and bending is due to the horizontal force, which is nothing but the draft. So, the draft requirement in the case of wheat seed I have taken as 3 rows. So, the total draft is reduced here. So, that is why the shaft dimension we are getting is 10 millimeters in one case, which is related to wheat, and on the other side, we are getting mustard, where you are getting 11.03 millimeters. So, in this case, since this is the highest dimension among these two, this is. So, this value is to be considered.

So, the final values you can take are. 8.34 we can take roughly as 8.5 millimeters; it is for the frame I am talking about, and then 25.02 we can take as 25 millimeters. Now, the shaft we can take as - diameter we can take as 1.25 or 1.3 centimeters, and the shank value we can take as - dimension we can take as 11 millimeters. So, these are the final values which are to be taken. So, you have to design - you have to take these values and then design the drums, then fabricate the drum seeder, which will be utilized for sowing both wheat and mustard seeds. So, this is all about the design of a multi-crop drum seeder, which is used for sowing seeds, seeds like mustard, seeds like wheat.

Next, I will take up some numerical problems where you can see how to find out the seed rate. So, the seed rate indicator of an 11-tyne, 20-centimeter (the distance between two adjacent tynes) seed drill was set to sow 65 kg per hectare. The seed drill was jacked up to collect seeds for a definite number of rotations of the ground wheel. If the radius of the ground wheel is 30 centimeters and the wheel skid in the field is 14 per cent. So, what you are going to find out is the wheel speed of travel that means, in meters per second or kilometers per hour for a wheel rpm of 75. Second, what should be the rpm of the wheel to cover one-eighth hectare in 20 minutes, okay. Now, the third one is: what should be the correction factor to multiply the indicated value of the seed rate if half of the seed drill gives 2.6 kg for the number of revolutions indicated in (b) here.

So, let us see now the first part, which is to find out the wheel speed. So, to find out the wheel speed, what you have to do is: what is the revolution? In one revolution, how much distance is it covering? So, what is given? The radius of the ground is given as 30 centimeters. So, in one revolution, the distance covered will be equal to $2 \times \pi \times r$. So, $2 \times \pi \times 0.3$. But the other problem here is, there will be a wheel skid. So, to solve this problem, we should have clear concept of what is a skid and what is a slip. In a slip - in wheel slip, the distance covered is reduced; in a skid, the distance covered is increased.

So, how to find out skid? The percentage of wheel skid will be equal to actual distance covered minus theoretical distance covered, divided by actual distance covered. So, this is the formula for finding out skid in fraction. If you multiply it with 100, then it becomes skid in percentage. So, now, skid in fraction: actual distance covered per revolution, theoretical distance covered per revolution, and actual distance covered per revolution. Now, what we know is the skid value, which is given as 0.14, and what we know is we calculated the theoretical distance covered: $2 \times \pi \times 0.3$, which comes to a value.

Now, what is the actual distance covered? It is equal to 1.14 times the theoretical distance. So, that means whatever value you are getting here has to be multiplied with 1.14 to find out the total distance covered, which comes to 2.14 meters. I have converted to meters: 30 centimeters is 0.3. So, now, what is asked is: what is the wheel speed travel for a wheel speed of 75 rpm? And the rpm is 75. So, that means in one revolution, we are getting 2.14 meters. In 75 revolutions, the distance covered will be 2.14×75. This is the distance covered in 75 revolution that means, in 1 minute. So, this comes to 161.16, this is distance covered meter per minute. Now, this has to be converted to kilometer per hour that is the question which is asked. So, what you have to do is you just multiply with 60 divided by 1000. So, that becomes kilometer per hour.

So, it comes to 9.66 kilometer per hour. This is the speed of wheel. I hope I am clear.

The next question is what should be the rpm, rpm of the wheel to cover one-eighth of hectare in 20 minutes. So, to start with we should know what is the area covered per revolution. So, in one revolution area covered will be length - distance covered in one revolution multiplied by width. So, width here will be equal to 11×20 that will be the working width. So, distance covered will be equal to $2 \times \pi \times 0.3$ and width is 11×20 - that I can convert into meter 2.2 meter. So, $2 \times \pi \times 0.3$ - this is the theoretical distance Now, the actual distance covered will be - actual area covered will be little more than that. What is that little is 14 per cent extra. So, the length which I have mentioned here that has to be multiplied with 1.14 and again 2.2. So, this will be the actual area covered. So, this is equal to 4.72 m^2. Now, what he is asking is what should be the rpm. So, in one revolution we are covering this much area. So, what is the area he is asking one-eighth of hectare. So, that means, 10000 m^2/8, this is the area to be covered. So, this much area to be covered. So, this becomes 1250. So, in one revolution we are covering this area. To cover this much area number of revolutions will be equal to 1250/4.72. So, that way you are getting 264.83. So, this is the revolution in 20 minutes. So, per minute you can calculate just divide by 20. So, that way you are getting around 13.24 rpm,

Now, the third question is: what should be the correction factor? Since this is calibrated, usually we calibrate to know whether it is delivering the actual seed rate or not. So, to know that, you need to know what is the given seed rate and what is the actual seed rate we are getting. So, what is given is, the seed rate is given as 65 kg per hectare. Now, what is asked? In this much area, one-eighth of a hectare, half of the seed drill gives 2.6 kg.

