Design of Farm Machinery

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Lecture 35 : Design of drum seeder

Hi everyone, this is Professor H. Raheman from Agricultural and Food Engineering Department. I welcome you all to this NPTEL course on Design of Farm Machinery. This is Lecture 35, where I will try to cover the design of a drum seeder. The concepts which will be covered here in this class are related to the working principle of a drum seeder, then what are the different components of a drum seeder, and how to design the drum seeder for sowing mustard seeds in dry land.

As the name says, drum seeder means there has to be a drum, and that drum will be utilized for sowing purposes. So, the concept came from the figure which I have shown on the left side. This is the wetland drum seeder where you can see there are drums available which are green in color. You can see these are the drums. These drums are dumbbell-shaped, and inside those drums, the seeds to be put into the soil are kept. That means this is a wetland drum seeder, specifically developed for sowing paddy in wetland. Paddy means not the normal paddy. It is pre-germinated paddy. So, the pre-germinated paddy is to be put into the wet soil, and for that purpose, this machine has been developed.

Now, the question arises: why is this machine required when transplanters are available? Sowing or raising paddy crop is either in dry land or in wetland. So, if it is dry land, we have to have different methods like broadcasting, or you can utilize sowing in rows. But in wetland, the common method is to go for transplanting, which means the paddy transplants are to be put into the soil. So, this requires the maximum water because you have to puddle the soil, and it requires maximum labour because you have to transplant the saplings, and then the soil has to be puddled. So, this requires a good amount of labour, a good amount of water, and a good amount of time. So, ultimately that will be a costly procedure. So, to overcome this difficulty, this is the machine which is developed and is available in the market. This is a human being operated that means, only one person can pull it. There are 3 drums means it will cover 6 rows. So, in 6 rows it will try to drop the seeds. Here there is no agitation, the simple mechanism is the drums are mounted on a shaft and the shaft is attached to two wheels, these are lugged wheels. So, there is a handle in the front and the person has to pull it in the puddled soil. So, the wheel will rotate, when the person will pull, the wheel will rotate and when the wheel will rotate, the shaft will rotate. The shaft is fixed to the drum, the drum will rotate. So, that means, the seeds which are present inside the drum that will be agitated and there are sets of holes present through which the seeds will be released to the ground. There is no furrow opener in case of wetland seeder. So, with that concept we tried to develop a seeder for dry land. So, the major components of this seeder: this is the figure which I am showing you, the dry land drum seeder

So, if you look at these 2 figures the difference is : there are individual drums which will be serving 2 rows, but here there is a single drum which will serve 2 or 3 rows depending on the type of crop which you are going to - type of seeds which you are going to sow. And similar to cage wheels, this dry land drum seeder is also having 2 cage wheels and the drum is mounted to the cage wheel so that once the cage will rotate, the drum will also rotate. And this drum is supported on a frame and in the front of the frame we have to provide some furrow openers, because this has to be operated in a dry land, so, furrow openers are to be provided. Depending on the number of rows you have to provide furrow openers in the front. And these furrow openers are mounted to the frame and there is provision by which you can raise or lower these furrow openers. Then the other thing is, if you look at the drum seeder from the back side, you can see that there are some devices - chains with V shaped channels. So, these are used for covering the furrows.

So, in a seed drill, the main function is you have to open the furrow, put the seed into the furrow, then the furrow is to be closed. So, these are furrow closers. These chains with links - these have links they are provided to close the furrow. So, in brief, we can say the major components of a dry land seeder are: number one is the drum, then the shaft to which the drum is mounted, then the cage wheels and shank. The shank is used for the furrow opener, the type of furrow opener we will discuss a little later - it could be a shovel type, it could be a sweep type. But usually, since this is a smaller equipment, we provide a shovel-type furrow opener. So, the working element, which is the shovel, will be fixed to the shank; the shank will be connected to the frame and finally the frame - the frame over which the shaft is supported and the shanks are supported. So, if you look, there is a different view I have shown you - an isometric view - you can see there are some wheels provided. These wheels are required for carrying it from the shed to the farm or to the field. So, for transportation, these wheels are used. Once you reach the field, you can just raise it. There is a screw arrangement - a nut and bolt arrangement - you can just loosen the nut, you can raise these wheels, and then it will be supported on these cage wheels and the furrow openers.

