**ADesign of Farm Machinery**

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**Lec 56 :Classification, working principle and factors influencing performance of threshing equipment**

Hi everyone, this is Professor H Raheman. I welcome you all to this SWAYAM NPTEL course on Design of Farm Machinery. This is lecture 56, where I will try to cover classification, working principle, and factors influencing the performance of threshing equipment. The concepts covered will be classification of threshing equipment, then components and working principle of threshing equipment, and then parameters affecting the performance of a thresher.

To start with, what is threshing? Threshing is the process of separating grains from the harvested crops. It can be achieved by either striking the ears (which is the impact force), by rubbing due to friction, or by stripping. So, a rotating cylinder and a concave are the two important components used to accomplish the threshing operation. Crops are forced to pass through the gap between the rotating cylinder and the concave and are subjected to impact, rubbing, and vibrations, which cause detachment of grains from the crop stems.

Let us now classify the threshers. So, we classify threshers based on the path of travel of crop with respect to the cylinder axis, based on the position of the crop bundle, and based on the types of cylinder used for carrying out threshing. So, we will further classify based on the path of travel of crop with respect to the cylinder axis. We classify into two types: one is axial flow type, and the other is cross flow type. When I say axial flow type, it means the path of travel of the crop is along the axis of the cylinder. So, the contact time increases, which means the crop will remain inside the cylinder and concave for a longer period of time, hence more number of bites, hence more separation that means more threshing. So, this is the one. Look at the figure which I am showing on the right side. We are feeding crop from one end that is at the top or you can feed at the side also that is possible and the crop will flow along the axial path, along the axis of the thresher and then it will come out.

So, below the cylinder there is concave. So, whatever grains are separated they will be falling on the concave and then to the outlet. This is axial flow thresher. Now, coming to the cross flow thresher, as the name says cross flow that means, the path of travel of the crop is perpendicular to the axis of the cylinder. So, here we are feeding the crop this side. So, the crop is passing through the cylinder and concave gap and the axis is perpendicular to the flow path, so that is called cross flow.

Based on the crop bundle position we can divide into two types one is hold on type the other one is the throw-in type. Hold on type means the operator has to hold the crop bundle and then expose that bundle to a rotating cylinder which is provided with some working elements and that will detach the grains from the straw. So, basically the detachment is by stripping you can say. Then, the other one is throw-in type. Here, in case of throw-in type you do not have to hold the crop, you just put the entire bundle into the concave and cylinder - cylinder and concave gap. So, that the cylinder will take this bundles inside and do the threshing.

Now based on the cylinder, we can divide into a number of threshers like a drummy and hammer mill type the figure which I am showing here. So, this is a drummy and hammer mill type. So, it consists of - the cylinder consists of beaters which are mounted on the shaft which rotates inside a casing. The casing is closed and there is a concave. So, concave has openings. So, through these openings the grains which are separated will be falling on the ground or on the tray. And, the difference between a hammer mill type and drummy type is in case of a hammer mill type it is similar to drummy type, but some additional components like the aspirator which will suck the chaffs - small pieces of the straw and then sieve shaker is provided. They are provided in addition to this drummy type. So, there is a difference, difference is both basic elements are same only additional elements like aspirator and sieve shaker are provided for hammer mill type. It has a cylinder with you can see beaters which has long bars on the end of the bars we have a structure that is going to strike the crop which is present inside the cylinder and concave.

Then comes your syndicator type, syndicator type is just like a flywheel with corrugations. You can see corrugations here, which are provided on the periphery, periphery of the cylinder and sides which rotates inside a closed casing. The entire cylinder is rotating inside a casing and the bottom portion of the casing is nothing but a concave and the rim of the flywheel is also provided with a chopping knife. So, the chopping blades which are provided, it improves bhusa quality that means, bhusa means smaller pieces of straw with respect to wheat threshing.

