Manufacturing Automation
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Lecture – 11
Rotary Disc Feeder and Centrifugal Hopper Feeder

Welcome back. We will continue our discussion on the hopper feeders that we started in the last class.

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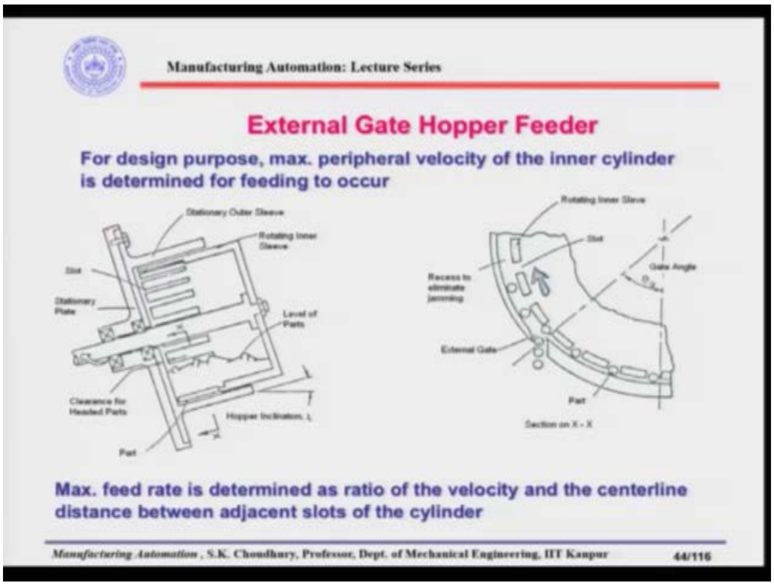

So, we started discussing the external gate hopper feeder and I said that here the design is quite simple, like we have a stationary plate. On the stationary plate we have a stationary outer sleeve and within that sleeve there is a rotating inner sleeve, which rotates. In the rotating inner sleeve we have the slots. In this section you can see this and the mass of the parts is at the bottom of the rotary inner sleeve. While rotating, from the mass of the parts, the parts will be nested in the grooves. And when the grooves will be aligned with the external gate, external gate is in on the stationary outer sleeve,

the parts will be coming one by one through the external gate. This is the simple design. Now, the maximum feed rate that you are getting from this hopper feeder that will be decided by the velocity and the distance between the adjacent slots. So, let us see how it can be determined.

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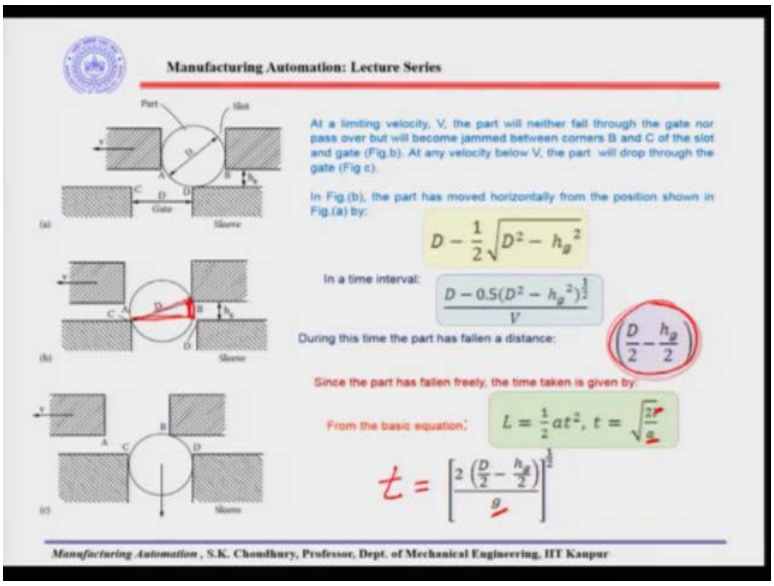

Now, these are the three positions of the part which are shown in the figure. Here, this is the rotary inner sleeve, which is rotating and this is the fixed sleeve which is stationary. Now, at a limiting velocity V, if the velocity is of a certain value, then the part will neither fall through the gate nor it will go through. But, it will jam between the slots, between the edges B here and the C. Now, at any velocity below the critical velocity V, the part will drop through the gate. If the velocity is very high in that case by inertia it will pass through the gate and it will not fall.

