Design of Farm Machinery

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Lecture 38 : Design of a remote controlled drum seeder for wetland

Hi everyone, this is Professor H. Raheman. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture 38, where I will try to cover the design of a remote-controlled drum seeder for wetlands. In the last two or three classes, we have been discussing drum seeders which are to be used in drylands. Now, in this class, we will try to discuss the drum seeder which will be used in wetlands.

So, the concepts which will be covered are the working principle of a remote-controlled wetland paddy drum seeder, then performance evaluation of the wetland drum seeder. Worldwide, rice is cultivated in about 167.13 million hectares of land. In India, rice is grown in about 43.86 million hectares of land, which is roughly around 26 percent of the total cultivated area of the world. So, after China, this is the second-highest rice-producing country in the world, with a total production of about 172.58 million tons of paddy and an average productivity of 3.88 tons per hectare. And it is the most prominent crop of India. This crop is the backbone of livelihood for millions of rural households. And it plays a vital role in the country's food security. So, this is the background of rice cultivation. Then, let us see what are the different methods which are being followed by our farmers. The most common method is transplanting - I am talking about wetlands. And the other method is direct seeding of rice. If it is dry land you can directly put the seeds on the field utilizing a seed drill. And, the other method which is available is direct seeding of rice in wetland. So, in puddled soil, we have to operate a machine which you can see. This is the machine which can be operated in the field in the puddled soil. So, that will do the growing of rice. And if you look at this one this is the transplanting.

Look at the postures of the operator and the duration for which they are being in that field. So, these are some of the things which are to be taken care of. In addition to this, the other advantages which are associated with direct seeding of rice, let us discuss one by one. It requires 12 to 33 per cent lesser irrigation water than the flooded transplanting method, because in case of direct seeding of rice in puddled soil, we do not need any standing water. So, that is a plus point.

Then with DSR crop matures 7 to 10 days earlier than transplanted rice, but it directly starts growing, it does not take time to establish. So, if there is a reduction in yield due to water stress. If there is a yield reduction due to water stress then the tune is up to 31 per cent - from 8 to 31 percent as compared to 14 to 43 per cent in transplanting - transplanted rice. Then direct seeding method needs only about 5 to 9 man-hours per hectare as compared to 25 to 50 person-days or man-days labour with transplanting. This I am talking about manual transplanting. Then higher net return is obtained in DSR method. So, in direct seeding, the other biggest advantage is direct seeding reduces methane gas emission due to non requirement of standing water in the field. So, we do not require a standing water that is one point and as the water is not standing, so, we are not getting any methane gas. With suitable cultivars, water and wind management, it is better to go for adapting wet seeding for rice cultivation. So, the man-hour requirement will reduce, water requirement will reduce and your losses will also reduce.

But, what are the difficulties associated with wetland seeding? The oxygen consumption rate of a person while operating drum seeder varies from 64 per cent to 83 per cent. These values are much higher than that of the acceptable work load limit, which is 35 per cent only. That means, the person cannot work for a longer period, he has to take rest. The endurance time of the subject is reduced up to 13.8 minutes. So, every 15 minutes or 20 minutes interval he has to take rest. His heart beat rate increases to 163 beats per minute. There are skin diseases like dermatitis, eczema and superficial fungal infections because he has to spend lot of time inside this puddled soil. So, these are some of the disadvantages or some of the things which should be considered if you want really to mechanize the paddy cultivation. We need to grow paddy, but these are some of the limitations. So, with that background we try to develop a remote controlled wetland seeder.

So, in the wetland, the drum seeder is the simplest seeder available. So, that's why we preferred the wetland seeder, and we try to make it remotely operated so that no persons are required to enter into the field. So, the problem that means spending a lot of time in the puddled soil will be overcome. So, the number of rows, as usual, we kept within 4, because beyond 4, it becomes difficult for a remote-controlled machine to take a turn at the end, and at the same time, the weight will increase. So, taking all those factors into consideration, we limited the number of rows to 4. And then, the spacing between 2 rows we have kept as 20 centimeters, and the type of seed in wetland, we cannot sow the normal seeds; the seeds are to be pre-germinated. So, that it can directly start growing after putting into the soil. And the fourth one is, we have selected a transmission module - that means wireless transmission module, which is HC 12, which is for a distance of 100 meters. Within that 100 meters, we can easily control that one. So, we prefer that one with respect to Bluetooth.