So, the major components are: this is a drum, and there is a shaft; that shaft has to pass through this drum, and the drum is supported on the shaft. The shaft is supported on a frame; there will be cage wheels, and the drum is rigidly fixed to the cage wheel. So that there is no slippage between the cage wheel and the drum. Once you pull the entire equipment, the cage wheel will rotate, and since the drum is attached to the cage wheel, the drum will also rotate. Then the shank, and this is the frame. So, individual components, I have shown here.

Now, to start designing a dry land drum seeder, suppose we are designing the drum seeder for a particular crop. What is that crop? You can take any crop, but the simplest one I have taken is your mustard seed. So, what are the things we require when designing a drum seeder? The first thing is : we should find out what are the agronomical requirements that means, what is the row to row spacing and whether the seeds are to be dropped continuously or the seeds are to be dropped at regular intervals.

Third thing is what is the seed rate? Then fourth thing is what is the test weight? Test weight means what is the weight of 1000 grains or 1000 seeds, what is that weight that is called test weight. Then bulk density, bulk density that will decide the volume of seeds. Then the fifth component is your hole size. Hole size means the holes through which - the drum has to have holes and through these holes the seeds should be released. So, the size of the holes and the spacing of the holes these are the things which are to be decided.

So, to start with what is the power source? Source is human being, human being means maximum power available is 0.1 HP. So, he cannot deliver 0.1 HP continuously. So, what you have to do is take a factor of safety of 2. So, the power available for pulling the drum seeder can be taken as 0.05 HP. Now, the next thing is: what is the forward velocity? The speed at which the equipment or the seeder is to be operated in the field. So, obviously, it is around 1 kilometer per hour. Somebody might wonder: why 1 kilometer per hour, why not 2 kilometers per hour? Yes, one can pull it at 2 kilometers per hour, but that he can’t do continuously. So, that is why I have taken an average speed, which is equal to 1 kilometer per hour, as the normal working speed. Now, the power available is 0.05 HP, and the speed at which we are going to operate is 1 kilometer per hour.

The next important thing is: what is the unit draft? The unit draft of the soil on which the seeder is to be operated. You might wonder why I am considering unit draft, because we need to open the furrow. So, some power will be required to open the furrow. So, for that, we need to know: what is the unit draft? Unit draft means the draft for unit cross-sectional area. That is, the cross-sectional area of the furrow made by the working element. So, since it is a seedbed, that means the soil is already prepared. So, that is why we have taken the unit draft value of 0.15 to 0.2 kg per centimeter square. This is a very low value, as I said, this is meant for a seedbed. So, which is already prepared, the soil is already prepared. So, that is why I have taken this low value.

Then, the furrow opener width. So, usually, you can take 3 centimeters or 5 centimeters, the minimum is better. The reason is, we want to just open a furrow in the soil so that the seeds will be dropped. Seeds will be coming from the holes and will be dropped; there is no seed tube. The seeds will be passing directly to the furrow. Now, the furrow opener width we have taken is 3 centimeters, and it is a shovel type.

So, operating depth, how much depth you can operate - 5 centimeters depth of sowing. So, the draft requirement for one working element, that means, for one shovel or shank this will be equal to unit draft × w × d. w is the width, d is the depth. So, that way, you are getting 3 kg. So, one furrow opener requires 3 kg. If you consider a factor of safety of 2, then the draft requirement per row will be equal to 6 kg.

Now how many rows you are going to provide. So, that depends - what is the row to row spacing and that depends what is the power available. Now, row to row spacing is 30 centimeter and the power available is 0.05 HP and you can operate at 1 kilometer per hour. So, from power available, if you look at this one, from power available 0.05 HP and the speed is 1 kilometer per hour. So, from there you can find out what is the maximum draft - a person can able to pull or a person can able to deliver. So, that will be equal to 13.5 kg. So, 0.05 HP. So, draft × speed/75 that will give you HP. So, HP in our case is 0.05. Now, speed we have decided as 1 kilometer per hour. So, from here, the draft available will be equal to 0.05 × 75/speed is 1 kilometer per hour that means, 10/36 meter per second. So, from here I got this value 13.5 kg. Now, for a single row you are requiring 6 kg and the total draft available is 13.5 kg. So, the number of rows can be calculated - the draft available by draft required per row. So, that way you are getting 2.25. So, you cannot take a fractional value. So, for decimal values, we have to round them. So, that is why I have taken 2 rows. So, the drum you are going to design should have provisions to show seeds in 2 rows. Since the row-to-row spacing for mustard is 30 centimeters, the minimum length of the drum should be more than 30 centimeters.