At a lower velocity it may clog between B and C; at a particular velocity which is an optimum velocity the part will be dropped through the gate. Keeping that in mind, let us see the first figure A. In this figure the part has just started falling, it is at the edge of the gate. Now, in the next figure the part has moved a certain distance horizontally and a certain distance vertically. So, with respect to figure A, in the figure B the part has moved horizontally. How we can find out? This is $D - \frac{1}{2}\sqrt{D^2 - h_g{}^2}$. This is the $\frac{D}{2}$, so, actually the part has moved up to $\frac{D}{2}$, D is the diameter of the gate or diameter of the part.

So, this can be given by $D-\frac{1}{2}\sqrt{D^2-h_g{}^2}$. From the figure we can find out that this is the horizontal distance, that is $\frac{D}{2}$, moved by the part. Now, at the same time when it has moved horizontally, from this position to this position, it has also moved vertically and that vertical distance will be $\frac{D}{2}-\frac{h_g}{2}$. Now, the horizontal movement of the part is because of the V. So, the interval that is time taken to move the part horizontally from this position to this position will be the distance divided by velocity.

The vertical distance that the part is falling is because of the gravity. So, that is why we can say that this time we can find out from the normal equation that is $L=\frac{1}{2}at^2$, from where $t=\sqrt{\frac{2L}{a}}$, a is the gravity, L is the distance. So, this distance L here is the vertical distance of fall due to gravity. So, the time that is taken for the part to fall vertically, can be given by this equation: $t=\sqrt{\frac{2L}{a}}=\sqrt{\frac{2\left(\frac{D}{2}-\frac{h_g}{2}\right)}{g}}$. This time is the time at which the part has moved vertically from this position to this position.

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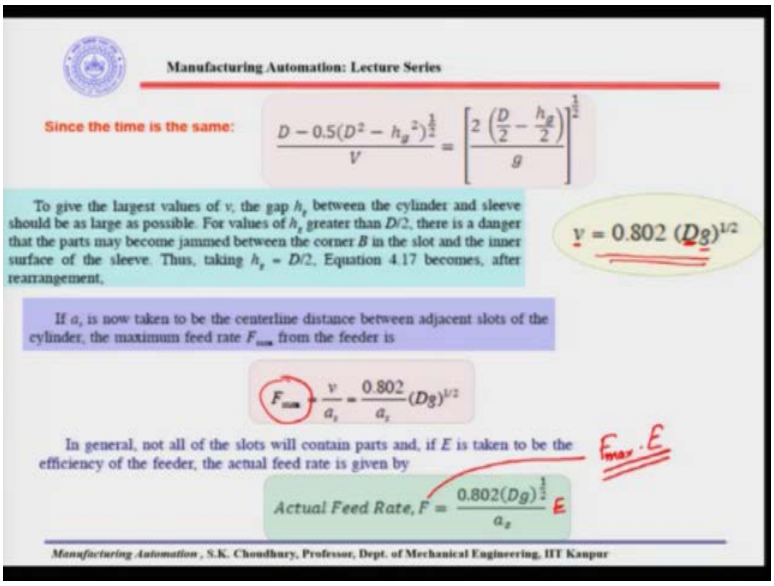

Now, since the time is the same, meaning that at the same time the part is moving horizontally as well as vertically. Therefore, the time taken for the part to move horizontally we can equalize with the time taken for the part to move vertically and we can find out from this equation the velocity at which the part will fall through the gate will be equal to $0.802\sqrt{Dg}$. D is the gate diameter or the path diameter, g is the gravity.

To give the largest value of the velocity, the gap h_g, which you have here, between the cylinder and the sleeve, should be as large as possible. So, when the gap between the sleeve and the outer disk will be as large as possible then the velocity will be maximum. For values of h_g greater than $\frac{D}{2}$, however, there is a danger that the parts may become jammed between the corner B in the slot and the inner surface of the sleeve. What we mean to say is that if this distance h_g is more, in that case the part will be jammed between B and the C or somewhere inside this within that sleeve.

