Design of Farm Machinery
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Week - 01
Lecture - 04

Hi everyone, this is Professor H. Raheman.

I welcome you all to this Swayam NPTEL course on Design of Farm Machinery.

This is lecture 4, where I will cover disk plough.

The concepts which will be covered here is, details of disk plough, constructional details, then what are the different types of disk plough, then how to represent forces acting on the disk plough, then influence of different variables on soil reaction, then plough adjustments.

The left side figure shows a disk plough.

So, it comprises of disks, which are mounted independently to a frame.

So, they are mounted independently to a frame and this is the bearing to which the disk is attached to the shank and this one is the rear furrow wheel.

The disk plough is used for primary tillage for weed control and mixing stubbles with the soil.

Blades of the disk ploughs are concave and they represent the sections of hollow sphere.

The concave disk blade, when it operates because of the friction of soil and disk, they will try to lift the soil which is cut, pulverize it and partially invert it and then throw the soil to one side.

So, the disk plough, they move all the soil towards one side.

The disk type implements - they can be operated when the field is infested with crop residues.

So, what happens you know, the disk will roll over the crop roots and they can be operated in non-scouring soils.

If the soil is not scouring then you have to provide this scraper, this red ones - these are scrappers, ok.

So, you have to provide these scrapers. But the problem here is, we do not get complete inversion.

The multiple disk implement they have a scalloped furrow bottom profile that means, a layers like structure will get. After operation you will find like this.

So, what are the different types of disk plough?

The disk ploughs are classified as standard disk plough and the vertical disk plough.

The figure which I showed, that is a standard disk plough where the disks are mounted independently to the shank and then to the frame.

Whereas, in case of a vertical disk plough - It is similar to a standard disk plough, but the disks are uniformly spaced along a common axle or gang bolt and they are clamped together through spacer spools.

So, the entire gang rotates as a unit, so that is the difference.

The standard disk ploughs they are usually provided with 3 to 6 blades each of diameter varying from 61 to 71 centimeter.

Whereas, vertical disk plough, the size of the disk are smaller. Smaller than the standard disk plough and the range is 51 to 61 centimeter. They are generally spaced 20 to 25 centimeter apart along the gang bolt.

The angle between the disk face and the direction of travel which is otherwise called disk angle and that is ranging from 42 to 45 degree whereas, the disk angle in case of a vertical disk plough is 35 to 55 degree.

In case of a standard disk plough, the disks are tilted backward at an angle from the vertical, which is known as tilt angle and the range is 15 to 25 degrees, where disks in case of vertical disk plough they are not tilted because they are mounted on the same gang bolt. They are not tilted rather they are vertical.

Standard disk ploughs are built with heavy frames and wheels.

The total mass ranges from 180 to 500 kg per disk.

In case of vertical disk ploughs, they are primarily related to a shallow plowing.

So, they are built much lighter than standard disk ploughs. Usually the weight is 45 to 90 kg per disk.

So, these are some of the differences between standard disk plough and vertical disk plough.

And the two angles which I, just now I said, one is disk angle, the other one is tilt angle.

Disk angle as I said the face of the disk makes with the direction of travel.

If you take a top view that will clearly indicate this angle which is usually in the range of 42 to 45 degree.

Then tilt angle the other important angle - how much the plane of the disk is tilted backward from the vertical.

So, this angle, which is called tilt angle.

So, this is ranging from 15 to 25 degree.

So, when we operate a disk, it will be subjected to parasitic forces.

So, that can be represented. I will take it may be in the coming class.

So, we will try to find out what is the speed effect of different variables on soil reactions.

When the speed was increased from 4.8 kilometer to 9.6 km/h, the draft was increased. Increased by 40 per cent in clay loam soil and 90 per cent in the fine sandy loam soil.

The side force was also increased with speed because soil was thrown farther to the side, but the vertical force V is decreased with increase in speed.

Hence, with the blade tilted, increasing the speed will improve soil penetration.

And a few researchers have indicated that if the blade is vertical then the effect is reversed that means, penetration is decreased if we increase the speed.

Now, let us see how this L, V and S, the useful soil forces they are affected by disk angle, tilt angle at two different soil conditions.

The figure here indicates clay loam soil which is given by the dotted line and the solid line is fine sandy loam soil.

