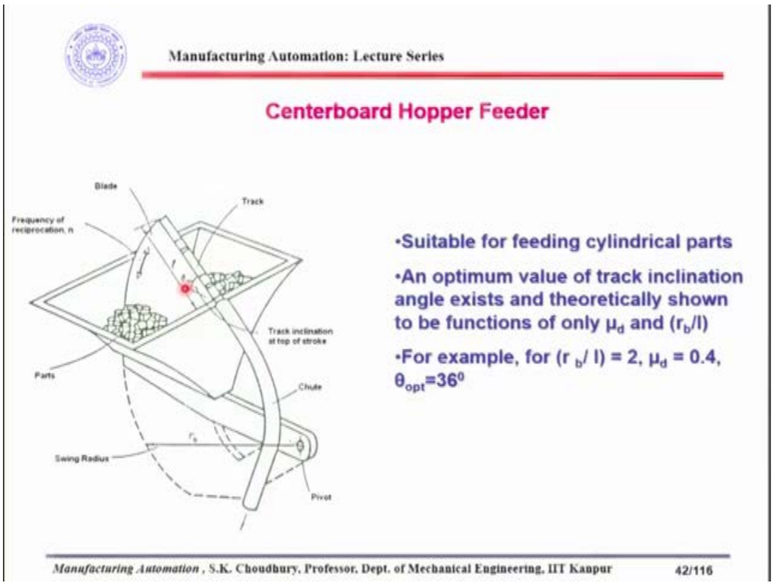
Manufacturing Automation
Prof. Sounak Kumar Choudhury
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture – 10
Reciprocating fork and External Gate Hopper Feeders

Welcome back to the Manufacturing Automation course. Let me remind you what we have discussed last time and what we started discussing is the centerboard hopper feeder. This is also one of the feeders for feeding small engineering parts to the assembly machine that is what we said.

(Refer Slide Time: 00:36)



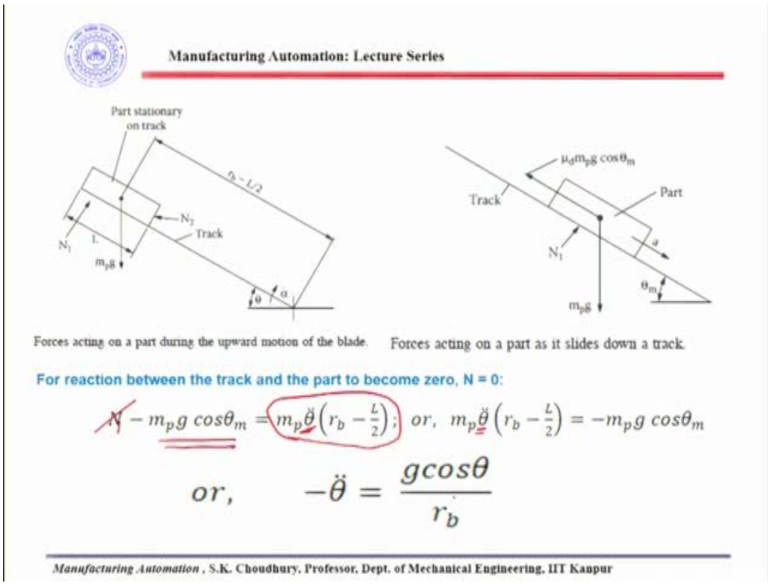
Now, here if you look at this diagram we have the hopper and in the hopper we have the mass of parts and particularly this kind of a hopper is suitable for feeding cylindrical parts. So, through the mass of the parts, as we said, there is a blade which reciprocates - it goes up and down. And, while going up and down through the mass of the parts, on the track of this blade the parts will be nested, small parts will be nested and at the topmost position of the blade when the blade will be aligned to this delivery chute, then all the parts will be sliding to the chute and going to the assembly machine.

So, this is a simple design and the basic thing to be designed here is the angle of the blade. Now, here one thing that we started discussing last time is that when the blade will be coming from the position below to the top, then till the halfway it will accelerate and somewhere from the midway it will start decelerating. So, there is a limit to the declaration because, if it is very high in that case the parts located on the blade will be thrown out. Now, for a certain deceleration therefore, which will be optimal at which value the parts will not be thrown out when the parts will be located on the blade, particularly on the top upper position of the blade, then the angle of inclination of the blade or the maximum angle of inclination the blade is an important factor.