And then, while designing, the main thing is how to decide the power source - what will be the power source. So, the power source will be your DC motor, and that power source will depend on what is the power required to propel the seeder in the wetland. So, what we have to do is, we did some experiments and tried to find out what is the force required to propel the weeder in the field. And what we found is, around 100 watts, that is the power requirement. So, roughly around 3 to 4 kg will be the force required to move it forward. Then, with that background, we try to develop a remote-controlled paddy seeder.

So, the CAD model is shown here - this left-side figure and the actual seeder that was developed are shown here. So, basically, it comprises three major units: one is the propelling unit, which is the wheel and the power transmission; then the seeding unit; and the third one is the transceiver unit. So, the propelling unit here is the cage wheels - two cage wheels are provided. These are made of polypropylene copolymer plastic and are fitted with lugs so that they can easily bite into the soil and provide a propelling motion to the entire seeder. Since it has to work in wetlands where the soil is soft, we have to make some provisions so that it does not sink. If it sinks, it becomes difficult to move it forward. So, we have to provide a float, which is shown here. This is also made of PPC material. So, the dimensions are kept in such a way that they do not allow the entire weight of the machine to cause the seeder to sink into the soil. So, you have to have a float. Then you have to have a seeding unit. Once you have the propelling unit, it has to be powered by a DC motor. So, the DC motor capacity has to be selected based on the torque or force requirement of the wheel to move the seeder forward.

So, we have already measured the force, and knowing the wheel radius, we can determine how much torque is required. Accordingly, the DC motor is selected to meet this torque requirement. So, the DC motor available in the market may not exactly match our requirement. So, we have to make some transmission arrangements. That is why, if you look closely, you can see there are some chain and sprocket arrangements. So, these chain and sprocket arrangements are provided to reduce the speed of the motor. The DC motor is available at 80 rpm. So, that has to be brought down to 10 rpm because the diameter of the wheel we selected is only 66 centimeters. So, that is enough to provide clearance so that the drum does not touch the soil surface during operation. So, once you decide on that diameter, then we have to find out what the speed should be because in the wetland, we cannot move at 4 kilometers per hour or 5 kilometers per hour - the speed has to be limited. So, that is why we are limiting the speed to 1 or 1.2 kilometers per hour - that is the maximum speed, and you can control it. You have to have a controller to control the speed. So, for that, you have to reduce the motor rpm. So, we have to provide some transmission units. The second important unit is, once you provide the transmission unit, then during turning, you have to have some provision - that means a clutch arrangement, so that the power should be cut off, allowing the wheel to take a turn. So, you have to have a clutch mechanism so that you can engage or disengage the clutch, allowing power to be transmitted to the wheel or not, depending on the requirement. So, you have to have a clutch device. That clutch arrangement is nothing but a mechanism actuated by a linear actuator, which is provided. There are two linear actuators provided for the two wheels. So, they will engage or disengage, allowing the power to be transmitted or not transmitted, or we cut off the power. So, we require power for these linear actuators, power for the DC motor, and then the other important unit is the seeding unit. The seeding unit is similar to the one we are designing for the dryland drum seeder. So, that is basically small drums which can contribute to 2 rows, that means each drum will provide seeds to 2 rows. So, 2 drums, so that will cover 4 rows with a spacing of 20 centimeters, which means the maximum width it can cover is 80 centimeters. Since this is a drum type, there is an opening through which you can put the seeds - pre-germinated paddy seeds into the drum. And it is attached directly to the wheel through a shaft, so that when the wheel rotates, the drum rotates. This provides the desired agitation. Next comes the transceiver unit. The transceiver unit is nothing but a transmitter, and there has to be a receiver. So, through the transmitter, we have to send the signals. The signals will be transferred and received by the receiving unit, which is provided in the seeder itself, okay. So, the remote control is your transmitter. An operator, who will be standing outside the field, will give instructions on what to do - whether to move forward at a higher speed, a lower speed, or whether to take a turn. All the signals are to be provided through the transmitter. This is basically an HC12 transmitter - a wireless transceiver unit that we have selected. Then, these are the final specifications. Once we design this, the final specifications are: weight is 43, so roughly around 45 kg, and the drum has 4 rows - it can cover 4 rows. The width of operation is 0.8 meters. The row-to-row distance is 20 centimeters, and you cannot vary this. So, it is fixed because the drum holes are on the periphery - holes are given. So, you cannot do this.