So, there are two soil types and figure 1 says - Figure (a) says the speed is at 5.5 km/h, the tilt angle is 0 and width is 18 centimeter and depth is 15 centimeter.

So, with increase in disk angle what is the corresponding L, V and S value that has been reported here in figure (a).

So, if you look at this then what we observe is L is initially, whether you take a sandy clay loam soil or whether you take clay loam soil or fine sandy loam soil initially the value is higher. As we increase the disk angle, it is reducing then with further increase in disk angle, it is again increasing, why it is so?

So, the reason is : when we increase the disk angle, the draft is increasing because the soil is thrown to a farther distance that requires more force.

So, draft requirement increases. When we decrease the disk angle, again the draft is increased.

The back side of the disk that is the convex side it comes in contact with the furrow wall, thereby there will be more resistance.

So, that thing is indicated When the back side is in contact with the furrow wall the side force should be minimum.

So, that is indicated here.

If you look at the plot of S versus disk angle, you can see S is minimum at 35 degree and is maximum at 52 degree.

So, same is the trend for both the soils that means, the draft is minimum at a particular point around say 42 to 45 degree.

So, that is the reason I indicated that disk angle should be between 42 to 45 degree.

Now, coming to vertical force - you can say vertical force decreases with increase in disk angle, that means, it helps in penetration.

If you increase disk angle, V is reducing.

Usually in a disk type implement, the soil reaction force L V and S, the V is always acting upward.

So, that upward force will try to lift the implement. It will not help in penetration.

So, if it is reducing that means, that is better penetration.

So, if you want better penetration then you go for higher disk angle.

Now coming to the side force, side force is again increasing with increase in disk angle, ok.

Now coming to the figure (b), where the difference is, there is a tilt angle, rest of the things is same.

Speed is same, width of cut is same, depth is same that means, 15 centimeter.

So, only change which I made is, we have increased the tilt angle to 15 degree.

Now, what you observed is, the same trend. Whether the tilt angle is 0 degree or the whether the tilt angle is 15 degree, the trend is same. With increase in disk angle, the draft is first reducing and then increasing and vertical force is reducing.

At the side force, the trends are little different in the sense, in one soil it is showing downward that is in clay loam soil and in fine sandy loam soil it is showing a trend in upward. May be some experimental error.

But, overall we can say that the trend is same whether you have tilt angle or whether we do not have tilt angle.

That means, draft is minimum at an angle say 45 degree for both the soils and vertical force is reducing that means, with increase in disk angle the penetration is better and side force is increasing with increase in disk angle.

So, that is one component.

Now, let us see when we are getting minimum value of draft at a particular disk angle.

So, what we did is the third plot which is figure (c), there we varied the tilt angle from say 15 degree to 25 degree.

And the conditions are : operating speed is 5.8 km/h, disk angle is kept as 45 degree and 23 centimeter is the width of cut and depth is 15 centimeter.

So, what we observed here is : again for two different soil conditions, with increase in tilt angle, the draft force is increasing ok.

The vertical force is increasing, this has a reverse trend as compared to disk angle and the side force is decreasing.

And L, V and S they are always higher for clay loam soil as compared to fine loam soil.

So, from all these discussions, what you can conclude is : if you want lesser draft then go for a disk angle of 45 degree 42 to 45 degree and a tilt angle of 15 degree.

If you want more penetration go for 15 degree, lesser tilt angle and higher disk angle.

Then there are few adjustments for disk plough.

Width of cut for disk blade can be changed by rotating the entire frame in a horizontal plane and adjusting the wheels to compensate for the changed frame angle.

So, thereby penetration in hard ground is improved. Because the total gravitational force is distributed over a narrower cutting width.

Now if you require penetration of a standard disk plough that means, if you want more penetration, then you have to decrease the tilt angle.

If penetration is not difficult, the use of larger tilt angle will result in better inversion of furrow slice.

Ok. So, a large tilt angle is best for sticky soils. These are some of the adjustments.

Now coming to, how to find out diameter of the disk, which diameter should be suitable?

So, if you want to find out the diameter of the disk, then there is a formula given here $D = k\frac{a}{\cos\beta}$. K is a coefficient, this value depends whether you are using for deep tillage or whether you are using for medium tillage.

So, if it is a deep tillage, the value of K is 2.5 to 3. If it is a medium tillage, the value is 3 to 4.