Because if the angle of inclination is more in that case what happens is that it will facilitate the parts to go down the track. But, at the same time if the angle of inclination is very high, in that case it will take more time for the reciprocation of the blade. And so, the production rate will be lower because the time taken will be higher and the rate always is one upon the time that is what we discussed earlier also.

Now, here an optimum value of track inclination angle exists and theoretically it can be shown to be a function of only the dynamic coefficient of friction and $\frac{r_b}{l}$. So, r_b we said is the pivot radius and the l is the length of the track. So, the length of the track in which the parts will be nested and of course, the maximum number of parts which can be nested will be defined by the l divided by part length which is capital L.

(Refer Slide Time: 03:45)

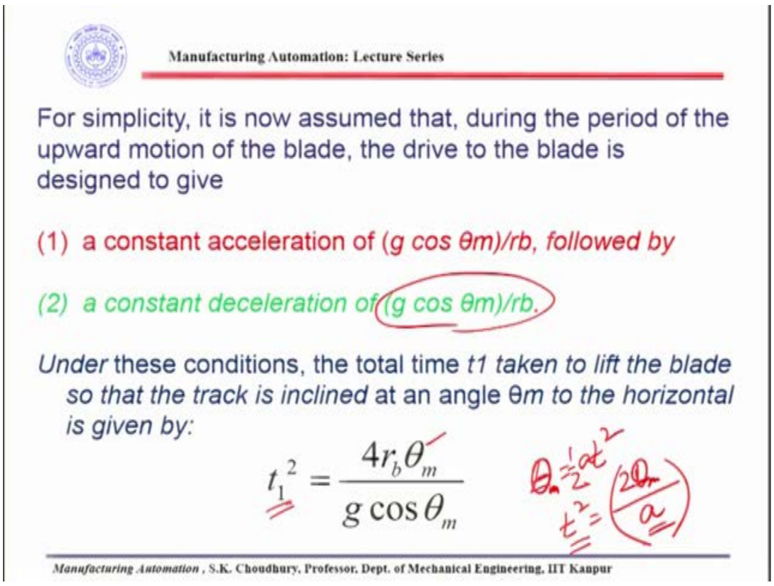


Now, here this diagram we started discussing last time. This is when the part is located at the uppermost position of the track and these are the forces which are acting. This is the mass of the part and this is the reaction, that is the normal force, imparted on the part and this will be the r_b and the total length is the r_b. So, the length of the part is L. Therefore, this length from here to here will be $\left(r_b - \frac{L}{2}\right)$ if we consider that this point is located at the middle of the part and this is the angle of inclination of the blade or of the track here.

Now, this is the position of the part when it is sliding down. Now, while sliding down, the forces acting will be the normal force N_1, this in the free body diagram, this is the linear acceleration a and $m_p g$ is the mass of the part and here this is the force which will be the friction force which is resisting the acceleration of the part. So, here in fact, reaction between the track and the part to become 0 for example, so, we say that the N_1 has to be equal to 0.

So, for N_1 has to be 0, let us write down the equation, $N_1 - m_p g\cos\theta_m = m_p\ddot{\theta}\left(r_b - \frac{L}{2}\right)$ which is the Newton's law. Now, from this equation N_1 to be equal to 0. So, $m_p\ddot{\theta}\left(r_b - \frac{L}{2}\right) = -m_p g\cos\theta_m$. From here what we can find out is the acceleration. So, this acceleration will be $-\ddot{\theta} = \frac{g\cos\theta_m}{r_b}$.