Then comes spike tooth type, spike tooth type thresher. As the name says spike tooth type means there are number of teeth which are called spikes they are present in the periphery of the cylinder. So, cylinder has to be rotated and along with the rotation of the cylinder the spikes will rotate and they will have a biting action. So, this arrow is not in this direction. So, it will drag the crop which is in the feeding chute. Through this chute crop bundles are fed into this. So, this will try to drag it ok. So, the working elements here are the spikes.

Now, the other one is rasp bar type. Both the spike tooth type and rasp bar type, they are same only the working elements are different. You can see instead of spikes there are bars which are corrugated and they are provided at regular intervals. So, these bars they are going to drag the crop which is present in the chute and put it inside the cylinder and concave and then the threshing action takes place in this portion only. Same is the case in this portion. So, in the lower portion. So, the bars are nothing, but the corrugated steel bars they are mounted axially axially on the periphery of the cylinder and bars are corrugated from outside to increase the friction between crop and cylinder. It is fitted with an upper casing and an open type concave at the bottom of the cylinder. The cleaning system is provided maybe with a blower and a straw walker at the bottom.

Now the other one is your wire loop type. So, as the name says wire loop type that means, the cylinder is provided with working elements which are nothing, but wire loops. The cylinder is provided with wire loops and this has to be rotated at a high speed. It may have concave or it may not have a concave. So, there is a possibility because in a pedal operated wire loop type thresher we do not have a concave directly this grains which are detached, detached from the straw they are just stripped, stripped from the straw and they are falling in front of the thresher. So, you can provide a concave or you may not provide a concave. The only thing is: the working elements are nothing but simple wires; they are bent in a fashion that is called a wire loop.

So, now comes the question of where to use which type of thresher. So, these are some recommendations given by different researchers. So, I have just summarized this. So, drum-type, hammer mill-type, and syndicator-type threshers are suitable for threshing wheat crops only, and they can produce fine-quality bhusa. Though the hammer mill-type produces fine-quality bhusa, its use is decreasing due to higher power requirements. So, that is another constraint. The raspbar-type, wire loop-type, and axial flow-type threshers, they are suitable for paddy crop threshing, and they do not make fine straw. So, portable wire loop-type, paddle-operated threshers are widely used by farmers in paddy-growing areas. Then, the raspbar-type threshers can be used for crops other than paddy and wheat. Spike tooth-type threshers can produce fine-quality bhusa. This thresher can be used for threshing other crops if the blower is mounted on a separate shaft, so that you can vary the cylinder speed to accommodate different crops for carrying out threshing.

Next comes the question: what are the components of a thresher? From these figures and discussions, we can conclude that these are the main components: there should be a feeding device, chute, or hopper through which the material to be threshed is fed to the cylinder and concave. Then comes the threshing cylinder, which could be either hammer-type, spike tooth type, rasp bar type, wire loop type, or syndicator-type. So, these are different varieties of cylinders available; depending on the crop, we have to select the appropriate threshing cylinder.

Then comes your concave. Concave is nothing but a wire mesh or a sieve, we can say. So, its function is to sieve. Whatever materials are to be detached out of this, only grain should - it should allow the grains. The rest of the materials can be retained. So, concave then comes your blower or aspirator, and finally, the sieve shaker. These blowers and aspirators or sieve shakers are additional components. You may not find them in all threshers they are fitted with. They are basically to remove this bhusa and to remove the impurities from the grains which are detached, so that finally, you can get clean grains from a thresher.

So, what is the threshing mechanism? Whether it is a spike-tooth type, whether it is a rasp-bar type, whether it is a hammer-mill type. So, the mechanism of threshing is: grains are to be detached, detached from the ears mainly because of three factors : one is by impact, second is by friction, third is by vibration. So, when I said impact, impact between rotating cylinder fitted with working elements and the crop material. So, because of the impact, some amount of grains will be detached, and again because of the compression and vibration, some amount of grains will be detached. Because of the compression and friction, some amount of grains will be detached. The friction will be between working elements and the crop, and crop and crop. The rubbing action between stems of the crop or between straws of the crop, and rubbing action between working element and the crop material. When I said vibration, vibration is because of the striking forces which are applied through the working elements. These working elements strike at regular intervals. So, in between intervals, as there is a certain time gap, so what happens? Assuming that the material is elastic, so when the working element strikes, there will be a compression—compression of the crop layer, and when the striking is over, then the compressed layer will try to elongate.

