Manufacturing Automation
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Lecture – 08
Reciprocating Tube Hopper Feeder

Welcome back. Let me remind you that we were discussing in the last class the vibratory bowl feeder and different effects on its performance.

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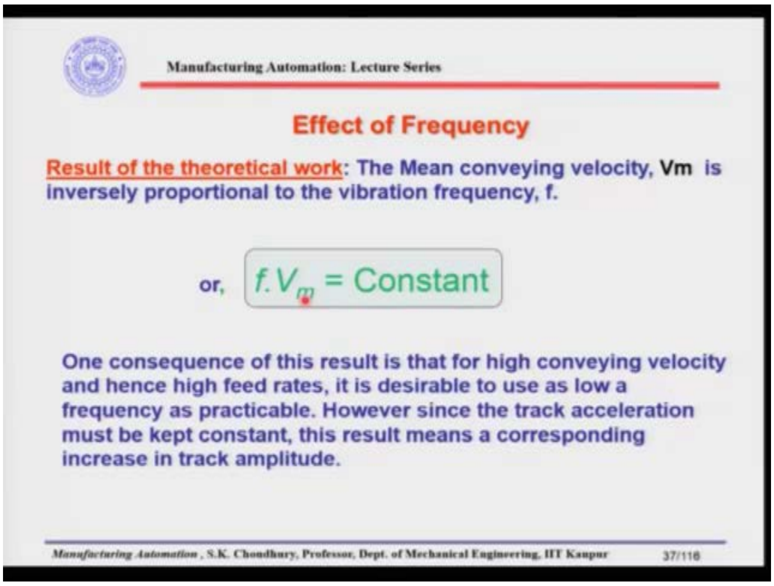

So, we have seen that, first effect is that fV_m remains constant; this is a theoretical work and because of that we said that if we have to increase the conveying velocity, the frequency to be selected should be as low as possible; that means, the amplitude of vibration has to be more, has to be as much as possible.

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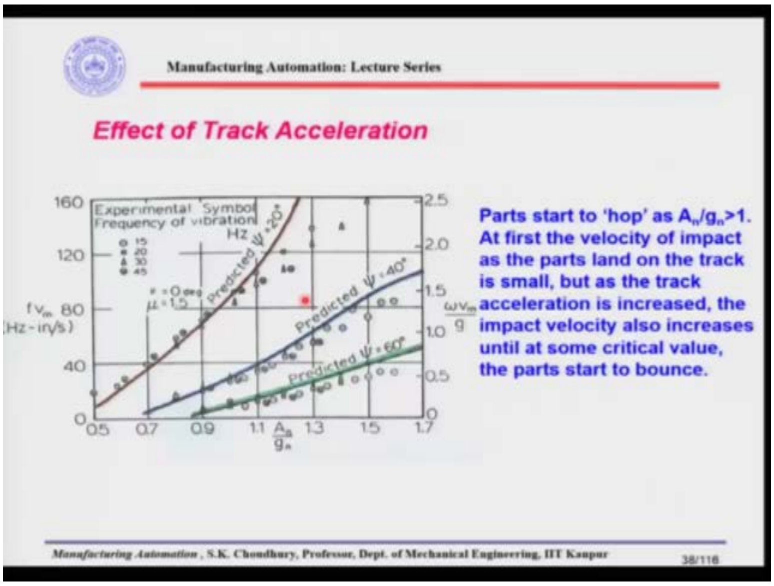

Second one which we have discussed is the effect of track acceleration and we said that beyond $\frac{A_n}{g_n}$ value of say 1.72 or 2, the impact velocity becomes very high and then the conveying velocity does not increase as much as it is for $\frac{A_n}{g_n}$ value less than 1.7 or 2. So, first thing is that $\frac{A_n}{g_n}$ which is the normal track acceleration, it has to be more than 1 for the parts to hop.

So, it is hopping and as $\frac{A_n}{g_n}$ is increasing more and more, the hopping amplitude will be more and therefore, the impact velocity will be more and while landing on the track, the part becomes unstable and therefore, the conveying velocity decreases that is another aspect that we have discussed in the last class.