Then, there are 8 holes, 20-centimeter diameter of the drum, then the number of holes is 8. The size of the propelling unit that means the DC motor is 180 watts, 24 volts, and it can provide 20 Newton-meters of torque. So, that is the important thing - how much torque it can provide, so that it can easily rotate the cage wheels in the puddled soil. Then, the driving square shaft - the central shaft to which the cage wheels are mounted - is a 20-millimeter by 20-millimeter square shaft. Then, the dog clutches are operated by linear actuators. There are two linear actuators, with a capacity of 24 volts and a 50-mm stroke length. That means, this is decided, how much distance you want to move? Based on that what is the stroke length. So, that much distance it can move in per second. 50 meter stroke length that means, it is moving at a speed of 15 millimeter per second. So, to cover 50 millimeter it will require 3.5 seconds. Then the capacity how much force it requires. So, that is 200 Newton.

Speed reduction ratio from motor to driving shaft that is given, then size of the float 820 millimeter length, 140 millimeter width, height is 50 millimeter. Then the motor driver There should be an Arduino UNO microcontroller, then HC 12 transceiver module, then batteries that is important 2 numbers of 12 volt 7 ampere-hour batteries because we require 24 Volt, they are connected in series. So that, we can make it 24 Volt and then based on the current consumption, we have to find out the number of batteries. So, that is why decided number of batteries as 2.

Then the remote control unit, which is provided with joysticks, potentiometer, then SPDT switch, Arduino UNO board. And they are to be powered. The controller and the receiver units are to be powered through battery - 9 volt 0.5 ampere hour battery. Now, coming to the propelling unit as I said a little bit before. So, if you look at this figure you can see - what is the role of this linear actuators? If you look at this figure this is attached to a clutch arrangement - a dog clutch here. So, power is transmitted from the motor to this intermediate shaft. The intermediate shaft is provided with a clutch - a dog clutch. So, when the linear actuator extends, it will try to disengage; there is a hinge here. So, this will try to disengage this clutch, which means power is disengaged. Power is not going to the main shaft. The same is the case here. So, if you look at this, you can see the dog clutch arrangement here, the dog clutch arrangement here. So, we have made a dog clutch arrangement with square grooves. So that it can easily engage and disengage.

Then comes your transceiver unit. The transceiver unit comprises two components, as I said: the transmitter and the receiver. And the transmitter has a right joystick - the right-side joystick - which means this one is the right-side joystick for movement of the seeder forward or reverse. Then, the left-side joystick, this one, is for engaging and disengaging the left-side dog clutch to take a left turn. Then, the middle joystick engages and disengages the right-side dog clutch. So, these two are for the actuation of dog clutches. Then, there is a potentiometer here to control the speed of the driving motor and an SPDT switch to supply power to the Arduino UNO microcontroller.

Then, this is the circuit diagram for the developed remote controller we have. Then, this is the circuit diagram for the receiver unit. Then, the developed receiver unit, which is put in the seeder. It comprises the motor drivers for the DC motor used for propelling, then the microcontroller power supply - all those things are provided in this receiving unit.