Taking h_g equals to $\frac{D}{2}$ because, as we said that if it is greater than $\frac{D}{2}$ it will be jamming, if it is less than $\frac{D}{2}$ it may not go through. So, let us take h_g equal to $\frac{D}{2}$, h_g is the gap between the inner sleeve and the outer sleeve. If this is equal to $\frac{D}{2}$, put the $h_g = \frac{D}{2}$ here, then the F maximum can be found out from the velocity divided by the a_s which is the distance between the adjacent slots. And this will be equal to $0.802\sqrt{Dg}$ is the velocity divided by the distance between the gap between the slots will be a_s so, divided by the a_s.

In general, not all the slots will contain parts and if E is taken to be the efficiency of the feeder, the actual feed rate is given by the maximum feed rate multiplied by the E. If you remember, we said last time while discussing the reciprocating tube hopper feeder and the centre board hopper feeder, that not all the time the feeder can actually provide the desired number of parts. So, there is a concept of efficiency and the actual feed rate should be the maximum feed rate into the efficiency. I hope this is understood. Here please put this efficiency because, $\frac{0.802\sqrt{Dg}}{a_s}$ is only the F_{max}.

And, actual feed rate, F is F_{max} into the efficiency and the efficiency as it was discussed earlier can be found out experimentally that is you have to run the feeder some times and find out what is the average number of parts coming out. From there you find out the efficiency and the efficiency to be multiplied by the F_{max} to get the actual feed rate, which will be, of course, less than F_{max}. Because F_{max} is the ideal situation where the maximum number of parts can be delivered, but in case of the actual feed rate since it is multiplied by the efficiency, efficiency is normally less than 100 percent. So, F is less than the F_{max} that is, actual feed rate will be less than the maximum feed rate.

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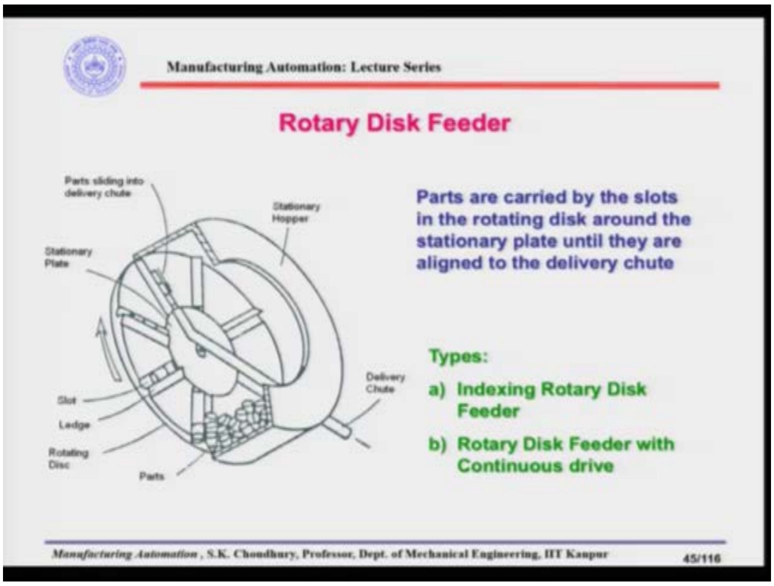

Well, the next feeder is the rotary disk feeder. This configuration is given in the pictorial view here. Parts are carried by the slots in the rotating disk around the stationary plate until they are aligned to the delivery chute. Now, here there is a stationary hopper and the base of the stationary hopper rotates. In the base of the stationary hopper there are slots and those slots are protected by, as you can see, this is protected by the ledges, here are the ledges.

These ledges will not allow the parts to fall if they are nested in the slots and the parts will also be protected by this middle disk which is stationary. So, the parts will not fall down in this direction while rotating because, of this stationary disk and because of the ledge the parts will not fall in this direction as well.