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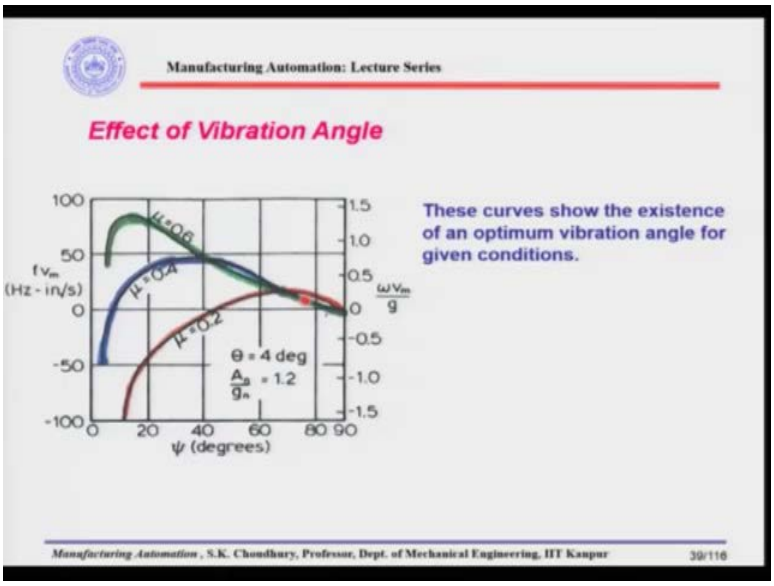

Effect of vibration angle: we said that there is an existence of the optimum vibration angle for different values of μ_s that is the static coefficient of friction and as we are increasing the vibration angle, the fV_m increases, but it becomes stable after some time and then it decreases because of the same effect as we have seen in the case of track acceleration.

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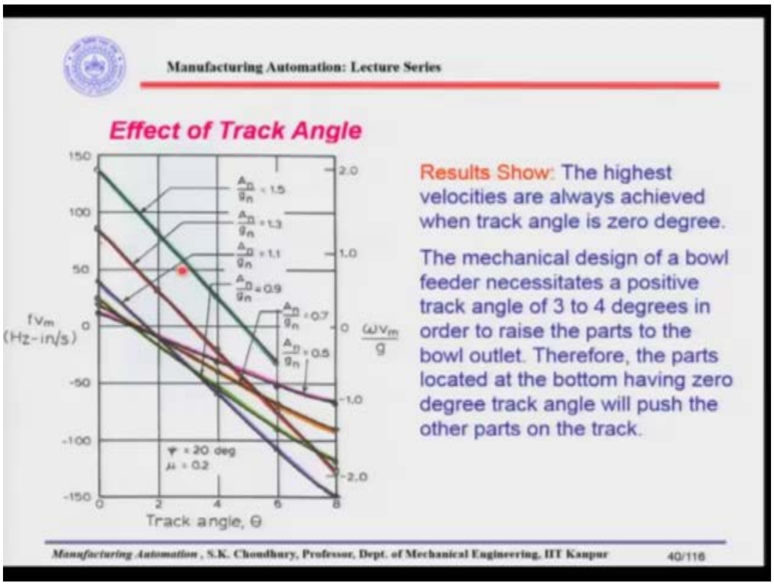

We have discussed the effect of track angle and we said that there is a very strange phenomenon that when the track angle is 0, the fV_m which is the conveying velocity, becomes maximum. So, the parts located at the bottom of the bowl feeder will push the parts which are located above where the track angle is more than 0^0, that is another conclusion.

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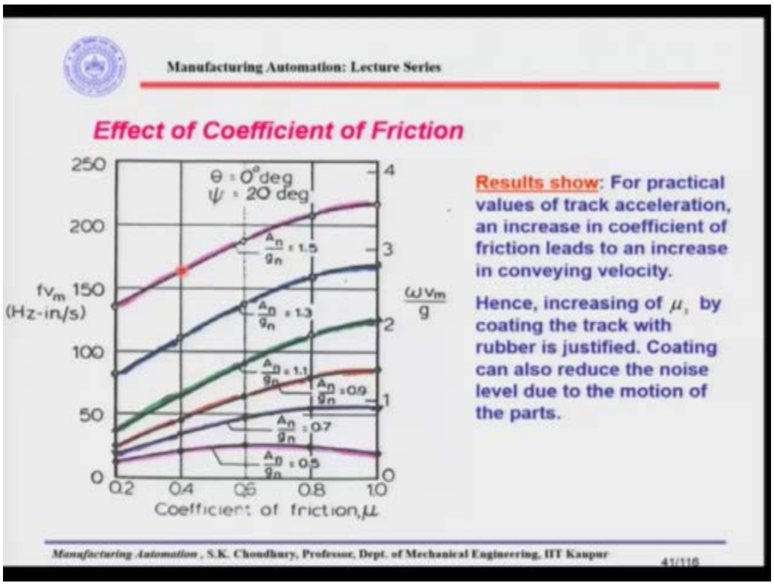