Then, this is the flowchart. If you look at the flowchart, first these switches are to be ON, then the remote control is ON, then this receiver circuit is ON. Now, you decide whether you want to move forward or whether you want to move backward. So, if you want to move forward then the right hand joystick should move upward then it will move. If you want to go backward then right side joystick in the remote control should be moved down. So, it will move the entire unit in the reverse direction. Now, if you want to take a turn, then whether you want to take a turn to the left or right that you have to decide. If you want to take a turn to the left, the left joystick moves left then right joystick moves up. First you disengage with this. Then, we engage this forward speed joystick, so that it is disengaged taking a turn. After this if you want to - when it is coming to the straight path, then again the left side joystick which is used to disengage the clutch, then engage the clutch then this has to be moved right side. Initially it was moved left, then it will move to the right, then it will be back to the straight path. Now, if you want to take a turn to the right, then middle joystick which is given the right side dog clutch that joystick should move up, then you take a turn with the help of this right side joystick moving up and middle joystick - middle joystick in fact, will cut off the power supply if you want to take a turn to the right. Then, when you put the right extreme joystick up, then it will move, take a turn then you release that one the middle joystick that will come back to the original position. The power is again transferred to both the wheels then again it will be normal this is the concept.

Then once you develop this one, this has to be evaluated that is we evaluated in the laboratory as well as in the field. So, before jumping into the field, we try to see whether the performance of the seeder is up to the satisfactory level or not in terms of missing index, in terms of multiple index, in terms of quality feed index, in terms of coefficient of field distribution uniformity, in terms of coefficient of seed dropping uniformity and in terms of seed rate. So, these are the parameters which we measured in the laboratory. For that we have taken the paddy variety which is IR 36 and then the forward speed we selected two levels, 1 and 1.2 kilometer per hour, then filling level inside the drum with seeds we have taken two - one third and two third. So, these are the dimensions which we measured with the help of a digital caliper that means, length, width, thickness, geometric mean diameter, then weight of 1000 of seeds - test weight, then bulk density, angle of repose.

So, these are the performance parameters, as I said. Missing index means those number of spacings between hills which are greater than 1.5 times the desired spacing. That is called missing index, which we consider as a missed hill. If the number of spacings between the hills is less than or equal to 0.5 times the desired spacing, then those are multiple indexes. That means there will be more number of droppings. So, that is the calculation part given here. The formulas which are used for calculation. Then, the quality feed index we considered is the actual number of droppings. Because in paddy seeds, we drop seeds in hills, not by numbers. So, in each hill, there will be 3 to 4 seeds. That is the concept. So, if it is between 0.5 to 1.5 times the desired spacing, then that is called the quality feed index. So, this factor, the I feed, is nothing but n3 by N. n3 is the number of droppings out of our observation which satisfy that condition, meaning between 0.5 to 1.5 s. So, that way we calculate this value. N is the total number of observations. Then, in addition to that, we also measure the coefficient of hill distribution, which means how many seeds are dropped per hill. Sorry, variability in hill spacing - variability means whether we are maintaining the spacing or not. The closeness of the hill-to-hill spacing has to be found out. So, that is found out by this coefficient of hill distribution uniformity. Then, the coefficient of seed dropping uniformity means the number of seeds which are dropped in each hill should be uniform. So, that variation we want to measure. So, that also we have calculated utilizing this formula.

Now, to do this exercise, what we did is we took a polythene sheet, spread it on the ground, and then we smeared that polythene sheet with grease. So that when the seeds are dropped from the seeder, they should not jump. So, they will stick to the sheet, and then we can take observations to find out all those performance parameters. So, the seeder has to be operated over this sheet, which is smeared with grease, and then we took observations like you can see here: the number of seeds which are dropped at regular intervals - these are hills. So, we took observations for this, and then finally, when I draw the graph, we can see the performance parameters on the X-axis and performance in percentage on the Y-axis.

