Design of Farm Machinery

Prof. Hifjur Raheman
Agricultural and Food Engineering Department
Indian Institute of Technology Kharagpur

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Lecture 28 : Performance evaluation of metering unit and design of hopper

Hi everyone, this is Professor H. Raheman. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. Today is lecture 28, where I will discuss the performance evaluation of the metering unit and how to design a hopper. The concepts which will be covered include some numericals related to calibration, so that you will know how to calibrate a seed drill. Then, performance evaluation of the metering unit, some coefficients you have to define, and then the design of components of a seed drill, where I will try to cover the design of a hopper, the seed-storing component. I will start with a problem related to calibration.

So, the problem is: while calibrating a 9 × 200-millimeter fluted roller seed drill for wheat seed, the seed rate is given as 100 kg per hectare. The following data were obtained after rotating the ground wheel 20 times. The diameter of the drive wheel is 50 centimeters, and the transmission ratio between the ground and the feed shaft is 1:1. So, find out the seed rate. When we calibrate, we have to find out whether the seed rate we mentioned is achieved or not, and then we will see whether there is uniformity between the furrow openers - the seeds which are dropped in different furrow openers.

To start with, there is a 9-row seed drill. So, the observations given here are for each tube, whatever quantity of seeds are dropped, that is given, and this has been replicated thrice. So, that means for each seed tube, there will be 3 observations, and for 9 tubes, there will be 27 observations. So, what exactly you have to do is first find out the average, the average seed drop amount in each tube. So, you have to take the average of 1, 2, 3, 60.5, 61.3, 61.5. So, that way it comes to 61.6. Similarly, you have to calculate the average of seed number seed tube number 2, 61.66. Then 63.23, then 63.67, then 61.9, 62.3, 62.93, then 62.96, 62.26, and 62.83. These are the average values, and these are in grams. Now, the summation of this has to be taken. So, that way you will get 561.88 grams. This is the total quantity of seed which is dropped in 20 revolutions. That means, in 20 revolutions, we have to find out what is the area covered. So, area covered - to find out the area covered, you need to know the diameter and, need to know the diameter of the ground wheel, and you need to know the width. So, the width of coverage will be - this is a 9-row seed drill. So, 9×200, that way 1.8 meters, and in one revolution, the diameter of the wheel is given as 50 centimeters. So, you can find out πD. So, in 20 revolutions, you just multiply by 20. So, that will give you the distance - length covered. Length into width will give the area covered, which comes to, ah, roughly around 2.826 - sorry, 2.826 meters square. So, the area covered will be 1.8×1.57. So, that way you get an area of - in one revolution you will get an area of 2.826. In 20 revolution you multiply with 20 that way you will get 56.52 m^2. Now, this much gram is dropped in this much area. So, in 10000 meter square, the quantity dropped has to be found out. So, that way we will get 99.41 kg per hectare. The seed rate was given as 100 kg per hectare, now we are getting a value which is very closer to that one - 99.41 kg per hectare. If you follow the BIS standard then the difference should not be more than 7 per-cent. So, that way the difference is not more than 7 per cent. So, this is accepted.

The second thing is we have to find out the variation, variation between the row to row. So, what we do is we calculated the mean value, we can calculate the mean value of this and then take the difference from the mean of individual seed tubes, how much is the difference. If the difference is less than 7 per cent then we will accept this that means, there is no much variation among the seed tubes. So, you just take 61.6, 61.66, 63.23, 63.67, 61.9 likewise. The summation of this divided by 9 that will give the mean value then (61.6 − mean value)/the mean value. So, that will give you the percentage deviation from the mean. So, you have to calculate this deviation for all 9 rows and then compare if that variation is within 7 per cent, then we accept it.