Next, what we said is the effect of coefficient of friction. We discussed that coefficient of friction is more, means, the conveying velocity of the bowl feeder will be more. So, there is a point in coating the track with rubber or some such material so that the coefficient of friction could be more. However, as we discussed last time that, it has to be decided based on the combination of the material of the track and the part that is being conveyed. So, this much we have seen last time.

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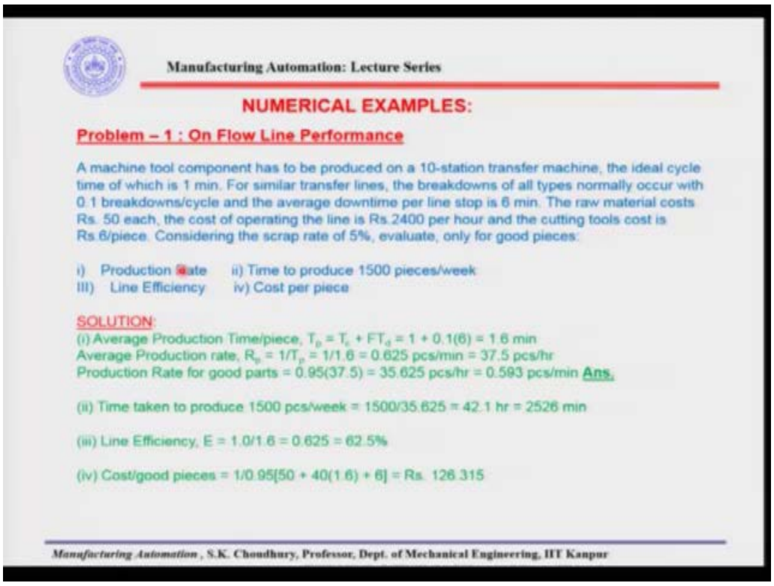

Let us see some numerical examples through which we can find out how the theory that we have discussed can be applied to practice. Let us say problem-1. So, we will come to the first example of the flow line performance which we have discussed earlier and let us take an example of the flow line performance. For example, a machine tool component has to be produced on a 10-station transfer machine, the ideal cycle time of which is 1 minute T_c, I will remind you which we have done two classes before.

See ideal cycle time of which is 1 minute. So, 60 second will be the T_c. For similar transfer lines, the breakdowns of all types normally occur with 0.1 breakdowns per cycle and the average downtime per line stop is 6 minute. So, this is the T_d if you remember. This is the time taken for diagnosing the problem and re-run the machine.

The raw material cost is Rs. 50 each, the cost of operating the line is Rs. 2400 per hour and the cutting tools cost is Rs. 6 per piece. Considering the scrap rate of 5%, evaluate only for good pieces, production rate, time to produce 1500 pieces per week, line efficiency and the cost per piece.

So, here to make the solution, first of all you have to remember that what are the things which are given here. Now let us see, average production time per piece, this is T_p, if you remember that was T_c plus the breakdown effect and breakdown effect is the T_d, the time taken and the frequency. So, here T_c is given as 1 minute, and frequency is 0.1

breakdowns, then the T_d is given as 6 min. So, $(1+0.1x6)$ will be 1.6 minute which is the average production time per piece.

Once we find out that, we can find out the average production rate which is 1 upon this time and this will be $\frac{1}{1.6}$ which is 0.625 pieces per minute or 37.5 pieces per hour, if we multiply by 60. Production rate of good parts because we have said that considering the scrap rate of 5%, now the production rate of good parts therefore, will be 0.95 because of the 5% of scrap into this 37.5 pieces per hour. So, actually what we will be getting is the 35.625 pieces per hour; these are the good pieces.