So, that means, for one-eighth of a hectare, this is the seed rate we require. So, for one-eighth hectare, what is the seed rate? The seed rate required is 65/8. This much is the seed rate required, which comes to 8.125 kg, which is required to be dropped. But what we got was 2.6 kg in half. So, for full width, the seed rate you get is 2.6×2, which is 5.2 kg. This is required, and this is what we actually got. So, the correction factor will be 8.125 divided by 5.2. So, that way, you are getting 1.56. So, this is the correction factor which has to be taken into consideration. I hope I am clear.

The next question is: a tractor-operated 9×20 cm seed drill - that means there are 9 rows with a fluted roller metering unit is to be calibrated for a seed rate of 65 kg per hectare. Find the volume of seed required to be delivered by the fluted roller for each row to get the desired seed rate and the area of the cross-section of each flute.

So, to compute these, we need some basic information. What are those basic information? What is the bulk density, which is given as 420 kg/ m^3? Now, what is the diameter of the fluted wheel - roller - the outer diameter? 8 centimeters. Diameter of the larger section of the flute: 6 centimeters, and thickness of the active layer of seeds: 4 millimeters. I will come to that - what is the active layer? Δb, the spacing on this side, because wheat seeds are not continuously dropped that is why this Δb is 10 millimeters. So, if you look at this, the radius of the ground wheel is 35 centimeters, the number of flutes is 8, and the speed ratio - we need to know the speed ratio between the ground wheel and the fluted roller, which is given here as 1:1. Now, if you look at this figure, this is the fluted roller. And we have taken only - considered one flute that enlarged diagram you can see here.

And the active layer, which you are talking about that 4 mm thickness of the active layer. So, this is the layer which is closer to this one - this much. So, this much seed which is present will be carried along with the fluted roller. So, that is the active layer. Now, the question which is asked here is: What is the volume of seed required to be delivered by the fluted roller?

So, what is the area it is covering in one revolution of the ground wheel? So, diameter of the ground wheel is given. 35 cm is the radius is given. So, diameter will be 70 cm and the spacing between row. So, this I am talking about one row. Now, $\pi \times Dg$, Dg is 35×2, 0.7 and then 0.2 is the spacing because 9×20, I am calculating per revolution what is the amount of seed delivered by the fluted roller per each row. So, that is why I have taken 20 centimeter. If I would have asked for the entire seed drill, then the spacing we can take as 1.8 meter. Since, you are asked, since I have asked for only one row. So, that is why spacing I have taken as 20 centimeter that means, 0.2 meter. Now, see, this will give you the area covered in one revolution.

Now, ratio between ground wheel to fluted roller is 1 is to 1. So, in one revolution, this much is the area covered and the seed rate is 65 kg per hectare. So, I have divided with 10^4. So, that way you are getting how much is the kg of seed is to be dropped in one revolution. So, I divided it by 420 that means, bulk density to find out its volume. I have multiplied and converted that meter cube into centimeter cube by multiplying by 10^6. So, this much will be the value or the volume of seed which will be dropped by one fluted roller, one fluted roller. So, in that fluted roller, there are 8 flutes.

So, the next question is: what is the area of the cross-section of each flute? So, to find out the area of the cross-section of each flute, which I have indicated here, you can see the flute is this area. So, this shaded area, and what is its width? So, how many flutes are there in each? These are the information required. So, the width, if you denote it as b, will be equal to $(b/2)/(D/2)$. This is equal to $\sin(2\pi/2)$/the number of flutes, z). So, now 2, 2 will cancel out. So, $b = D \sin(\pi/z)$. Now, Δb has to be deducted half from this side and half from this side; then only the actual width will come. So, that is why I have taken $b = D \sin(180/Nt)$. So, 2π by z by two. So, then only you can get 180/Nt. So, then that value comes to 2.06 centimeters.

Now, for smaller cross-section, $b = D \times \sin(\alpha_1/2)$. Now, the b value you have got is 2.06. Now, we have to find out this α_1 value. So, the α_1 value comes to 29.84 degrees.

Now, for the larger section on this side, it is subtending an angle β. So, if I put it in this formula, So, 1.57, this is 2.06. So, the value of β comes to 40.16 degrees. So, this angle is 40.16 degrees, and this angle is 29.84 degrees.

Now, the area of cross-section of each flute = $\frac{D^2}{8} \times (\alpha_1 - \sin\alpha_1) + \frac{r^2}{2} \times (\beta - \sin\beta)$. So, the β value we have calculated. And the D value and r values are given. So, just put them in this equation. So, that will give you the cross-sectional area of each flute.

So these are the references. So, finally, I can conclude that we discussed the design of different major components of a drum seeder and how to determine the dimensions of the drum seeder when utilizing it for multiple crops. So, what you conclude from here is: the larger dimensions are to be taken so that it can be utilized for both crops. Then, we solved some numerical problems on how to find out the seed rate when there is a skid and how to determine the area of flutes. That is all.

Thank you.