(Refer Slide Time: 06:06)

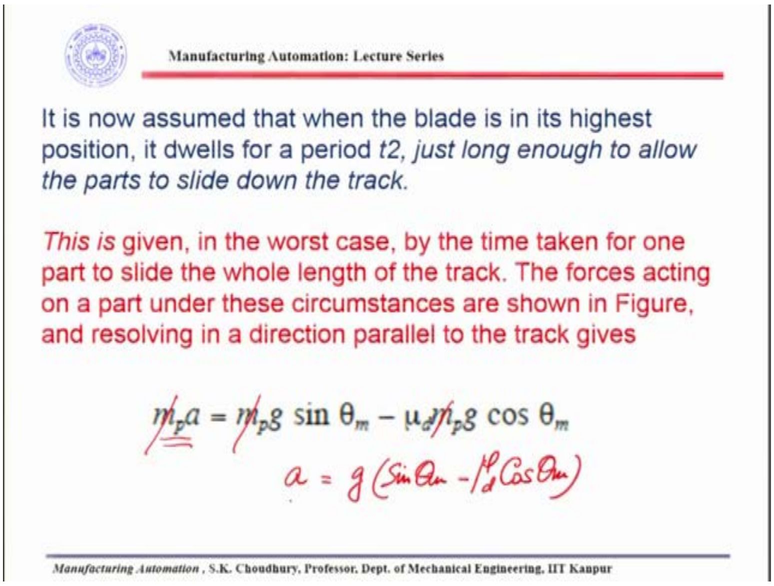


Now, let us assume for simplicity, that during the period of the upward motion of the blade the drive to the blade is designed to give a constant acceleration and a constant deceleration. The values will be what we found out here and this is $\frac{g\cos\theta_m}{r_b}$. So, what we are saying that when the blade is going from the lower position to the top, it will go at a constant acceleration and a constant deceleration; the values of both acceleration and deceleration will be $\frac{g\cos\theta_m}{r_b}$.

Now, under these conditions the total time t_1 taken to lift the blade so that the track is inclined at an angle θ_m. So, this θ_m is here. So, for that θ_m to the horizontal is given by $t_1^2 = \frac{4r_b\theta_m}{g\cos\theta_m}$. It is coming from, if $L = \frac{1}{2}at^2$ so, $t^2 = \left(\frac{2L}{a}\right)$. L here is the r_b; t^2 is equal to $\left(\frac{2L}{a}\right)$ or here we can say that it can be also θ_m.

So, $\frac{g\cos\theta_m}{r_b}$ is the one that we have here as that acceleration or deceleration. So, $t_1^2 = \frac{4r_b\theta_m}{g\cos\theta_m}$. This is coming from once again that θ_m can be written as $\frac{1}{2}at^2$ and then $t^2 = \frac{2\theta_m}{a}$. So, the acceleration a is given as $\frac{g\cos\theta_m}{r_b}$. Therefore, $t_1^2 = \frac{4r_b\theta_m}{g\cos\theta_m}$.

(Refer Slide Time: 08:13)

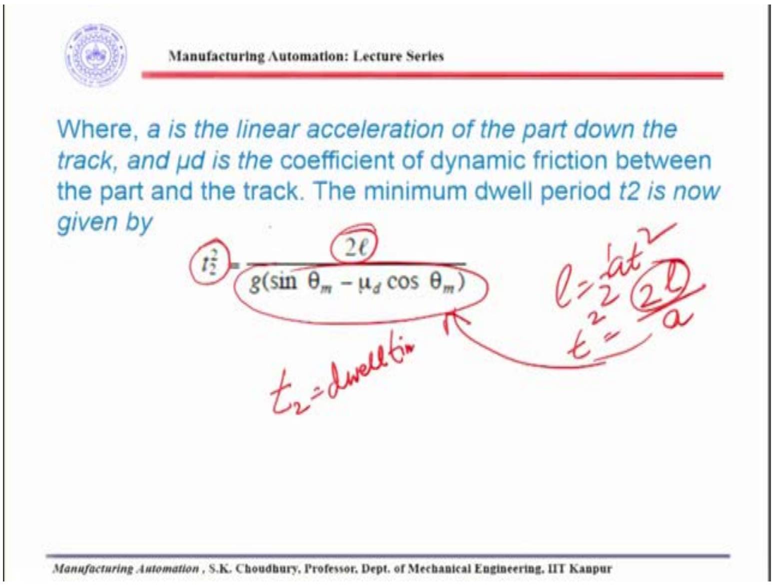


It is now assumed that when the blade is in its highest position, it dwells for a time t_2. See earlier we have discussed that when the blade is going up it will dwell for sometimes because all the parts need some time to slide. Now, this dwelling time should be long enough to allow at least one part to go from the top position to the entire length of the blade and coming to the exit, that is coming to the delivery chute.