So, 'a' is the depth of operation in centimeter and beta is the tilt angle.

So, if you know these values, then you can find out what should be the value of D and what value of D you should take.

If 'a' is this much and if you want to maintain a tilt angle of beta and for shallow tillage or medium tillage, then you can find out what should be the diameter of the blade.

Now, if you look at the figure which is given.

So, diameter of the disk at a depth 'a', if you like to find out, then the procedure is if you take $D_a/2$ this distance say. This is a right angle triangle if you just join it.

You just join this one.

So, this becomes a right angle triangle. This is $D_a/2$. This distance is $D/2 - a$. This is the depth of operation.

So, now, applying Pythagoras theorem, we can find out expression

$$\left(\frac{D_a}{2}\right)^2 = \left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - a\right)^2$$

So, that way you can find out diameter at any depth. "a" is the depth D is the diameter. If diameter of the disk blade is known, diameter at any depth we can find out by utilizing this equation. $D_a = 2\sqrt{a(D-a)}$

Then the other important component is, what should be the spacing between disks?

So, when we look at the standard disk plough, we have we have seen that there are number of disks mounted. Then what should be the spacing between disks which has to be maintained.

So, I have indicated here 2 disks. They are tilted by an angle β. 'a' is the depth of operation, 'c' is the ridge height. Then I have taken the top view.

So, this figure shows you the top view.

Shows you the top view and S is the spacing between disks.

So, this is the spacing between disks 'S' and 'c' is the height of the ridge, which i have taken as less than 0 point less than equal to 0.3 times the depth of operation.

Now, if you look at that right angle triangle ABC.

So, BC that AC is making an angle theta 0, which is your disk angle or otherwise you can call it a setting angle. Both are same.

Now, BC will be equal to, this AC is nothing, but D_c diameter at ridge height.

So, that becomes D_c. So, $D_c \sin\theta_0$. BC is equal to $D_c \sin\theta_0$.

Now, look at the right angle triangle ADF. So, DF will be equal to either you go on this right triangle or you can go by FDG this right angle triangle. Because we know that FG value: FG is nothing, but your 'S'. So, now, this is θ_0 which is setting angle.

Now, FD. $FD = FG\cos\theta_0$. In other words you can write as $S\cos\theta_0$.

Now, EF. This smaller distance EF. So, if you consider this CEF right angle triangle, then $EF = CF\sin\theta_0$

.This angle is $\sin\theta_0$.

So, this angle will be $\sin\theta_0$.

This angle will be $\sin\theta_0$, sorry θ_0.

Now, $EF = CF\sin\theta_0$and this EF is nothing, but the transposition.

The CF, CF is nothing, but your transposition, which is 'e', the distance between two axes of the adjacent disks center line. This distance is 'e'. So, $EF = e\sin\theta_0$.

Now, $D_c\sin\theta_0$ that is BC is equal to BC = DF ─ BC = DF ─ EF. So, DF is $S\cos\theta_0$ and EF is $e\sin\theta_0$.

So, that can be written as D_c is equal to if I arrange this.

So, Dc if you take $\sin\theta_0$ to the right side, then $D_c = S\cot\theta_0 - e$

Now, Dc will be equal to because diameter at c, it has a tilt angle.

So, that is why divided by $\cos\beta$. Otherwise I can if there is no tilt angle I can take as c×(D ─ c). But since it has a tilt angle.

So, $\boldsymbol{2\sqrt{\frac{c}{cos\beta}(D-\frac{c}{cos\beta}})}$.

So, that way you will find out Dc and the total expression is

'S' is equal to if you substitute this expression here, then from there you will find out if you rearrange $S = \left[2\sqrt{\frac{c}{\cos\beta}\left(D-\frac{c}{\cos\beta}\right)}+e\right]\tan\theta_0$.

The value of transposition of disk 'e' should be such that the spacing should be greater than 2a always, so that there is no overlapping or clogging of soil.

Now let us look at the problem, how to find out width of cut of a disk plough.

A single bottom disk plough with a diameter of disk 76 centimeter is operated at a disk angle of 50 degree and a tilt angle of 25 degree and depth of operation is 12 centimeter.

So, what is asked is, determine the width of cut of disk plough.