Now, next is the time taken to produce 1500 pieces. So, per week given is immaterial because these many pieces are planned to be made within a week. So, how much time it takes that has been asked. So, time taken to produce 1500 pieces overall is 1500 divided by the production rate. So, 35.625 for the good parts only because of 5% scrap rate we are considering, this will be 42.1 hour or 2526 minutes.

Therefore, the line efficiency will be $\frac{T_c}{1.6}$; 1.6 is T_d. So, $\frac{T_c}{T_d}$ will be the line efficiency which is 62.5% and finally, the cost per piece, cost per good piece to be evaluated. So, the cost per good pieces will be $\frac{1}{0.95}\left(50+40x1.6+6\right)$. If you remember the formula, it was the raw material, line operating time and the cost of the tooling. So, here the tooling is given as the cutting tool cost is rupees 6 per piece.

It is coming in here as 40, this is the line operating because it is a 2400 rupees given here. So, the cost per good piece will be Rs. 126.315, this is the solution. Here we are using the theory that we have learnt in the flow line performance analysis and you can find out the production rate, time to produce number of pieces, efficiency, cost per piece and so on.

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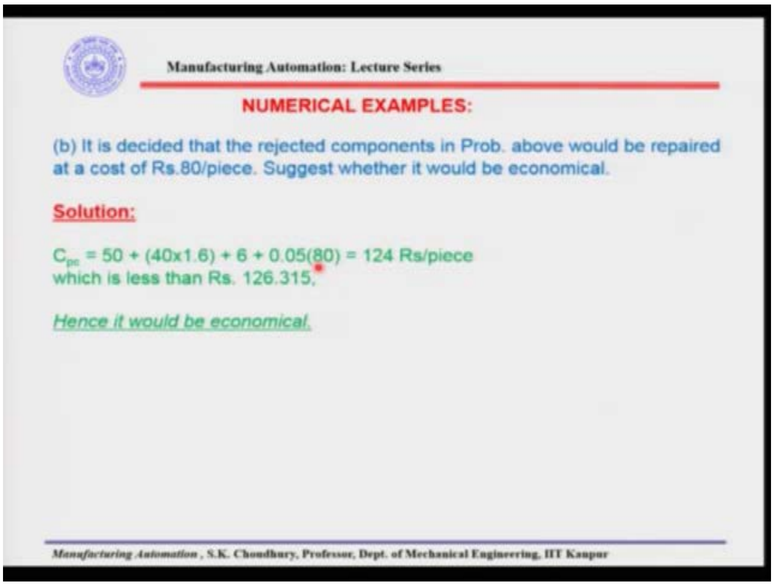

Now, suppose in the second example, it is decided that the rejected components in this problem, those which are rejected, have to be repaired and the repairing cost is Rs. 80 per piece. Suggest whether it would be economical. Now, let us see, if we have to repair with a cost of 80 per piece then how this problem will be changed? Now, this is the actual cost which is the raw material, line cost and the rejection cost which is for the breakdown and the tooling cost.

Apart from that we have to incur a cost of rupees 80 per piece. For good pieces, therefore, 0.05 has to be multiplied by the cost and overall these are not changing. So, $\left(50+40x1.6+6\right)$ is not changing, this is the T_d plus 6 is the tooling cost plus this cost for repairing that is Rs. 80 for good parts 0.05 and that will be Rs. 124 per piece. So, this is less than Rs. 126.315.

Therefore, it will be economical. This example is given particularly for you to have an idea whether you will actually reject the parts and throw it out. What is being done in many cases is that you are going to repair, but before you repair you have to find out, you have to analyze this way that whether it is economical because we are not talking about one part, we are talking about the thousands of parts which are being produced and many are also being rejected, the rejected parts are also too large a number.

So, you have to find out and analyse whether it will be economical and then you decide whether you have to repair or you will be able to throw them out.