So, there will be some vibrations, radial vibrations. So, because of the vibrations, there will be some grains which will be detached. So, these are some of the mechanisms by which the grains are detached during threshing with a thresher. As I said, the rasp bars, the rasp bar consists of a number of bars that are mounted on several star-shaped hubs to form a cylinder. The hubs are mounted on a common shaft which is supported by bearings, and then this shaft is driven by a V-belt and pulley from a power source. The bars are corrugated on the outside, and the concave is made of parallel bars. This concave, when I said made up of parallel bars or spikes, some concave they are also provided with spikes, but the spikes provided on the concave and the spikes provided on the cylinder are not in the same row. So that they do not strike each other. As the cylinder rotates, the crop is dragged into the gap between the cylinder and concave. When I said gap, we have to maintain a gap. At the inlet, the gap is a little higher, and at the outlet, the gap is a little lesser. That means the gap is gradually reduced from the inlet to the outlet side. So, thereby it creates a kind of compression in the crop layer which is dragged into the system by the cylinder. So, when it is dragged, that means some impact force is already acting, and several teeth are rotating, so impacts are given to the crop, and the crop is compressed. So, there will be - the crop will be forced to pass through the gap. So, there will be a rubbing action. So, impact and rubbing action, and in between, I said there will be vibrations.

So, these three factors will create the environment by which the grains will be detached automatically, you can say, from the stems or the straws. The strokes of successive bars against the grain layer passed through the working slit compress this layer, as I said, with a certain frequency. Then, this layer represents an elastic material which expands partially between the successive rasp bars or spiked tooth strikings. As a result, what will happen is that there occur in the layer forced radial vibrations of frequency equal to the number of strokes of the rasp bar during the time required for a particular section of the layer to be shifted through the working slit. That means, in between the time the crop is staying between the inlet to the outlet, there will be a number of strikes. So, it depends on what the RPM is, it depends on what the gap is? How many bars or spikes are provided? And what is the angle which is subtended by the concave?

These are the factors which will decide how much - how many times the crop is going to be struck by the working element or the rasp bars. So, the number of strikes - strikes of crop with bars can be calculated as $i = \frac{Z \alpha n}{2\pi}$. That means, $\alpha$ is the angle which is subtended by the concave and the cylinder, and Z is the number of bars which are fitted to the cylinder.

Then, if the cylinder has an RPM of n, then $\frac{Z\alpha n}{2\pi}$ will be the number of strokes a crop is going to receive while passing from the inlet to the outlet of a thresher.

Then, let us see what the parameters affecting the performance of a thresher are. So, we divide these parameters into three groups: one is crop parameters, the other is machine parameters, and the third is operating parameters. Now, under crop parameters, we can take the moisture content, type of crop, grain-to-straw ratio, and the green matter present. Because while harvesting, we may harvest some weeds or unwanted materials – plants - along with the crops. So, when you bundle it, it is difficult to remove that. So, when you put the bundle into the system, these green matters create some problems.

So, that is what we will discuss. Then, under machine parameters, we have the type of cylinder, type of tooth, concave gap, and length of the concave. Then, under operating parameters, we have the rpm of the drum and the feeding rate. In machine parameters, we can also include drum diameter. So, these are the parameters that are going to affect the process.

Let us now see, one by one, what exactly these parameters are and how they influence the performance. Under crop parameters, damage to large beans is more than to smaller beans at the same impact velocity and orientation. The moisture content is a major factor in controlling grain damage. So, if you look at the effect of moisture content. So, on the x-axis, we will find moisture content, and on the y-axis, we have two components: one is unthreshed grain, which is represented by this graph, and the damaged grains, which is represented by this curve, which is curve number 2.