The next question is about a centrifugal broadcaster, which is used for sowing seeds, where we try to find out what the uniformity will be. So, this has been discussed in the last class: how to find uniformity for this. So, I will take up a problem. So, that will give more clarity. So, a row of 10 square trays, each of 15 centimeters by 15 centimeters in size, are arrayed across the 20-meter swath of a centrifugal seeder, which is seeding, say, alfalfa seeds. After the passage of the seeder, the following amounts of seed in milligrams were found in trays numbered 1 to 10. So, that way, 20 milligrams, 32.8 milligrams, 32, 30.5, 29.3, 29.1, 30.3, 31.5, 32.7, and 23.5. So, we measured the weight of grains falling in these trays. Then, what is asked is to find out the mean, the standard deviation, and the coefficient of variation of the amount of seeds in the trays. Also, calculate the seeding rate. Also, calculate the seeding rate.

So, this will be the arrangement now. So, in each tray, starting from 1, 2, 3, 4, 5 up to 10. So, the quantities are given. Now, we have to find out the standard deviation. So, for finding out the standard deviation, again, you have to find out the mean. So, this is the formula which will be utilized for finding out the standard deviation.

So, q_i is nothing but the weight of grains which is present in each tray. So, that way we can calculate q_i mean summation of $q_i/10$ because the number of trays is 10. So, we can find out what will be the value of $\bar{q}$, that is q mean weight of seeds, mean weight of seeds in each tray. Now, q_i is known. So, q_i minus $\bar{q}$ whole square. So, individually you have to calculate starting from 1 to 10 and then take the summation of that one divided by n minus 1 square root. So, that will give you the standard deviation value. So that way, we are getting a standard deviation value of 4.12 and the mean value, $\bar{q}$ is 29.17 milligram. Now, to find out CV, 100×standard deviation/$\bar{q}$. So, if you substitute this then we will find out CV as around 14.12 per cent. So, this is accepted because the ideal one is 0, but you will never get 0; there is some variation. Now, up to 20 per cent, it is allowed that means, if the CV value is within 20 per cent then you can say that it is uniformly distributed. So, now, you are getting a value of 14.12 per cent. So, it is fair enough; you can conclude that the centrifugal seeder which is used for seeding is giving uniformity of distribution. So, we calculated mean, calculated standard deviation, coefficient of variation, and then we have to calculate the seeding rate.

For seeding rate, we know the mean value and the area of each tray is 15 centimeter by 15 centimeter. So, that way you are getting 225 centimeter square and the amount of seed is known, which is q bar. So, $\bar{q}$ divided by this × 10000 × 10^4 cm^2 is to converted into meter square and then divided by 1000. So, that will get kg per hectare. So, it comes to 12.96 kg per hectare.

So, this is how we calculate the uniformity of distribution as well as the calibration, how to find out the seed rate for a given seed rate. The next thing is when we try to evaluate the performance in a sticky belt or in a plastic sheet coated with grease or in sand bed. So, the main aim is to find out what is the spacing between two adjacent seed droppings, so, that is important. So, if the spacing is less than 0.5 the desired spacing is there for a given crop and if that spacing is not maintained and if you say that the spacing is denoted as S. So, how many are satisfying this or how many seeds are not satisfying this that we have to calculate.

