Design of Farm Machinery

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Lecture 29 : Designs of fluted roller metering unit and ground wheel

Hi everyone, this is Professor H. Raheman. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture 29, where I will cover the designs of the fluted roller metering unit and ground wheel. The concepts that will be covered are the design of a fluted roller metering unit and the design of a ground wheel. Now, let us see what a fluted roller is and how it looks like.

So, whether you mount it at the bottom or any other place does not matter, but the seed should be available to the seed metering unit. So, this complete unit is called a fluted roller. This rotating part, there is one rotating part and one fixed part. The fixed part is called the bottom, and the rotating part is called the fluted roller or the roller. This roller is fitted to a shaft - either a square shaft or a circular shaft - that gets power from the ground wheel and rotates. It can rotate in a clockwise direction or an anticlockwise direction; both are possible. But the anticlockwise direction is preferred because it will drag the seed and then allow it to drop at the bottom. If you use a clockwise direction, it will take the seed, carry it to the top, and then release it so that it falls by gravity. So, both are possible. If you look at this, there is a thickness - the thickness of the flutes - that will control the exposure length. The greater the length, the more seed volume will be accommodated. So, that is the concept. Now, knowing about the metering unit and its components, the next thing is: As I said, this has a rotary element displacing seeds and is known as the feed roll; the other one is a stationary unit of the immobile guiding surface called the bottom. And the space between this feed roll and the immobile unit that is bottom that is occupied by seeds. So, I am indicating a dotted line you can see. So, some thickness of grains will be activated, activated in the sense, when the feed roll rotates those thickness of grains will also rotate or move along with the feed roll. So, next thing is I have taken a cross section and then I have indicated how the flute will look like. It is basically comprises of 2 sections of spheres you can say. I have indicated A 1 and A 2, but these are the cross sections I have indicated.

So, if you take the full view then it becomes a segment of a sphere. But, they are of different sizes one is: the centre of one is in the this side, the centre of the other one is on the other side. So, what you have to design in a fluted roller is : what will be the size of the flute and then how many flutes are to be there and what will be the volume of each flute. So, for calculating the volume of seed to be fed by one flute, first we have to calculate the area, area of this flute into length perpendicular to the screen.

So, area I have divided into two, A_1 and A_2. So, A_1, I have indicated A_2 and then multiplied with the length of the flute that will give you the volume of each flute. Now, if I denote it as $A = A_1 + A_2$, then A is the cross-sectional area of each flute may be in centimeter square or meter squared does not matter I have just given an unit here. Then what is the volume? Volume of seed which has to be fed by 1 turn of ground wheel that we have to calculate. So, for calculating the volume of seed for one turn of the ground wheel, we need to know the diameter. So, diameter is denoted as Dg, and Sr is the width of coverage. If you know the number of metering units, just multiply the numbers with the spacing between two adjacent furrow openers or the metering units; that will give you Sr. Q is the seed rate divided by the bulk density. So, that will give you the amount of seed to be handled by the flute in one revolution. So, this 100 I have multiplied because Q is in kg per hectare and Dg is in centimetre or metre. So, that is why, to convert that, I have multiplied by 100.

Now, if you look at this diagram again, the volume of seed fed by one turn of the fluted roller is given by this formula. There, I have added another factor, which is G, the transmission ratio: the number of teeth on the ground wheel to the number of teeth on the fluted roller. Dg is the diameter of the ground wheel, Q is the seed rate in kg per hectare, bulk density in kg per meter cube, Sr is the width in meters, and g is the ratio. So, that way, this is the expression to find out the volume of seed handled by the fluted roller in one revolution. Now, the volume of seed displaced per revolution of the fluted roller is given by: if you consider the diameter of the fluted roller, the outer diameter (you can say capital D), and the inner diameter from the bottom of the flute to the bottom of the flute (if you take that diameter as small d), $(\pi/4)(D^2 - d^2) \times Lf$.

So, in this expression, what we have neglected is the area which is lost - it is not occupied by the flute - this area. So, that is why what I will do is multiply it with a coefficient. Now, if you express this sum of this area as a coefficient multiplied by the area of the flutes. So, denote it as αV_1; then $V_2 = V_1 - \alpha V_1$. If I take V_1 common, then $(1 - \alpha) \times V_1$.

So, V_1 again you can take this value. So, that way, actual volume of the flutes $V = (1-\alpha)\frac{\pi(D^2-d^2)L_f}{4}$ excluding this area. α is a coefficient for material fill reduction. We can take 0.2, 0.3 depending on what spacing we have given between two adjacent flutes. A feed roll can have 8, 10, 12 flutes. So, depending on the diameter, we can find out what will be the value of α.