This is given, in the worst case, as it is written here, by the time taken for one part to slide the whole length of the track. The forces acting on a part under these circumstances are given here. So, this we have seen. These are the forces shown when the parts are sliding down. This can be written as $m_p a = m_p g \sin\theta_m - \mu_d m_p g \cos\theta_m$.

So, the difference between them, because these two forces on the right are in the opposite directions to this, given by $m_p a$. So, this will be the equation when the part is going down; that means, this is the friction force and this in this direction this will be the force which is $m_p g \sin\theta_m$. So, these two differences will be equal to $m_p a$.

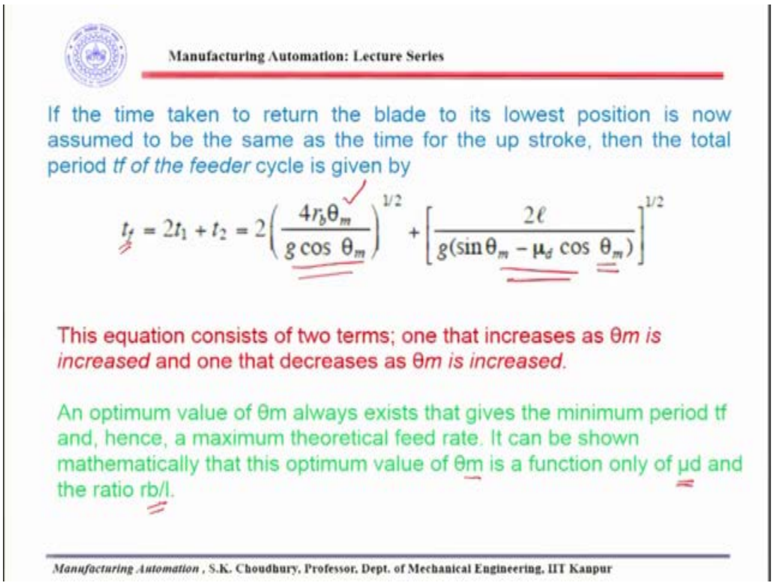
(Refer Slide Time: 10:02)



Here, a is the linear acceleration of the part down the track and μ_d is the coefficient of dynamic friction between the part and the track. Minimum dwell period is t_2. From here you can find out that t_2 can be derived in the same way as the t_1. So, this will be the 2l divided by the acceleration; the acceleration we could find out from here that a is equal to m p is getting cancelled from everywhere. So, this will be g and the sin theta m minus mu d and the cos theta m; this acceleration that you are getting.

So, therefore, this value we can put this acceleration that will be $2l$ divided by the acceleration because that $l = \frac{1}{2}at^2$ again. So, $t^2 = \left(\frac{2l}{a}\right)$. The a in this case is $a = g(\sin\theta_m - \mu_d \cos\theta_m)$, this is the acceleration and l is the length of the track. So, we can find out that what is the dwell time. Of course, the dwell time t_2 will be the whole thing to the power half that is root over this one. This is dwell time t_2. We have that t_1 is the time taken for part to go up.

(Refer Slide Time: 11:35)