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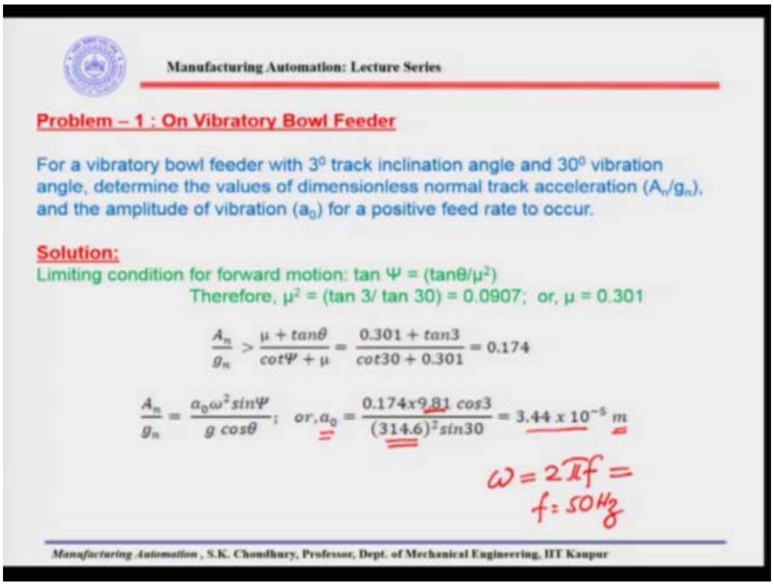

Next example, I have taken on the vibratory bowl feeder let us discuss it whatever we have just now discussed. Let us say the problem is, for a vibratory bowl feeder with 3^0 track inclination angle. So, if you remember we said that practically for mechanical design, the track inclination angle has to be 3 to 4^0. Although, I remind you that at 0^0 track inclination angle, the fV_m which is the conveying velocity, part conveying velocity is maximum, but we have to provide it because it has to be inclined and it has to go spirally.

Now, for a 3^0 degree track inclination angle and 30^0 vibration angle, determine the values of dimensionless normal track acceleration which is $\frac{A_n}{g_n}$ and the amplitude of vibration for a positive feed rate to occur. So, we have to find out that fV_m so that the part goes up the track and not backwards. Limiting condition for forward motion is $\tan\Psi = \frac{\tan\theta}{\mu^2}$ you remember that, we have done that, that this is the forward motion finally, we got it there by simplifying.

Therefore, $\mu^2 = \frac{\tan\theta}{\tan\Psi}$, Ψ is given as the 30^0 this is the vibration angle and the track inclination angle is 3^0 which is the θ. So, $\mu^2 = \frac{\tan 3}{\tan 30} = 0.0907$ and therefore, the μ will be 0.301, you can find out square root of this. Next, we found out the μ because we have to find out the dimensionless normal track acceleration which is more than μ for the parts to go up the track, the condition is $\frac{A_n}{g_n} > \frac{\mu_s + \tan\theta}{\cot\Psi + \mu_s}$, θ is the track inclination angle, Ψ is the vibration angle.

So, θ and Ψ are given, μ we found out as 0.301. So, you can find out the condition is $\frac{A_n}{g_n} > \frac{\mu_s + \tan\theta}{\cot\Psi + \mu_s}$ = 0.174. So, $\frac{A_n}{g_n}$ has to be more than that so that the parts can go above up the track. Now, $\frac{A_n}{g_n}$ and the amplitude of vibration we have to find out next. we know that $\frac{A_n}{g_n} = \frac{a_0\omega^2 \sin\Psi}{g\cos\theta}$.

So, from here you can find out that $a_0 = \left(\frac{A_n}{g_n}\right)\frac{g\cos\theta}{\omega^2 \sin\Psi}$. This is what we are doing, ω is $2\pi f$ this is the angular frequency, if you remember, and f we know that this is 50 Hz in India, 50 Hertz. π is equal to you know that 3.1417. So, this is you can find out. So, we have found out that this is equal to this, this is the ω = 314.6 and this is ω^2. So, overall we can find out that the amplitude of vibration will be 3.44 x 10^{-5} in meter.

Meaning that here we can actually see the direct implementation of the theory that we have studied before. I hope this is clear.