So, what we observe from here is: at 1 kilometer per hour, one-third filling (which is the blue line); at 1 kilometer per hour, two-thirds filling (which is the orange line); at 1.2 kilometers per hour, one-third filling (the gray line); and at 1.2 kilometers per hour, two-thirds filling (the yellow line). So, if you compare between 1 and 1.2, the missing hill is less at 1 kilometer per hour and one-third filling. So, we want less missing. So, that is what is obtained at 1 kilometer per hour forward speed and one-third seed filling. Now, multiple index, which is not desirable, should be as low as possible. That means the spacing, when it is reduced to less than 0.5 s, becomes a multiple index. So, there is not much variation you can see in one-third and two-thirds fillings for the same speed; here also, the same thing. So, the only thing is at higher speed, you will have a little higher value - a little higher value. Now, if you look at the quality feed index, then this blue line is giving you the maximum that means the number of hills dropped are between 0.5 s to 1.5 s. So, that is maximum we are getting at one-third filling, and as we increase the speed or increase the depth of filling in the seeder, that will also reduce.

Then seeding uniformities. So, if you look at all these figures, then you can see the best one is 1 kilometer per hour, one-third filling. So, taking all those uniformity coefficient or distribution coefficient and the missing hills, multiple hills, you can see that that is the best.

Now, if you look at the seed rate, you are getting a seed rate of 26, around that 26 kg per hectare. And that variation is not much you can say, if you look at this - these two they are very close. That means, whether you go for one-third, two-third does not matter, whether you go for 1.2 kilometer per hour or 2 km per hour - when you increase the speed, the seed rate is increased little bit. So, with this background what we conclude is that we should go for testing the seeder which we developed - remote control seeder with the forward speed of 1 kilometer per hour and at a box filling of or drum filling of one third. So, now I will show you the video. You can see that with a remote control, the seeder is moving here. And it is also dropping seed, then look at the float, float is sliding over the soil surface and we will see a turning at the end. Power is disengaged to the right side and is available to the left side. So, it is taking a right turn. So, this is how the machine was operated or the seeder was operated in the field. Then we try to measure the consumption - current consumption, what we found is the driving motor is consuming 2.67 ampere. Linear actuators are consuming 0.53 amperes. Both linear actuators consume 0.53 and 0.51 amperes, and the Arduino UNO board is consuming 0.09 amperes. So, two 12-volt, 7-ampere-hour batteries, if connected in series, can operate the seeder continuously for up to 1.3 hours. Then, we tried to determine the minimum turning radius, and we observed that it was 0.8 meters. We also measured the deviation from the straight path. So, if you look at the plotted data, there is not much deviation. The deviation is within $\pm$ 5 percent. So, when the turning radius is 0.8 meters, it means it covers a width of 0.8 meters and takes a turn of 0.8 meters. So, it does not create much difficulty in maintaining the row-to-row distance. Then, we measured the distance up to which signals can be sent using Google

Earth. So, it is 96.92 meters, and the actual velocity measured in the field is 0.85 kilometers per hour. The field capacity was 0.063 hectares per hour with a field efficiency of 78 per cent. The time to take a turn is around 17 to 19 seconds maximum, and the response time to take a turn is 0.42 seconds. These are some of the outputs from the seeder we tested. These are the field trials conducted in the actual field. The seed rate obtained is 28 to 30 kg. The missing index, multiple index, and quality fit index were all measured. Increasing the filling level in the hopper from one-third to two-thirds and the forward speed from 1 kilometer per hour to 1.2 kilometers per hour resulted in reduced quality. So, quality in terms of feed index, distribution uniformity, seed rate, missing index, multiple index, and seed-dropping uniformity were all reduced. So, that is why we prefer to operate at one kilometer per hour and one-third drum filling. The current consumption, which we already discussed, and the range of wireless communication were also discussed. So, finally, we can say that these kinds of arrangements are necessary to mechanize paddy cultivation effectively. So, the only difficulty we faced here was the slippage of the wheel.

So, the cage wheel which we designed requires some modifications to make it more effective and productive. So, these are some of the attempts we made at IIT Kharagpur.

So finally, these are some of the references required for designing. Finally, I can say I discussed the need for a remote-controlled paddy seeder in wetlands and the different components of such a seeder. Then, we discussed how we designed it, the power transmission system, how to determine the power requirement, and other related aspects briefly.

I hope this will help you in further designing such machinery. Thank you.