Now, let us see how to decide the dimensions of the drum. Now, for mustard, as we know, the seed rate is 5 kg per hectare, and the bulk density is 610 kg per cubic meter. The number of fillings - meaning how many times you will fill the drum, since this is a very low seed rate of 5 kg per hectare, there is no point in multiple fillings. We can take only one filling, meaning the entire 5 kg can be put into the drum. So, the drum should have the capacity to handle this 5 kg at a time.

So, the volume of seeds. So, we know the seed rate and the bulk density. So, 5 kg/610 will give you the volume of seeds, which is 0.00819 cubic meters. This is the volume of seeds that must be accommodated in the drum. Now, the drum has a volume, but the level up to which we fill the seeds is important. So, the level should be between one-third to half, not more than that. We must provide some free space so that during operation, there will be agitation and free seed flow. So, assuming that this volume will be accommodated in one-third of the cylinder volume, then 0.0018819 will be equal to one-third of pi by 4 D square L. Pi by 4 D square L means this is nothing but the volume of cylinder, since the drum is cylindrical in shape. So, if you know the diameter and if you know the length, then you can find out what will be the volume. The length and diameter we have to find out so that it can accommodate this much volume of seeds. So, the number of rows we have taken as 2; hence, we have taken the length of the drum as 30 into 2, which means 60 centimeters. We have kept the length of the drum. So, if you put this in the equation, then we will find out the value of D, which comes to 23 centimeters.

So, now we have decided the length of the drum. Now, we have decided the diameter. Next is, this will be the drum. I have not indicated the holes and the sides, and there will be a series of holes, but actually, we do not require that. We require only two sets of holes in the case of mustard, that means this one and this one. So, this distance should be 30 centimeters. These are extra, which are to be closed. Now, the drum has to be rotated.

So, as I said, we require some cage wheels. The drum is to be inserted into these cage wheels, and the cage wheels will be fitted to the drum. So that once the cage wheel rotates, the drum will rotate. That means the diameter of the cage wheel is higher than the diameter of the drum. So, what should be the diameter of the cage wheel? Let us now see.

So, lugged wheel radius will be : 23/2 that means, 23 is the drum diameter we have decided, so, this becomes your radius, radius of the drum. So, the inner circle which you are seeing that is to be equal to the drum outer diameter. So, we can take as 23/2. Now, another 5 centimeter we have added. So, that we can provide these lugs and this spacing. So, together it comes to 16.5 centimeter, lugged wheel radius. Now to find out this whole size and number of rows - number of rows we have decided then drum diameter you know then area covered in one revolution that is important, Because here the cage wheel is coming in contact with the soil, drum is not coming in contact with the soil. So, the distance travelled per revolution of the cage hill will be equal to - in one revolution what is the distance it travels that much distance the drum has to cover. So, the area which is covered in one revolution, if you know the diameter of the drum - diameter of the cage wheel is denoted as D_g, then $\pi \times D_g$ that will be the distance covered by cage wheel. Then, I have indicated N_g/N_p, N_g means number of revolution of the ground wheel, N_p, number of revolution of the drum. So, this ratio here is taken as 1. So, we do not have to consider this one, directly we can take as 1. So, $\pi \times D_g \times L$. L is the length. So, this is the length, this is the width. So, multiplication of these two will give you how much area is covered in one revolution.

Now D_g diameter of the ground wheel will be equal to $(16.5 + 5/2)\times 2$. I took 5 by 2 because this wheel will not enter into the soil entirely, only half of this will enter. So, that is why I have taken 5/2. So, $(5/2)\times 2$ that become 38. So, that diameter becomes 38 centimeter that means, 0.38 meter.

Now after knowing this area and the and knowing the diameter and the area which is covered next thing is in that area how much seeds you are going to drop. Because in one revolution of the ground wheel area covered becomes $\pi \times D_g \times L$. So, that becomes 0.716 m^2. In this much meter square how many seeds they are going to be dropped. Now, the seed rate we know, as mustard seed rate is 5 kg per hectare. So, now, we multiplied seed rate with area, so that will give you this much kg of seeds which is required to be dropped in that area.