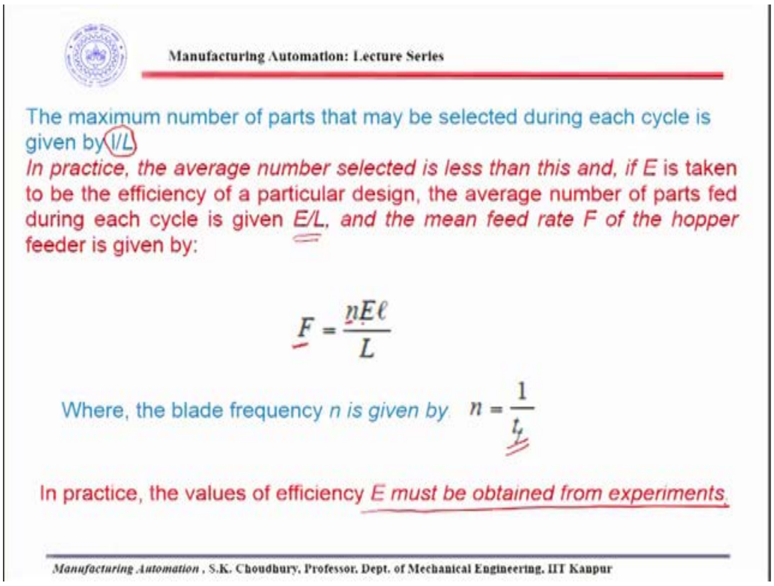


Now, for simplicity let us say that the time taken to return the blade to the lowest position from the up position is the same as the time taken for the blade to come from the initial position to the top position. Therefore, the total time that will be taken will be equal to going up and going down. So, this is $2t_1$ plus the dwell time that it is stopping for some time for the parts to slide down the tracks. So, the total time will be $2t_1 + t_2$ which is given by 2 into this is the t_1 that we found out and this is t_2 that we found out.

Now, if we look at this equation we will see that these two terms, that is the first term and the second term, they are actually quite different in the sense that one will increase with the increase with θ_m and another will decrease with the increase in the θ_m. So, for example, this term is increasing with the increase in θ_m and this term is decreasing with the increase in the θ_m.

Therefore, an optimum value of θ_m will always exist that gives the minimum period t_f that is the total time and hence a maximum theoretical feed rate because the theoretical feed rate or the overall feed rate will be defined by the time taken for the blade to come up, that is time taken for the blade to complete a cycle, a cycle is going up and coming down including the dwell time. It can be shown mathematically that this optimum value of θ_m is a function only of the μ_d and the $\frac{r_b}{l}$.

(Refer Slide Time: 13:22)

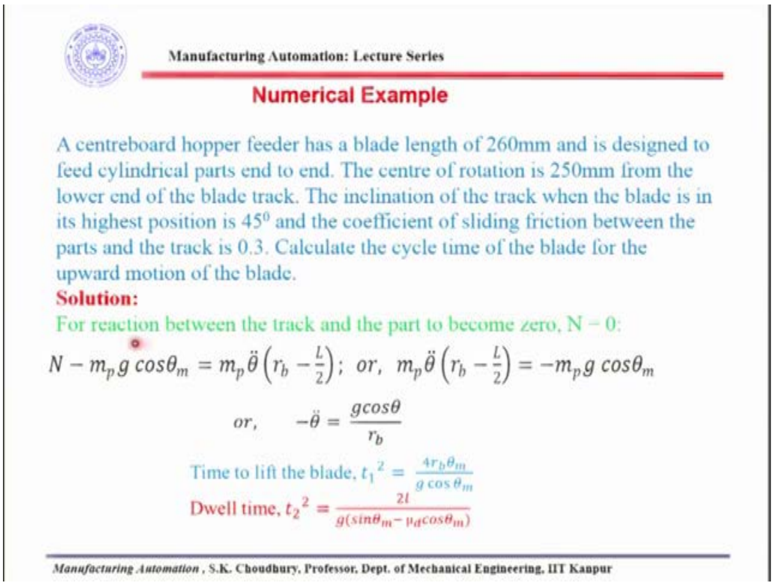


The maximum number of parts, I just told this, that may be selected during each cycle that will be the l, which is the length of the track divided by the L which is the length of the part. So, the $\frac{l}{L}$ will be the maximum number of parts that may be selected during each cycle. In practice the average number of parts selected actually will be less than the small $\frac{l}{L}$ because not all the time the parts will be nesting on the track, meaning the track will not be filled up fully during each of these cycles.

So, there is a concept of the efficiency of the bowl feeder and the efficiency can be experimentally measured for this bowl feeder or for any bowl feeder that you are selecting or designing. It has to run for several times and see how many parts on an average is coming on the track. Because, as you understand that $\frac{l}{L}$ is the maximum number of parts, that is when the track is filled with the parts, but not all the time the track will be filled up and therefore, it has to be multiplied by the efficiency.