So, the parts will be picked up from the base of the rotating disk, base of the bowl here and when the slots will be aligned with the delivery chute, the parts from here will be sliding down and going through the delivery chute. There are two types: one is the indexing rotary disk feeder, another is the rotary disk feeder with the continuous drive. In the sense, that there are for example, the one that is shown here that is used for small cylindrical parts; that means, few of the parts will be nested on this slot. And therefore, when it is getting aligned with the delivery chute it has to stop for some times so that all the parts could slide down the slot.

Now, if it is a continuous drive, in that case it will not stop when it is aligned with the delivery chute. So, the parts have to be different; we will discuss at a later stage that those parts are the disk type parts. So, one at a time it will go; it is going through the delivery chute at that time it is not stopping, but that part is falling down because there is only one part. So, there are two types; one is the indexing rotary disk feeder which is shown here; that means, once again, it will go and stop in the next position for some times for all the parts to slide down and then it will continue rotating and so on.

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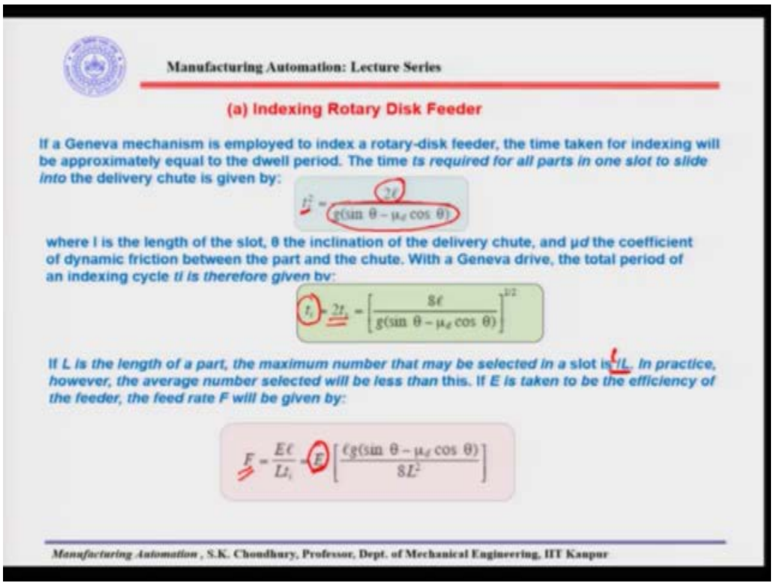

Now, here in the indexing the rotary disk feeder, if a Geneva mechanism is employed to index a rotary disk feeder, the time taken for indexing will be approximately equal to the dwell period. This we are assuming that it is driven by a by a Geneva mechanism. So, when it is indexing and when it is dwelling, let us say those two times will be the same; that is the indexing time and the dwelling time till the parts are moving down the slots.

The time t_s, let us say required for all parts in one slot to slide into the delivery chute is given by this, as shown in the slide. This you may remember. This we have derived, that this is the acceleration and this is the length. We have also discussed it earlier. So, this is the one that is the time interval or in another feeder also we have shown that this is the dwell time.

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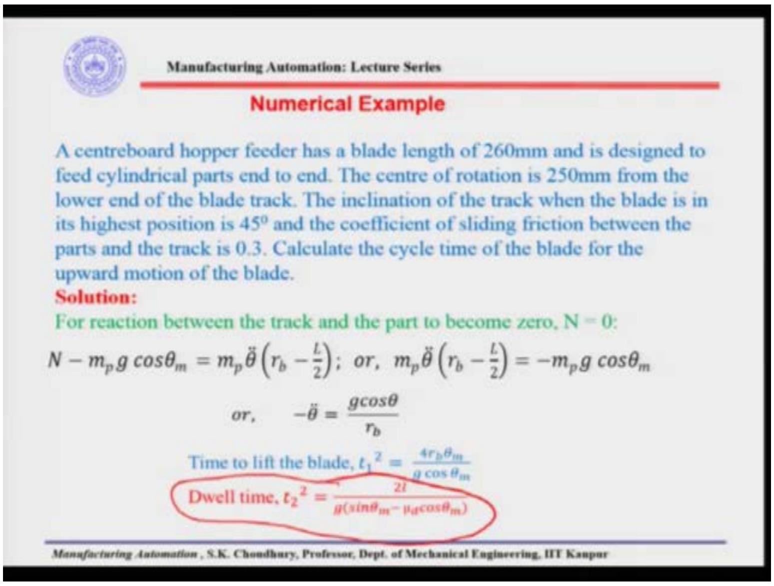