Now, this much kg of seed will be dropped, but in 2 rows. So, each row will handle this divided by 2. So, this much is the amount or the weight of seeds which is to be dropped per row. In the drum seeder we are not interested for weight, we are interested for numbers because we want that seed should be coming out of the hole. So, we are interested for numbers. To find out the numbers we are going to take the help of this test weight. Test weight as I said this is nothing, but the weight of 1000 seeds. So, in case of mustard the test weight is 8 gram. So, 8 gram you will get 1000 seeds. So, 1 gram will get 1000/8.

Now, this is the amount which is to be dropped in 1 row. So, when I multiply the 1000 by 8, so that this much number of seeds. So, 22.38 number of seeds, it cannot be a fraction. So, I have taken a round figure as 22 seeds. These many numbers of seeds are to be dropped in one revolution of the drum or in one revolution of the cage wheel.

So, assuming that only 2 to 3 seeds. So, let us say 2 seeds. So, 2 seeds will be dropped per hole then we require 11 number of holes. So, on the periphery of the drum in a row you have to make 11 holes. So, periphery of the drum is known $\pi \times$ d/number of holes 11. So, that will give you the distance, the peripheral distance between the center of the hole to the center of the hole. The next thing is: what is the size of the hole? The spacing we decided. The size of the holes: we have already conducted some tests for mustard seeds and wheat seeds at IIT Kharagpur, where we found that a hole size of 3 millimeters is sufficient for the continuous dropping of mustard seeds. So, that is why the hole size I have not mentioned here. So, the hole size you can take as 3 mm in diameter. So, 3 mm in diameter, and the spacing is the spacing between two adjacent holes in the drum is 6.57 centimeters.

The next thing is: the major component is the shank. How to design the shank? The shank is nothing but the portion to which the working element is attached. Now, the shank will be subjected to bending because this is symmetrical; the working element is a shovel. So, this is a symmetrical tool. So, the shank will be subjected to only bending. So, for finding out the bending moment - how much bending moment is acting, we need to know what is the height of the shank, that means the clearance from the point where the soil, the horizontal soil reaction is acting, to the point where it is attached to the frame. So, that is otherwise called the throat clearance. So, the lugged wheel radius plus the depth of sowing becomes your throat clearance.

So, we have already calculated the lugged wheel radius, then we have added another 5 centimeters because, in the beginning, we assumed that the depth of operation is 5 centimeters. So, now, it comes to 19 centimeters. So, the bending moment will be equal to the draft × h. The horizontal component of pull, which is the draft, draft × H, where H is the throat clearance. Now, the draft we have calculated as 6 kg, and I have converted it to Newton. Now, this is in meters; this is the distance. So, Newton meter -this much is the bending moment which will be acting on the shank - a shank. And the stress due to this bending will be equal to, $\sigma = \frac{BMY}{I}$, where Y is nothing but the distance of the extreme fiber from the neutral axis, and I is the moment of inertia. Assuming that the shank is of square cross-section, a solid square cross-section of mild steel. So, let its dimensions be b

$\times$ b. It is a solid square; the moment of inertia will be $b^4/12$, and Y will be b/2. Now, what will be the allowable stress due to bending? I can take it as 50×10^6 Pascal. So, if you substitute here, the bending moment we have calculated, then from here, we will find out the value of b, which means the dimensions of the shank will be equal to 11.03 millimeters. So, roughly, you can say 11 millimeters.

The next important component is the design of the frame. Now, the frame, as I told you, is provided in the front, and to this, the shanks will be attached. These are the shanks, which will be attached. So, in the case of a drum seeder used for sowing mustard seeds, there will be 2 rows, so there will be 2 shanks. And the distance between them is t0, which is nothing but 30 centimeters, and the length of the drum will be 60 centimeters. But what is the length of the frame?

The length of the frame is not equal to the length of the drum because we have to provide some clearance. The shaft will be supported on the frame. So, that is why I have taken a distance roughly around 37.5 × 2. This is 15. Again, I have put a 15 centimeter distance here, where I have placed the cage wheel, and then beyond the cage wheel, I have put some clearance so that the shaft will be supported on the frame. So, the shaft will be supported on the frame. So, the frame is a little longer than the length of the drum.