So, the mean feed rate F, will be equal to the n which is the frequency of the blade into the efficiency and the $\frac{l}{L}$ which is the maximum number of parts which is coming on the blade in one cycle. Now, the blade frequency n this is given by $n = \frac{1}{t_f}$. So, frequency is always 1 by time. t_f is the total time taken for the blade to go up and coming down including the dwell time. In practice, the value of efficiency must be obtained from experiments as I said that it has to run for sometimes and find out what is the average number of parts which are being taken in the cycles during the blade coming up and down.

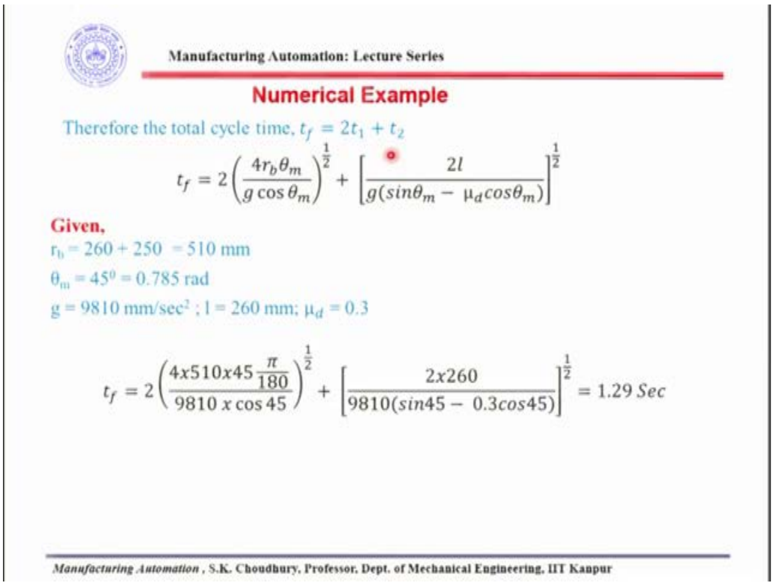
(Refer Slide Time: 15:32)



Let us take a numerical example. Say a centerboard hopper feeder has a blade length of 260 mm. This is just an example. It is designed to feed cylindrical parts end into end. The centre of rotation is 250 mm from the lower end of the blade track, that is the pivot lower end. The inclination of the track when the blade is in the highest position is 45^0 and the coefficient of sliding friction between the parts and the track is 0.3. Calculate the cycle time of the blade for the upward motion of the blade.

I will remind you that for the reaction between the track and the part to become zero, we will write the Newton's second equation that $N_1 - m_p g \cos\theta_m = m_p \ddot{\theta}\left(r_b - \frac{L}{2}\right)$ or from here we are getting that the acceleration is $-\ddot{\theta} = \dfrac{g\cos\theta_m}{r_b}$. So, to lift the blade, that is the time taken for the blade to go from the initial position to the top most position will be given by $t_1 = \sqrt{\dfrac{4r_b\theta_m}{g\cos\theta_m}}$. Similarly the dwell time will be given by $t_2 = \sqrt{\dfrac{2l}{g(\sin\theta_m - \mu_d\cos\theta_m)}}$.

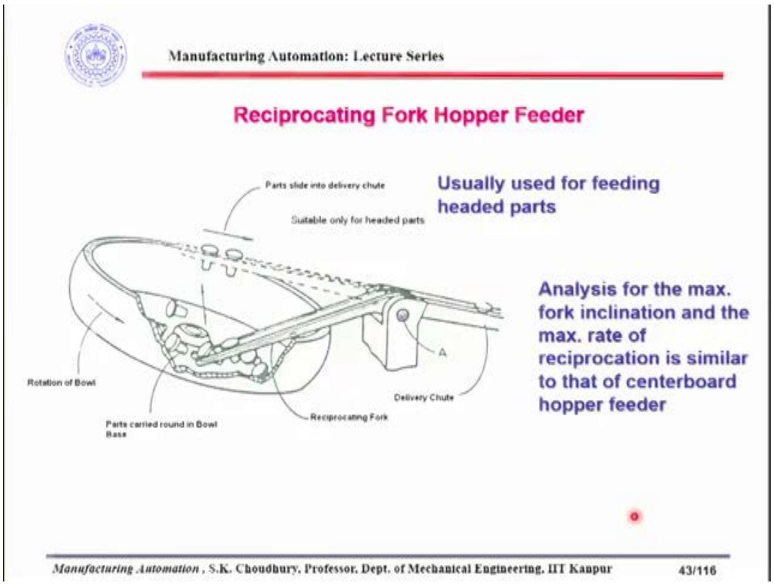
(Refer Slide Time: 17:09)