So, this dwell time is given by $2l$ divided by this acceleration and this acceleration we found out. Similarly, we are getting for this feeder also the $t_s^2 = \dfrac{2l}{g(\sin\theta_m - \mu_d\cos\theta_m)}$.

Now, l is the length of the slot as it was in the case of the other feeders we have seen. θ is the inclination of the delivery chute and μ_d is the coefficient of dynamic friction between the part and the chute. With a Geneva drive the total period of indexing cycle t_i

is therefore, given by, since we said that both the time as the same, so, it will be 2 t_s which is equal to $\sqrt{\frac{8l}{g(\sin\theta_m - \mu_d \cos\theta_m)}}$.

So, this is the total time taken for this to index and the dwell. If capital L is the length of the part, the maximum number of parts that may be selected in a slot is small $\frac{l}{L}$, l is the length of the slot and L is the length of the part, this we have seen earlier. Now, in practice this does not happen; this is the maximum number parts. So, it will be multiplied by the efficiency as it was done for other feeders. And therefore, that actual or mean feed rate will be given by the maximum feed rate into the E which is the efficiency and maximum feed rate we found.

So, we can find out what is the mean feed rate or average feed rate. So, this is also called the mean or average feed rate and without E, when you are not multiplying by the E, this is the maximum feed rate that the feeder can provide. Here let me tell you why we are bothered about the maximum feed rate and the actual feed rate. See what happens, all these bowl feeders, right now that we are discussing, are all connected to the assembly machine as I said. Now, the parts are being fed from the feeders to the assembly machine and there has to be some kind of a feed rate to satisfy the requirement of the assembly machine.

If the feed rate is more than the machine can accept, in that case there will be a clogging because, the machine will not accept less than or more than what it requires. But, if the feed rate is less than the machine can accept, in that case machine has to wait, machine has to starve. So, we have to very scrupulously design the feed rate of each of these feeders so that it can satisfy exactly the number of parts that the assembly machine requires. Therefore, finding out the efficiency is very important for each of these feeders.

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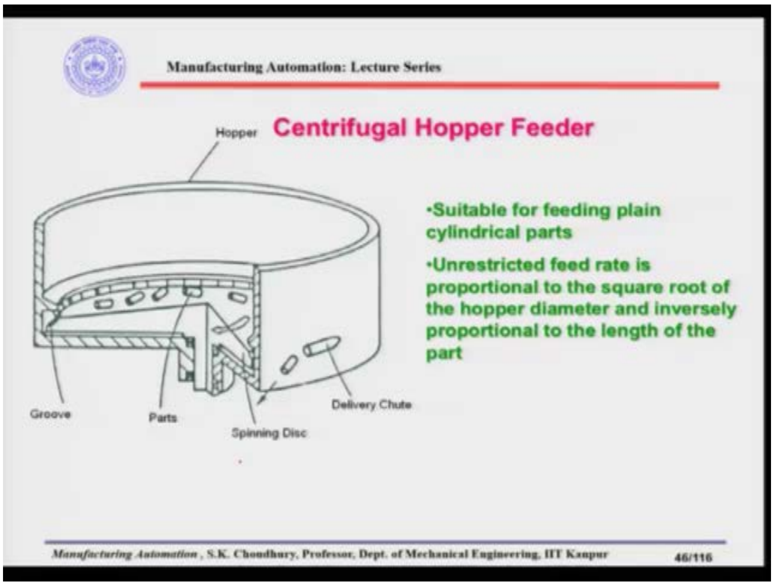

Now, here is another hopper feeder which is called the centrifugal hopper feeder. In the centrifugal hopper feeder, the working process is very different. Here what happens is that there is a hopper, this is closed and the base of the hopper rotates, rotates at a velocity so that there is a centrifugal force. And, the parts are located at the base, it is little inclined. At the outer periphery of this inner wall of the hopper there are slots as it can be seen from the figure. Now, when the hopper is rotating the parts will also start rotating and then the parts will get the centrifugal force.