So, what we can gather from here is that with an increase in moisture content, the amount of unthreshed grain increases. The simple reason is that when moisture content is higher, it requires more peripheral force to detach the grains. Since you are not changing the peripheral force, then obviously, some grains will not be detached. So, that will result in an increase in unthreshed grains. So, that is why with an increase in moisture content, the unthreshed grain increases, which means threshing efficiency decreases.

So, there is an optimum moisture content for each crop, so that you can get maximum threshing efficiency. So, for example, paddy we take 12 per cent, 12 to 14 per cent is the moisture content at which you should to carry out threshing. Now, if you look at figure the curve 2 this is nothing, but damaged grains. So, drier the grain higher is the grain susceptible to damage. So, when you increase moisture content the damage is reduced.

So, as per BIS standard, the total damage per cent should not be more than 2 per cent. Total losses is allowed up to 5 per cent, but out of that 2 per cent is the damage which is allowed. So, while designing a thresher, while testing a thresher we should stick to this otherwise it is very difficult to get a BIS standard. Now, presence of green matter. Presence of green matter with crops makes difficult the falling of grain through the grain layer onto the concave surface.

This green matter whether it is stalk and leaf, they will be crushed by the cylinder, cylinder working elements. As a result they will exclude some juice of specific viscosity which will tend, which will tend to reduce the shifting capacity of grains through the concave, hence, grain losses increase. So, these are some of the factors and the other factor is type of crop because we do not require same peripheral speed of the drum for different crop. Pddy it requires different peripheral speed, soybean it requires different peripheral speed. So, type of crop will also affect the performance of the thresher.

~~Now, coming to the machine parameters.~~ Under crop parameters the other parameter is your grain to straw ratio that is an important parameter. If you look at this diagram on the x axis that is the grain to straw ratio and the y axis is your percentage of damaged grains. So, now grain to straw ratio initially it was 1 is to 2.33 and slowly it has gone down to 1 is to 0.66 that means, more grains are on the right side less grains are there in the left side. So, as you move towards the left that means, more straw is there more cushioning effect is there, hence damage is less. As you go towards the right side, grains are more exposed to the cylinder and the working elements. So, that is why, because of the higher exposure possibility of damage increases, hence we are getting more damage.

Then coming to the machine parameters effect of peripheral speed. So, if you look at this effect of peripheral speed, we increase peripheral speed from 22 to 34 meter per second and the y axis is again amount of damaged grain amount of unthresh grain. That means, the curve number 1 indicate the amount of damaged grains and curve number 2 indicates amount of unthreshed grain. Now, if you look at curve 1, with increase in peripheral speed what is happening? Damaged gains are increasing. So, the reason is there will be more number of strikes and the impact force is higher. So, obviously, the damage will be more if other conditions are kept same. Now, amount of unthreshed grain, there is a reduction obviously, more impact - more detachment of grains. So, unthreshed grain should reduce, but the rate of reduction varies. It is a little higher at the initial stage, then after that, it is almost constant. That means there is no point in increasing the peripheral speed beyond 26 meters per second in this observation.

The second one is the effect of feeding rate. This is related to the operating parameters. If you keep feeding the thresher, then we can see, how increasing the feeding rate (how much crop you are putting into the threshing system) affects the performance? Then, the y-axis again shows the amount of grain that is shifted, represented by curve 1, while the amount of damaged grain is represented by curve 2. We can see that with an increase in feed rate, the amount of damaged grain reduces, and the amount of grain shifted also reduces. That means each thresher has an optimal capacity; if you exceed that, it will decrease efficiency. That means the strokes are not sufficient, or the number of working elements is not enough to detach grains. So, you have to maintain a particular feed rate for a given thresher.