So, what we will do here is: Let us first draw the, first draw the disk, then when there is no tilt angle this is the front view. When there is a tilt angle this is the front view.

Now what is given is 76 centimeter that means, O if you denote is as OE, OE is equal to 76 by 2 ok. And the depth of operation is given as 12, this is given as 12 centimeter.

Now what will be the width of cut?

So, now find out 'x' because it has a tilt angle phi.

So, we find out 'x'. So, 'x' will be equal to $\frac{d}{x}$ = cos∅, if ∅ is the tilt angle d/x will be cos∅

Now, x will be d/cos∅.

So, d is given, cos∅ is given, we can find out x.

Now x is nothing, but this distance. We know OE. OE is your diameter, radius, 76/2 and x is d/cos∅.

So, difference will give you OC, ok.

Now OA is nothing but your radius, which is 76/2. So, $OA^2 - OC^2$ square that will give you 'y'.

So, OA^2 square is $(76/2)^2$, but OC^2 is nothing but $\sqrt{(76/2 - x)^2}$. So, that will give you 'y' and this is half the width of cut.

Now, twice of 'y' will give you total width of cut.

So, that will give you the width of cut of disk plough.

This is the case when there is a tilt angle. When tilt angle is not there then things are more simpler.

You do not have to find out 'x', you can directly take 'd' and from there you find out this 76/2 − d instead of taking 'x'. It will be minus 'd' and that will be more simpler.

Let us now compare, because we have already discussed about disk plough and in previous classes we have discussed about moldboard plough.

Let us now see what are the differences between disk plough and moldboard plough.

The difference has to be discussed based on certain parameters.

So, what are those parameters, I have listed in the first column.

The soil condition where disk plough is suitable, where moldboard plough is not suitable.

So, disk ploughs are most suitable for conditions such as hard soil, dry soil, in sticky soil where the moldboard plough will not scour and in loose push-type soil such as peatlands, in stony and root infested soils.

Whereas, moldboard plough, it works well other than the soil which is mentioned for disk plough.

Working element: In case of a disk, the working elements are concave disk usually representing the sections of hollow sphere.

Whereas, moldboard plough, the working element is your share. Share, which is of rectangular shape and it has a pointed edge which penetrates into the soil.

The other aspect in working elements is: the surface is moving during operation in case of a disk plough.

The disk is moving. Whereas, in case of a moldboard plough the working element, share is not moving, it is fixed.

Then in case of a disk plough, the plough angles are different. Angles like disk angles and tilt angles are there. Whereas, in case of a moldboard plough, it has no angles.

No angles in the sense there is no disk angle or tilt angle. It has angles like horizontal suction and vertical suction.

Then coming to the soil inversion side, soil inversion is partial in case of disk plough, whereas, soil inversion is more complete in case of moldboard plough. Because of the moldboard, it gives a better inversion.

Now, the side force. When you operate a tillage implement, there will be side force and the side force is absorbed by the furrow wheels in case of a disc plough. Whereas, in case of a moldboard plough, it is the landside which will absorb the side force.

Then soil reactions. If you look at L, V and S, the vertical soil reaction is always acting upward in case of a disk plough.

So, that is why penetration is difficult. We have to have more weight of the implement. So that, it penetrates on its own.

Whereas, penetration in case of a moldboard plough is much easier, because V is always acting downward and the horizontal suction and the sorry the vertical suction helps in proper penetration.

So, penetration is not a difficult is not a difficult task in case of a moldboard plough.

Plough, the moldboard plough is fitted with a colter, there is a problem in penetration, because colter is very hard to enter into the soil. The vertical force is always acting upward in case of a colter.

So, if a plough is fitted with colter, the plough coulter combination, the vertical force depends whether it is acting upward or downward depending on the resistance acting on the colter.

If resistance is more that means, V is acting upward. But in general, we can say V for disk plough is always upward. V that is vertical force for moldboard plough is just opposite to disk plough, that means, it is always acting downward.

So, these are some basic differences, otherwise both are used for primary tillage, the initial opening of soil.

So, these are some of the references and the conclusion is we discussed about the constructional details of this plough and what are the forces acting, how the forces are changing with different variables.

And we have found out how draft is dependent on different parameters like disk angle, tilt angle and the speed, type of soil and then we discussed how to compute the disk spacing and the diameter of the disk at different depths.

Thank you.