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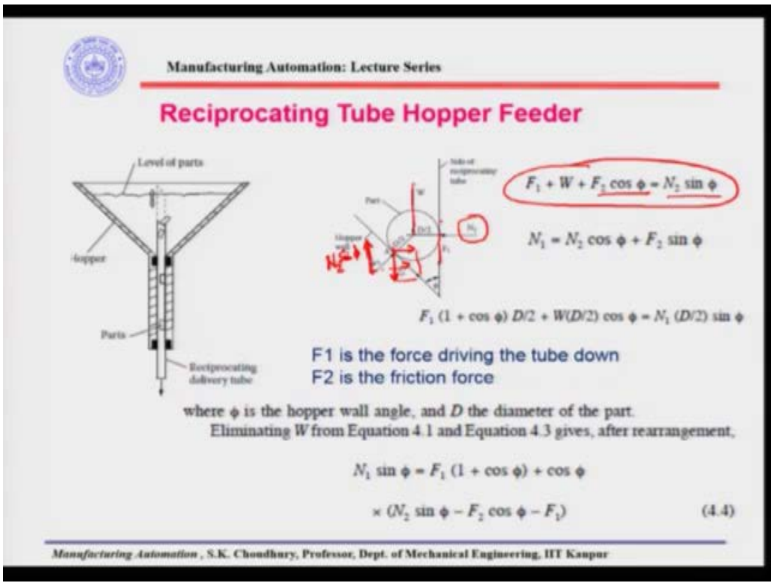

Now, our next feeder for the small parts, the one that we have discussed is the vibratory bowl feeder, the next feeder we will be discussing is the reciprocating tube hopper feeder. How the reciprocating tube hopper feeder works? Here is a feeder, there is a bowl and the mass of the parts, small parts are inside the bowl. Now, within the bowl, through the mass of the parts, there is a hollow tube which reciprocates, goes up and down.

So, the reciprocation can be made by a cam device or by any mechanism which is able to reciprocate the tube, and while it is going through the mass of the parts and going above the mass of the parts, in this process since this tube is hollow, the parts from the mass of the part in the bowl - located inside the bowl, will come one by one and go inside this tube and the part will be coming from the bowl feeder at the exit.

Now, of course, in this design you understand that it has to be sealed so that the parts do not get stuck as shown in the figure. So, the parts have to enter inside this hollow tube and as you can see that the hollow tube up here is slanted, it is cut slant because any part which will be coming on this tube cannot block the entrance. So, if it is slanted, part will come and it will slide. So, this is slanted here and parts cannot block the entrance of the tube.

Now, this kind of hopper feeders are very simple in design as you can see and they are very efficient and used in the production for transporting small parts from the feeder to the outlet. From here the part goes to the assembly machine where the parts are being assembled; that means, the assembly machine is taking parts from the feeders and the feeders can be of different design. Like for example, we have seen initially the vibratory bowl feeder, there the principle is that by the vibration we are moving the parts, here it is even more simple that this reciprocating tube takes the parts one by one.

This can be used for cylindrical parts or for round shaped parts and accordingly the inside silhouette or the inside shape of the hollow tube should be made according to the shape of the parts. Here there is a sealing that will not disturb the reciprocating movement of the tube, but at the same time it will prevent the parts to fall and block this part.

Now, while designing such kind of hopper feeders, it is very important to see that the parts should not jam between the reciprocating tube here and the hopper wall; that means, the hopper wall angle should be made in such a way that this jamming does not happen, this is very important. Let us say for example, here we have the diagram this is the side of the reciprocating tube and this is the hopper wall. This is a line diagram.

Let us say this is the part which is a cylindrical one and the cylindrical part is jamming between the hopper wall and the side of the reciprocating tube. Let us see what happens here and to prevent that jamming what can be incorporated in the design of this kind of a hopper feeder.

So, let us see in this line diagram, we have the normal force here N_1, we have the normal force here is the N_2 which is being imparted on the part from the hopper wall because of the weight of the part itself and this is from the side of the reciprocating tube. Now, F_1 is the force which is required to drive the reciprocating tube.

F_2 is the friction force, F_1 is the force driving the tube down and F_2 is the friction force because of the normal force N_2 imparted on the part from the hopper wall. N_2 is the normal force because of the F_2 which is the friction force, F_1 is that force which is required to drive the reciprocating tube through the mass of the parts, then W is the weight of the part. Now, here the W is not exactly the weight of a single part. Now, on this part, since it is a mass of the parts, on one part, which is as shown here, there are other parts located.

So, the W is the weight of this part plus other parts which are stacked on the particular part, let us say this is consolidated as W. $\frac{D}{2}$ is the radius of the job, of the part. Here, ϕ is the angle between the side of the reciprocating tube and the hopper wall. Then in this case let us see the equilibrium equation. So, along the vertical direction, what we will have? let us say along the vertical direction we have F_1 in this direction, we have the W in this direction straight, then we have the F_2 which is inclined. So, it has to be F_2 $\cos\phi$.