So, the total time taken is $2t_1 + t_2$. I am reminding you how we have derived the theoretical formula. So, this is the equation that is for the total cycle time. Now, here putting r_b which will be equal to 260 plus 250 because what we are saying is that the centreboard hopper feeder has a blade length of 260 mm and from the lower point of the blade up to the pivot is 250. So, the entire r_b will be 250 mm +260 mm.

And, θ_m is given as 45^0 degree which is 0.785 radian; g we have taken as a 9810 mm/s^2, acceleration due to gravity, the length of the track given is 260 mm this one and the μ_d is 0.3. So, you put all these values here in this equation and we will find that this will be equal to 1.29 second. So, within 1.29 second the blade will accelerate, it will start decelerating, it will stop for sometimes then again it will accelerate and decelerate and going back to the initial position. So, this time is the t_f going up, dwell and coming down. So, in this example it takes 1.29 seconds. Hope it is clear.

(Refer Slide Time: 18:40)



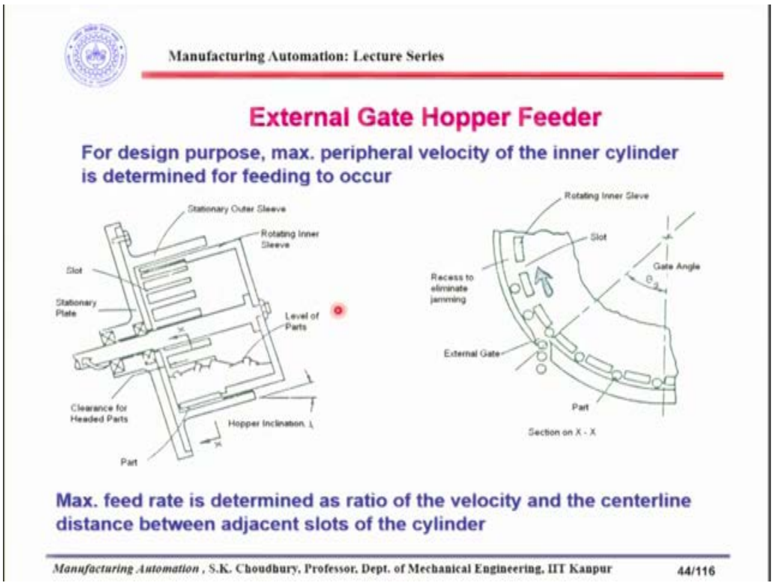
Now, the next hopper feeder is the reciprocating fork hopper feeder and if you see here the difference between the reciprocating fork hopper feeder and the one that we have earlier seen, the centerboard hopper feeder, is that here the fork which is reciprocating is actually taking up the parts and this fork has a slot and on this slot the headed parts will be hanging.

So, this kind of reciprocating fork hopper feeders are suitable for feeding the headed parts like the bolts, for example, or a rivet with the heads, for example. Those heads will be hanging here because there is a slot in this. When it is coming through the mass of the parts here and going up, it will take up some of the parts and then here it will dwell for the parts to slide down this track. This is the delivery chute. When it is aligned with the delivery chute, all the parts will be sliding from the track to the delivery chute.

Now, for the purpose of the better feeding, the bowl is rotated and it is also inclined at a certain angle with the vertical axis. This is to facilitate the parts to ride on this fork when it is reciprocating. Analysis for maximum fork inclination and the maximum rate of reciprocation will be, as you understand, similar to that of the centerboard hopper feeder because here in this case what is happening is that this fork from the initial position will start accelerating and on the midway somewhere it will start decelerating and then it will stop for sometimes, that is a dwell period or dwell time, then it will start accelerating and somewhere in the middle it will start decelerating and going back to the initial position.