Now, the effect of the shape of the drum - this is again related to the machine parameter. Now, if you look at these two, the cylinders are of two different types. Both are rasp bar types, but the cylinder shapes differ, one is circular, and the other is hexagonal. So, what is the advantage of providing a hexagonal shape? Here, the vibration will be greater in the hexagonal case because once it is compressed, it has more clearance afterward. So, the crop material can elongate a little bit. If you maintain the same peripheral speed, you will get better separation in the case of the hexagonal type. Hence, the threshing efficiency for a hexagonal drum is higher.

Now, rasp bar type and spike tooth type. As the cylinder rotates the crop is forced through the gap between the concave and rasp bar and is subjected to a combination of impact and rubbing action to accomplish threshing. If you look at this, spikes are present and rasp bars are present and both are not suitable for same kind of crop depending on the impact force requirement we have to select. Because spike tooth type thresher they give more impact force. One more thing here I want to point it out is the bars which are provided in the cylinder they are corrugated and the orientation of these corrugations in adjacent bars they are not in same direction one is opposite to the other. So, that the crops are not dragged to one direction they are flowing at 90 degree to the axis of the cylinder by providing this arrangement.

Then, the type of tooth. If you increase the friction, if you want to increase the friction then you can provide some corrugations on the teeth, so that will improve the threshing action. and the shape. So, you can bite from this side, you can reorient that one, you can bite from the other side. Both sides can be possible. Depending on the requirement whether you require more impact force, whether you require lesser impact force, you have to select or whether you require more friction whether you require lesser friction you have to select this kind of teeth and their orientations are to be fixed on the cylinder. So, I have given some threshing elements, the spikes you can say for oats and wheat, these two are for oats and wheat, these two are for barley. So, barley requires more force to detach, so that is why we are providing with corrugated teeth.

Then effect of concave gap, as I said there should be gap, but that gap has to be more in the inlet side and less on the outlet side. And slippage of grains from the drums increase with increase in concave gap, the more you give gap there will be more slippage that means, there will be relative movement between crop and the drum or the cylinder, thereby your losses will increase.

Then effect of length of concave, when we increase concave length that means, the crop is remaining inside the system for a longer period of time. Hence, there will be more number of strikes and more number of broken grains and threshed grains will be obtained.

Effect of cylinder diameter. With a smaller diameter of the cylinder, the inlet velocity of crop material is lower than in drum with higher diameter, that means, smaller diameter will drag the crop at a lesser speed. So, what will happen is the speed at which the crop is moving inside the gap is less. So, there will be a greater number of bites. Thus, more separation and higher threshing efficiency compared to the larger diameter. But again, with an increase in feed rate at a smaller diameter, what will happen is there will be accumulation, accumulation of crop. So, that will increase the losses that have to be eliminated. So, the time of action of the cylinder is shorter, which consequently reduces the amount of threshed and shifted grains under this condition. An increase in diameter with an appropriate increase in concave length results in a greater increase in threshed grain. So, only increasing the concave will not help all the time. So, you have to increase the cylinder diameter to achieve higher threshing efficiency.

An increase in the drum diameter increases the grain output of the threshing unit, provided the wrapping angle is greater than 90 degrees. The wrapping angle means the angle subtended by the concave at the center of the cylinder.

Then, the peripheral (rotational) speed of the drum decreases with an increase in drum diameter. Suppose we fix the peripheral speed and only increase the drum diameter. So, obviously, the rotational speed will decrease, thus the amount of unthreshed grain will increase because each crop requires a certain amount of striking force or peripheral speed. If this is not met, there will be unthreshed grains.

So, these are some of the references. In this class, we tried to discuss what is threshing, then we classified threshers based on different parameters, and then we tried to discuss the parameters that influence the performance of threshing equipment. We divided this into crop parameters, machine parameters, and operating parameters, and then we tried to discuss how each of these parameters influences performance. These are required for designing, which is why I discussed these things.

Thank you.