So, parts will be thrown to the outer periphery, outer wall of the hopper and they will get nested in the subsequent slots. Now, when these slots will be aligned to the delivery chute, which is at a tangential to the wall of the hopper, the parts will be coming out; these parts will be coming out from the delivery chute. This kind of hopper feeders are suitable for feeding plain cylindrical parts and the unrestricted feed rate is proportional to the square root of the hopper diameter and inversely proportional to the length of the part, this we will see later.

Let us see first what is unrestricted feed rate; unrestricted feed rate is the feed rate when the hopper feeder is not connected to the machine, not connected to the assembly machine. That means, the feed rate is not related to the number of parts that machine requires and that is why it is called the unrestricted feed rate, let us see how it happens.

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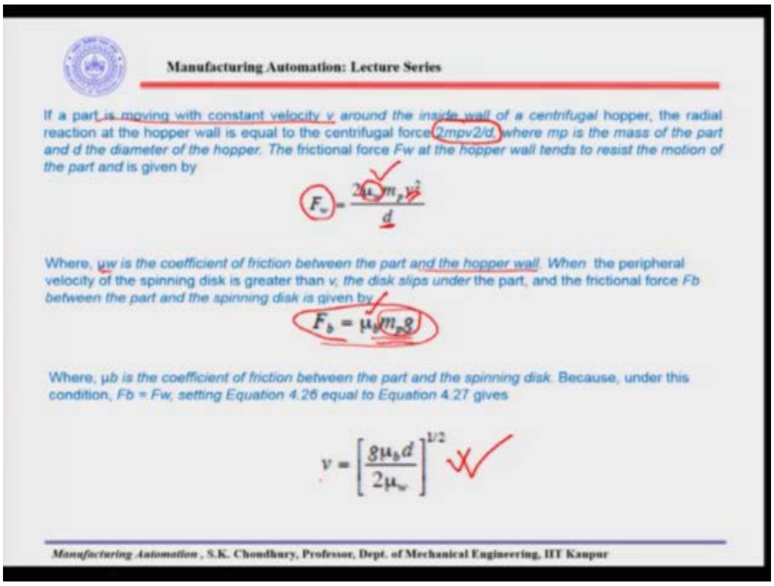

If a part is moving with a constant velocity V around the inside wall of a centrifugal hopper feed hopper, the radial reaction at the hopper wall is equal to the centrifugal force and that centrifugal force is $\frac{2m_pV^2}{d}$. This is the centrifugal force imparted on the parts. And, the part will be thrown to the outer wall inside the bowl feeder, where m_p is the mass of the part and d is the hopper diameter. The frictional force F_w, this is the frictional force at the hopper wall, tends to resist the motion of the part and this is given by $F_w = \frac{2\mu_w m_p V^2}{d}$.

Now, if you see from here, this is understood because this is the centrifugal force. So, this centrifugal force is multiplied by the μ_w, which is the coefficient of friction between the part and the hopper wall. So, if this force is multiplied by the coefficient of friction between the part and the hopper wall, this will give you the frictional force at the hopper wall which will tend to resist the motion of the part.

When the peripheral velocity of the spinning disk is greater than this velocity V, the disk slips under the part. And the frictional force F_b between the part and the spinning disk is given by this factor: $F_b = \mu_b m_p g$. Let me explain it to you what is it. What we are saying is that there is a part velocity V at which this is happening, this velocity we are talking about.

Parts are moving at a constant velocity V, now when the spinning disk velocity is more than this velocity, the part will slip over the spinning disk; because the spinning disk velocity will be more than the part velocity. And, then there will be a frictional force between the part and the spinning disk and this can be given as $F_b = \mu_b m_p g$.