Now, what are the forces acting on the shank? There will be a vertical force and a horizontal force. The horizontal force has been taken into consideration for determining the size of the shank. Now, to determine the size of the frame, we have to consider the vertical forces. What are the vertical forces acting, and where they are acting? So, the vertical forces which are acting is weight of the frame. So, weight of the frame, assuming that it is uniformly distributed. So, I have indicated as W_f is the weight of the frame which is uniformly distributed, then the vertical force which are acting at each shovel. So, that I have denoted as K_v. the frame will be subjected to both bending as well as torsion. So, bending is due to the vertical force and torsion is due to the horizontal force that is draft. Now, what is the weight of the frame if you assume as 2.5 kg. So, total reaction force because the frame is supported at the two ends. So, the reaction force R_A will be equal to R_B will be equal to summation of the vertical forces which is nothing, but weight of the frame + $\sum k_V$ that means, K_v here K_v here. So, divided by 2. So, if you know K_v then you can find out the reaction force R_A and R_B which are acting at the end, acting upward that is another thing. Next thing is we know the draft force. Now, if you assume that the load angle, the angle at which the shovel, the shovel is connected to the shank this is shank the shovel is connected here. So, this angle is the load angle. That angle if you know then you can find out what is the vertical force acting. So, this is your K_H which is draft, this is your K_v which is the vertical component. Now, α you have taken as 25 degrees. So, now, $K_H \tan(90-\alpha)$. So, that will give you the value of K_v. K_H is nothing but draft. So, draft we know. So, $K_H \cot\alpha$ will give you the value of K_v. So, that way 6 is the draft, 6 kg is the draft force. So, now, you got a value of 12.87 kg. So, now R_A and R_B will be equal to 14.12 kg. Now, you know the vertical forces where it is acting. So, we will try to find out what is the bending moment about the center line central axis.

So, $R_A \times (t_0 + t_0/4)$ that means, $t_0/2$, $t_0/2$ up to cage wheel then the clearance $t_0/4$ minus where these forces are acting downward. So, half of this weight of the frame is acting at this point which is equal to $(t_0 + t_0/4)/2$. And this is $(W_f/2) \times (t_0 + t_0/4)/2$.

So, this distance. Then, $K_v \times t_0/2$. K_{v1} or K_{v2}, whatever this is, K_{v1}. So, K_{v1} into $t_0/2$. So, that way we will calculate the bending moment. t_0 we have decided because this is a mustard seed. So, t_0 is 30 centimeters. So, from there we can find out this will be the bending moment. Now, the total bending moment is this one. The total torsional moment will be equal to the draft into the throat clearance. So, assuming that the draft is acting at the tip of the shovel. So, the clearance is 0.19 m.

So, there will be 2 shanks. So, $2 \times 6 \times 9.81 \times 0.19$. This is the total torsional moment. Now, we know the torsion. So, stress due to torsion, we will utilize this formula: torsional moment into h by 2. h by 2 because the frame is not a solid square section; it is a rectangular section of thickness b, and the width is h. So, this is h, this is b thickness.

Now, thickness and h, if you know, then this is the formula, $\tau_s = (TM \times \frac{h}{2}) / \frac{bh(b^2+h^2)}{12}$, which can be utilized for finding out the stress due to torsion. Similarly, stress due to bending, $\sigma_b = \frac{BM}{z} = \frac{6 \times BM}{bh^2}$. Now, assuming a ratio of h/b as 3:1. So, we can reduce this equation to this form and this equation to this form, and then utilize the maximum shear stress theory, $\tau_{max} = \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau_s^2}$. Now, substituting these two values, we will find out the dimensions of the frame. So, we have taken a shock and fatigue factor for this torsional moment here and bending moment here. So, 1.5, 1.5 I have taken, and by putting this value, we find out the value of b to be equal to 7.96 millimeters. That means the thickness is this much, and the width will be 3 times that.

So, that becomes 23.88 millimeters. Now, the design of the shaft supporting the seed drum, which I will cover in the coming class. So, in brief, we can say we have discussed the principle of the drum seeder, the components of a drum seeder, and the design of components of the drum seeder for sowing. Components mean I have only covered the frame and shank, the drum size, and the things which are left, like the shaft, which I will discuss in the coming class.

Thank you.