So, in the figure I have indicated s distance between 2 adjacent seed drops and that is denoted as s. Now, I will define a terminology called missing index. Missing index means is the number of spacings between the seeds which are greater than 1.5 times the desired spacing. Desired spacing was s if the spacing is more than 1.5 s that means, here the spacing is more than 1.5 s. So, that means, this we consider as missing index missing droppings. So, you may have several such missing droppings. So, that you count. Then you try to find out missing index which is equal to $(n_1/N) \times 100$. So, N is the total number of observation, n_1 is the number of spacing which are exceeding 1.5 s and then taking the ratio multiplying with 100 that will give you missing index. Similarly, you will find another parameter which is called multiple index with the spacing between the seeds those are lesser than 0.5 times the desired spacing that means, lesser than 0.5 s. So, if you look at this one, the spacing is now reduced between 2 adjacent seeds it was 0.5 s whereas, the desired spacing is s. Now, if you get such observations then you have to count it in that sticky belt method or in a belt sticky or in a plastic sheet smeared with grease in those. There you have to find out how many such observations are there. So, if you denote it as n_2, then $(n_2/N) \times 100$ that will give you multiple index which is denoted as I_{mult}. So, n_2 is the number of spacing which are lesser than 0.5 s and N is the total number of observations then multiplied 100 that will be expressed in percentage. Similarly, one more parameter will be computed like quality feed index. We consider the missing index and multiple index. Now we are considering quality feed index. Quality feed index means, the spacings which are obtained between seeds that are lying between 0.5 to 1.5. So, between 0.5 s to 1.5 s, if the seeds are dropped then we consider as the quality dropping. The spacings which are obtained between seeds that are lying between 0.5 to 1.5. So, between 0.5 s to 1.5 s, if the seeds are dropped then we consider as the quality dropping. So, we express that in quality as quality feed index. So, the number of spacings between the seeds those are lesser than 1.5 times but, more than 0.5 times of the desired spacing then we express that as quality feed index which is equal to n_3, $(n3/N)$ into 100. So, n_3 is the number of spacings which are between 0.5 to 1.5 and N is the total number of observations then multiply with 100 that will give you in percentage. In addition to these there are some other parameters like coefficient of hill distribution uniformity. That means, basically we are going to measure the uniformity of distribution which is denoted as Se is the variability in seed to seed spacing or hill to hill spacing. It indicates closeness of the seed spacing to the desired spacing, how closely we are maintaining the desired spacing and is expressed as $(1 - Y/Z) \times 100$. That means, Y - mean of the absolute difference between actual spacing between seeds and mean seed spacing. So, that is the difference and then Z is the theoretical or the desired seed spacing. So, Y by Z. So, $(1 - Y/Z) \times 100$ that will give you coefficient of hill distribution. Then comes coefficient of seed dropping uniformity in hills. Here, when you are going to drop seeds in hills, in a hill there will be more than one number of seed may be 2, 3, 4. So, you need to know what is the variation between hills, whether all the hills are provided with 2, 3 seeds or more than 3. So, that if you want to measure then this is the parameter which will be used to evaluate that. So, Sh which is nothing but coefficient of seed dropping uniformity in hills = $(1 - u/w) \times 100$. u means a mean of absolute difference between the actual numbers of seeds per hill and mean number of seeds per hill. Then w is the required number of seeds per hill. So, that way u by w has to be computed as $(1 - u/w) \times 100$, which will give you the percentage value. So, these are some of the parameters which are to be computed after carrying out testing of a seed drill or planter in the sticky belt method, the sand bed method, or the plastic seed method. So, that will give you the performance of the seeder or metering unit.

Now, this is a figure where I have indicated the seed drill, showing the width of coverage and the spacing between two adjacent seed tubes. So, this is from the back side. So, that is why this is a 9-row seed drill. So, in the front, there will be 4 rows. And in the back side, there will be 5 rows, altogether 9 rows. So, if I say 9 × 200, that means if the spacing is 200, the spacing between two adjacent seed tubes - two adjacent seed tubes means one in the back and the other one in the front that will be 2 adjacent. If you take these two, then you end up with a higher spacing.

20 means 200/10, 20 centimeters × 9 rows. So, that way, 180 centimeters or 1.8 meters. So, that will be from the center of the wheel to the center of the wheel; that distance is called the width of coverage. Now, the first component in a seed drill or a planter is the seed storage component, which means seeds are to be stored where they will be stored; you have to have a box, which is otherwise called a hopper. So, a hopper has to be provided for each of the seed drills - either independent hoppers or a common hopper - and from there, you can take seeds to different seed tubes.

So, the main thing we are going to design in a seed hopper is its capacity, and then accordingly, we decide the dimensions. So, L_b is the width of the hopper; it should be equal to $W - 2b$, where W is the cutting spacing into the number of rows. So, that will give you W. 2b is nothing but the distance between the wall of the hopper to the center line of the ground wheel. Because here, there are two ground wheels. So, power is taken from one of the ground wheels to the metering shaft. So, this is the ground wheel, and power is taken through a chain and sprocket, going to the metering shaft. So, the distance between the center of the inner side of the wheel and the wall of the hopper, we have to provide certain clearance. So, if that clearance is taken as b, then we can find out the width of the hopper—the width of the hopper will be $W - 2b$. So, the length of the seed box—or you can say the distance between the sidewall of the hopper - that is b. The b value can be assumed as 150 to 200 millimeters, or you can take the spacing divided by 2. Then, the maximum seed rate for which you are designing the seed drill has to be taken. So, this is in kg per hectare. Suppose, for wheat, the maximum seed rate is 120 kg per hectare. Usually, the normal seed rate is 100 kg per hectare, but if you go for late sowing, you have to provide more seeds - that means, instead of 100 kg per hectare, you have to go for 120 kg per hectare. So, the seed rate has to be fixed. Then, the hopper should handle this amount with a few number of refillings because you cannot handle 100 kg at a time.