$m_p g$ is the force which is acting when the part is located on the spinning disk and this will be multiplied by the coefficient of friction between the part and the spinning disk which is μ_b. So, similar to this, for example, if you see here this is the force into the coefficient of friction, here also this is the $m_p g$, which is acting down.

This will be multiplied by the μ_b, which will give you the frictional force F_b between the part and the spinning disk. Now, these two forces, F_w and the F_b are same because this is the same part and the same material that is there, only thing is that material of the spinning disk and the material of the wall may be different. Therefore, we are saying that this is the μ_w and this is the μ_b. So, if we equalize them, that is, $F_w = F_b$ and then if we solve them we will get the value of the V which will be equal to $V = \sqrt{\frac{g\mu_b d}{2\mu_w}}$.

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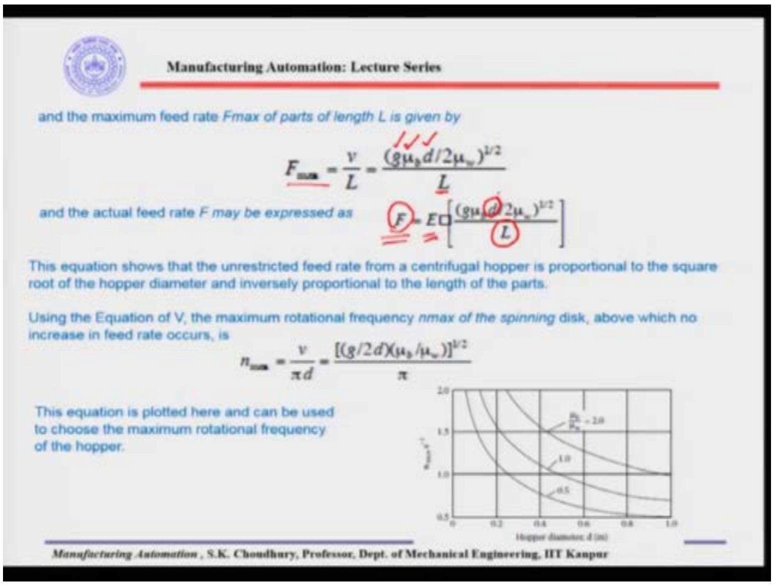

So, this velocity is important to find out because, as we said that the feed rate can be determined from here. This will be F max is equal to this velocity that we found out, here this velocity divided by the L which is the length of the part. So, knowing the V, knowing the length of the part we can find out that what will be the maximum feed rate. Well, why we are saying that knowing the velocity, because we know the g, μ_b we know because we know the material we know the material of the part, material of the spinning disk, material of the wall. So, we can find out from the handbook what is the μ_b and what is the μ_w. μ_w is the frictional coefficient between the wall and the part.

So, if we know the material of the wall, material of the part then you can find out μ_w, material of the spinning disk and material of the part gives you the μ_b. So, these are known, we have selected the hopper diameter d so, all these factors will be known, part length we will be knowing. So we can find out exactly what is the maximum feed rate. That we can adjust, of course, the maximum feed rate we will not get as we said that it has to be multiplied by the efficiency to get the actual feed rate. This actual feed rate we have to manipulate so that it could be the unrestricted feed rate, as we said, that when this feeder is not connected to the machine assembly machine.

But, when it is connected to the assembly machine we can adjust this F accordingly, depending on how many parts and at what rate the assembly machine can take. This equation shows that the unrestricted feed rate which is F from a centrifugal hopper is proportional to the square root of the hopper diameter and inversely proportional to the length of the part. So, this is important, when I said that we can actually manipulate; that means, we can adjust the actual feed rate, when the feeder is connected to the assembly machine.

Since, we know that this feed rate depends on the square route of the hopper diameter and the length. If we cannot change the length we have another parameter, that is the hopper diameter and by changing the hopper diameter or by regulating the hopper diameter in a certain way we can actually figure out how much F we should get. So, that the machine does not starve or it does not get clogged, meaning that this F should match with the number of parts that the assembly machine requires. The rest of the things we will discuss in the next class.

Thank you.