So, all these factors that we have considered in the centerboard hopper feeder, that is the deceleration has to be limited because otherwise again the parts will be thrown out when the parts are located particularly at the topmost position of the fork. And, for the certain deceleration we have to limit the track inclination angle because at a higher angle all though the parts will be facilitated to be sliding from the track, but it will take more time. So, the cycle time will be more and therefore, the production rate will go down.

(Refer Slide Time: 21:17)



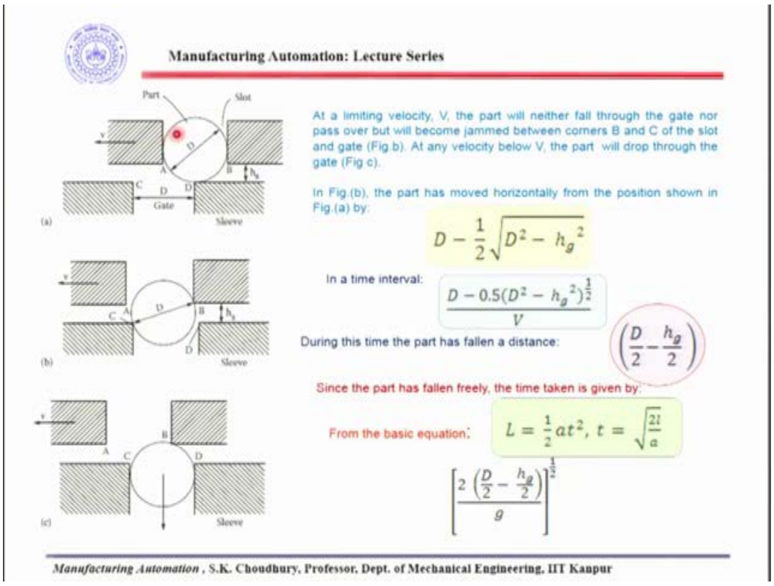
This is a new kind of hopper feeder which is different from others that we have discussed. This is called the external gate hopper feeder and as the name says there is an external gate through which the parts will be falling. The design of this feeder is quite simple. As we can see in this drawing, it has a stationary plate and on this stationary plate we have a stationary outer sleeve connected; this is rigidly connected here and inside that there is a rotary inner sleeve. This sleeve is rotating inside the stationary outer sleeve and there is a gap between the rotating inner sleeve and the stationary outer sleeve. In the rotary inner sleeve there are slots cut like this, in this section it is shown.

So, the mass of the parts is located at the base of the rotating inner sleeve and when this is rotating, the small engineering parts, as we said, cylindrical parts will be nested in these grooves and when these grooves will be aligned with the external gate the parts will be falling one by one, this is the idea. So, once again, there is a stationary outer sleeve, inside that there is a rotary sleeve which is rotating in the rotary sleeve there are grooves. So, the mass of the parts at the base of the rotary inner sleeve and the whole thing is inclined to the horizontal at a certain angle.

Let us say here, as it is shown in the figure, when this rotating inner sleeve will be rotating, the parts will be nested in the grooves here and whenever during the rotation the groove will be aligned to the external gate, the parts will be coming out of the gate one by one. So, this is the entire functioning of the external gate hopper feeder. This is quite popular. This is also used in industry for feeding the small parts, small engineering parts to the assembly machine.

Here the maximum feed rate is determined as ratio of the velocity and the centerline distance between the adjacent slots of the cylinder, meaning that whatever we have the velocity of the rotating inner sleeve that will be divided by the distance between the inner adjacent slots and that will determine the maximum feed rate of the feeder.

(Refer Slide Time: 23:58)



Let us see that how it is actually decided, how it can be obtained. Now, at a limiting velocity V, velocity of the rotating inner disk, the part will neither fall through the gate nor pass over, but will become jammed between the corner B and the C of the slot and gate. This is the slot and this is the gate through which it is coming out. This is the external gate.

So, if the velocity is certain or it is a limiting velocity, the part will neither fall nor it will go through. So, it will be clogged here, it will be jammed between the corner B and C of the slot and the gate. At any velocity below V the part will drop through the gate and if the velocity is more than the limiting velocity, by inertia the part will pass through the gate and it will not fall through the gate. So, how we are getting it finally, the conveying velocity, as we said, by dividing the velocity with the centerline distance, that we will discuss in the next class.

Thank you.