So, if you handle 100 kg, so what will happen the volume of the seed box or the hopper will increase which is not desired. The cost will increase. Unnecessarily we are adding weight to the rear side of the tractor. So, that way you have to decide the number of fillings. So, usually 3 to 4 fillings if you take. So, you are basically designing Q/3 or Q/4 that will be the quantity for which you are going to design the seed box.

Now, what is the field capacity then? So, for finding out the field capacity of the seed drill we need to know the width. So, which we have calculated the distance between two adjacent row and the number of rows. So, that is equal to $W \times S \times N_f$. S is the speed and N_f is the transmission ratio ratio between ground wheel and the feed shaft. So, that way we will calculate field capacity and then W_s weight of the seed which has to be accommodated and then corresponding volume has to be found out.

So, Q for finding out the weight of the seed we know the seed rate and we have calculated the field capacity. So, that way you will find out what is the quantity of seed you are going to put into the box and divided by the number of fillings. So, Q is the seed rate per hectare. So, if you divide into number of fillings say 4 or 3. So, your H is the value that 3 or 4, then field capacity if you know then you can find out what is the weight of seed, but weight has no role is the volume of the box should accommodate.

So, the volume of the seed box will be equal to W_s/bulk density. When you divide the weight by bulk density, then we will find out the volume of seed to be put into the hopper at a time. Then, consider 10 per cent extra volume to avoid spillage from the hopper. Because many times you are moving into the field with some bumps, etcetera. So, some jerks will be there. So, if you completely fill it, then there is a possibility that there will be spillage. So, to overcome that, we give some free space. So, that is why whatever volume you are getting here, we are just taking 10 per cent extra. So, that will be the volume of the hopper. Next is for easy construction and free seed flow, which is important. The seed should always be available at the bottom where the metering units are fixed. So, to do that, we have to take a cross-section like a trapezoidal cross-section. So, you can see the slants are there. So, the seed should always be available in this space, and the metering mechanism can be kept at the center. So, that is the best arrangement.

Now, if you are taking a trapezoidal section, then you find out the cross-sectional area, multiply it with length, and that will give you the volume of the trapezoid, that means the seed hopper. Then, knowing theta, you can find out, if you find out this, this is nothing -. ‘a’ is nothing but the width of the metering unit plus some clearance on this side and some clearance on that side. If you fix ‘a’ value and if you know theta, then you can find out b, okay? So, looking at this, the expression $(a + h \cot \theta) \times h \times L_b$ will give the volume. Now, θ here is the angle of a side wall with respect to the horizontal, and this θ should be greater than the angle of repose. The angle of repose means the angle at which the grains can freely flow without any obstruction. So, that has to be found out, and the angle θ should be at least equal to or greater than that. So that, all the time, seeds will flow easily to the bottom side. Then, the wall thickness of the seed drill is designed by assuming that the seeds exert uniform pressure at the bottom of the seed box, as in the case of a retaining wall with submerged backfill. So, what you can do is take a mild steel sheet of 1 to 1.5 millimeters, or you can take a plastic sheet also. Nowadays, plastic sheets are very common. So, those can be utilized, but the thickness has to be increased. So, what is the pressure? If you know, you can find out the thickness of the wall. The pressure is more at the bottom and less at the top - zero at the top, maximum at the bottom. So, these are some of the references. In brief, I can say we discussed how to evaluate the performance of metering units in the laboratory. Then, we tried to solve some numerical problems, and I hope that will clear your knowledge related to calibration, performance evaluation. Then, we did some design work - the design of a hopper.

Thank you.