Then as I said there will be grains available between the fluted roller and the bottom part and those grains will be moving along with the fluted roller. So, the velocity of grain which is closer to the fluted roller, it will move at the same speed as the fluted roller, but the velocity of the grains which are closer to the bottom it may not move even. So, the velocity is not constant it is varying throughout the thickness. Maximum is at the contact between feed roll and the grains and the minimum is at the bottom. So, now this is the case, velocity here is maximum and velocity here is minimum. So, the grains may not move here, but the grains which are closer to - towards the feed roll they may move. That is why I have done another circle indicating that this thickness of grain they are always moving along with the fluted roller. And we are interested in finding out what is that volume of seed which is moving along with the feed roll. So, these are extra, extra means whatever volume of flutes you have calculated and whatever grains will be accommodated, accommodated in that flute in addition to that this will be the volume of seeds. So, there are different ways by which you can calculate. The first way is if you know the velocity of seed closer to this point where we call it the active layer. If V_s is the velocity of the active layer, then $V_s = V_f\left(1-\frac{S}{S_1}\right)$. S_1 is the maximum gap between fluted roller and the bottom and S is the active layer thickness of active layer and V_f is the velocity of the fluted roller. So, as I said the grain which is closer to the fluted roller, it will have a velocity equal to the feed roll and the grain which is at this point - at the end of the active layer, it will have a velocity V_s. So, this can be calculated by utilizing this equation. Where $V_f = \frac{\pi D N_w}{60}$, where N_w is the speed of roller and D is the outer diameter of the feed roll. Now, the active layer being displaced, they have a different speed as I said differential speed as you move away from the feed roll - its velocity will go down. So, $\frac{V_s}{V_f} = \frac{(\frac{D}{2})}{(\frac{D}{2}+S)}$. Now, to find out this S, which is the thickness of the active layer this will be equal to: if you rearrange this one then you will find out the expression from which you can calculate S. But only thing is you need to know the value of V_S, V_f we can calculate, you know at what rpm we are rotating the feed roll and D we can calculate we can assume a value of D, but only thing is, we need to know the value of V_S. So, if you know value of V_S then utilize this equation or there is an empirical equation available, where you can calculate the thickness of the active layer $S = S_1/(m+1)$. S_1 the value- spacing between the feed roll and the bottom this spacing, that you can fix 2 centimeter 2.5 centimeter like that so that during rotation there should be sufficient space, the grain should not be damaged by the feed roll that is the constraint. Now, S_1 you can fix then m + 1. For finding out S you need the value of m. Some values of m are available like for wheat it is given as 2.6 and you can take the same value for paddy also and for millet the value is given as 1.4. Now, substituting here, we can find out what will be the thickness of active grain which will be moving along with the feed roll.

Next thing once you decide the thickness of grain which is active, what is its volume? So, $V_3 = \pi D S L_f$, L_f is the length ~~of the~~ perpendicular to the screen or board whatever you call. Then the total volume of seed which will be displaced in one revolution that will be equal to summation of V_2, V_2 means summation of the volume of flutes plus volume which is displaced due to contact with the feed roll. So, $V_2 + V_3$. So, that will be the total volume of seeds which will be displaced. So, that if you substitute for V_2 this expression, this is L_f. $(1-\alpha)\pi(D^2-d^2)L_f/4+\pi D S L_f$. So, now volume of seed per revolution of the ground wheel, this is for one revolution of the feed roll. Now, if you know the gear ratio then just multiply to find out what is the volume which is displaced in one revolution of the ground wheel. Now, area covered per revolution of the ground wheel is : if you know the diameter know the width - width of coverage then you can find out what is the area covered. Then volume of seed per revolution of ground wheel can be found out from this expression knowing the seed rate. And then when you divide the area multiplied by the seed rate with a bulk density, then we will find out the volume of seed which should be required which is required to be displaced. So, ~~this A_1 sorry~~ this Vg should be equal to V'. So, V' will be equal to say this much and V_g is equal to this much this volume should be equated to find out or to decide the dimensions of the fluted roller. So, if you look at this equation, there are good amount of unknown parameters like what should be the length of the flute, what will be the value of s, D then diameter of the ground wheel. So, these are all values which are to be fixed then only you can calculate otherwise it is not possible to calculate. Something has to be fixed then the other parameters are to be calculated.

Only thing is we know this - if you know the if you fix the ground wheel diameter and the number of rows of a seed drill and the spacing between two rows we can calculate what is the volume of seed to be displaced and then we put try to equate that with this equation to find out what is the different dimension like small d capital D etcetera. Or our design should be such that it should satisfy this. Even if you assume these values then those whatever assumptions you have made that should satisfy this seed rate that means, this volume of seed.

Now, if you come closer to the single flute, I have said that it comprises of two cross sections that is A_1 and A_2. Now, let us see how to find out the area of this flute. So, the area of the flute in the beginning I said A is the area of the flute, $A = A_1 + A_2$. Now, let us find out what will be the value of A_1. Now, if you look at the area AOC, this is a segment of a circle AOC, this one. So, the area of triangle AOC, this is a triangle, and if D is the diameter. So, then I have indicated that D/2 is the radius. So, then the area of AOC $= \frac{D^2}{8}\sin\alpha_1$, where α_1 is the angle subtended by the flute at the center. this section is subtending an angle α_1. So, if you know α_1, if you know the radius, then you can find out. Here D is the diameter. So, $\frac{D^2}{8}\sin\alpha_1$. Now, the cross-section of the flute ADC, this one, this side A_2 will be equal to A_{c1} minus A_{t1}. So, A_{t1} we calculated. So, actually in this figure, this is A_1, this is A_2, if you look at the expression this is A_1, this is A_2. Now, A_1 will be equal to the total segment area minus this So, this segment area minus this triangle. So, for calculating the segment area this is the formula. Formula in the sense in 360 degree we are covering $\frac{\pi D^2}{4}$ that is the area and for α_1 what is the area? So, that way you have calculated this one $\frac{\pi D^2}{4} \times \frac{\alpha_1}{2\pi}$. Now, this will be - this area $\frac{\pi D^2}{4} \times \frac{\alpha_1}{2\pi}$ minus this one. So, that will give you the shaded portion, here A_1. Now, similar way we have to find out this A_2 value that means, if you consider AO_1 and C so that segment. So, A_{c2} will be the segment total segment here $AECO_1$ then that we will find out $A_{C2} = \pi r^2 \times \frac{\beta}{2\pi}$, where β is the angle subtended at the centre O_1 and then area of this triangle AO_1C. So, that will be equal to again, if this is r then $\frac{r^2}{2}\sin\beta$. So, the difference between these two will be equal to your this shaded area. This is the expression for A_2, this is the expression for A_1, now $A = A_1 + A_2$. So, that will be the total expression. So, now you substitute for A_1 and A_2, this will be the total expression for finding out the cross sectional area of the flute. So, what we need to know is what is the angle it is substending. So, there are two segments. So, one is this α_1 which is substended by the section ADC, the other one is β which is substended by the section AEC.

So, to find out β and α_1, we need to know how many flutes are to be provided. So, now if you look at this one, the width will be equal to $D\sin(\pi/N_t)$, where, π/N_t means the number of flutes. If it is denoted as N_t, then $D\sin(\pi/N_t) - \Delta b$. We have some clearance here and also on this side. If clearance is not there, you can neglect this portion (Δb). So, the volume of seed delivered in one revolution of the fluted roller is, finally, the AN_tL_f. So, that will give you the total volume of flutes and the volume of seed displaced in that active layer, which is πDSL_f.

So, that way, you can utilize this equation or the previous equation I mentioned, where you assumed the other equation like this one. These two equations can be utilized, and this has to be equated to the volume required to be dropped to find out the different dimensions of the flute. So, these are the equations for the flute.

The next important thing is, since the fluted roll is powered by the ground wheel, we need to know how to construct or design a ground wheel. The ground wheel is not a powered wheel, which we should keep in mind. It is a towed wheel where the power is taken from the towed wheel to the feed roll. So, you can have different gears or a chain and sprocket, but it should not be a belt and pulley because, under load, it may slip, and you may not get the correct seed spacing. So, what type of wheels should you use? The first option is a pneumatic wheel, or you can use a cage wheel. Pneumatic wheels are not preferred because the soil is soft, and there is a possibility of the wheel skidding.

The towed wheels do not slip; they skid. So, that is why what happens is, if we assume that in 10 revolutions it will cover, say, 10 meters, actually it will cover more than 10 meters. So, that way, spacing will be affected. So, we have to have a wheel which has lugs so that it can properly enter into the soft soil and have a grip, ensuring it does not skid. So, when considering a cage wheel, the first thing is determining its effective diameter, because all our calculations we just saw depend on the diameter of the ground wheel or the drive wheel.

So, what effect does a cage wheel have if selected, and what should be its diameter? And then, how to determine the effective width. So, the rim of the ground wheel has a width in the range of 25 to 40 millimeters, meaning the thickness or width of the wheel is between 25 to 40 millimeters. The more the width, the more the resistance to rotate. So, that we have to decide. The diameter should be between 300 to 800 millimeters.

So, when I said diameter, it is not the tip diameter; I am talking about the effective diameter. So, in a lugged wheel, the effective diameter will be equal to half of the lug. Here, we assume that half of the lug is entering into the soil surface. So, that means this portion is in contact with the soil surface, and on this side, this portion is in contact with the soil. So, that is why this will be the effective diameter, and based on this, all our calculations are made: πD_g. So, this is not this D; this is this D. So, πD_g will give you the distance covered in one revolution.

So, if you select a smaller diameter - suppose somebody says, 'I will go for a smaller diameter, smaller than 300 millimeters - there will be chances of skidding. But a large diameter will again create a bending moment because the clearance will increase, the seed drill will be raised, and the furrow openers - the tip of the furrow openers and the point at which it is mounted to the frame - that clearance will increase, so there is a tendency for a higher bending moment. So, taking all those factors into consideration, we have to keep the diameter within 300 to 800 millimeters. So, these are some of the references, and in short, I can say we discussed how to design a fluted roller. There are two ways I discussed: how to calculate the area of flutes and then how to calculate the volume of flutes by multiplying the length of the flute.

We also discussed the ground wheel, how to consider the dimensions of the ground wheel so that you can effectively design a seed drill or planter.

Thank you.