That means, there will be two components. One component is here which is F_2 and one component is here. So, this component we are taking as the $F_2 \cos\phi$ because it is taking the vertical forces. So, $F_1 W$ and the $F_2 \cos\phi$ this will actually be in this direction. So, in the other direction will be $N_2 \sin\phi$.

These are the two components we can take here, one is here, one is here, this is the component which will be $N_2 \sin\phi$. So, since this component is going on the other direction. So, these two forces will be resisted by the $N_2 \sin\phi$ that is what we are saying. Then this equilibrium equation becomes: $F_1 + W + F_2 \cos\phi = N_2 \sin\phi$.

So, this is the force equilibrium in the y-direction. In the N_1 direction that is in x-direction, we have N_1 then we have the N_2 that also we can resolve into two components, one is here, one is here.

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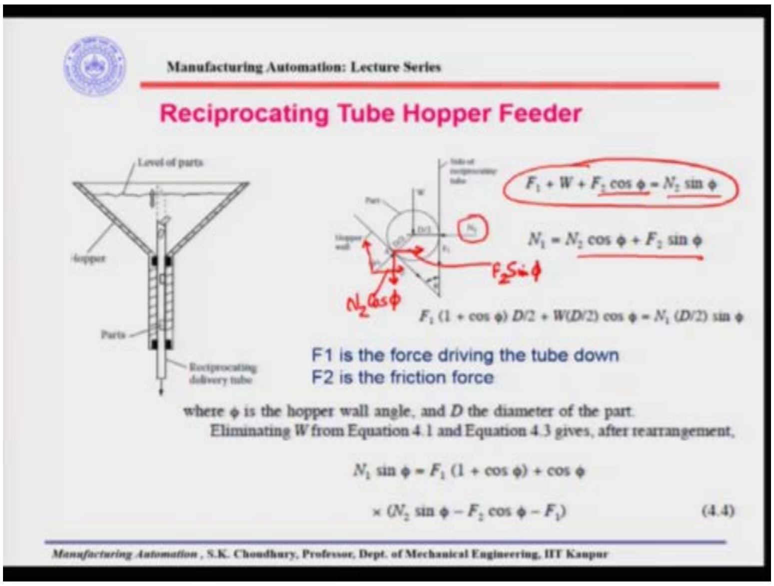

This will be the $N_2 \cos\phi$. So, we have N_1 which is resisted by $N_2 \cos\phi$ and it is also resisted by the $F_2 \sin\phi$. This is the one which is $F_2 \sin\phi$. N_1 in this direction is resisted by $F_2 \sin\phi$ and $N_2 \cos\phi$ this is clear. So, this is the in the x-direction, this is in the y-direction. Now, let us see, if we say that point A here,

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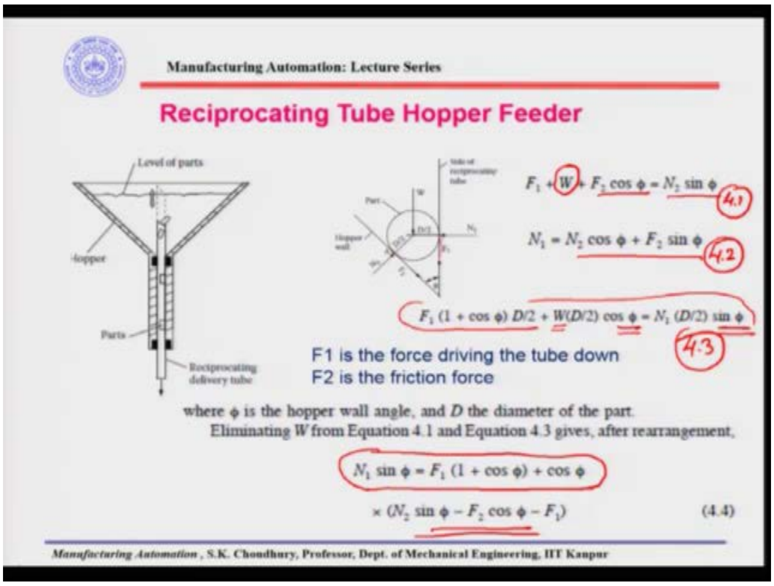

about that point, all the moments that are being produced will be, let us say, F_1 is carried over up to the centre. So, this will be $F_1 \frac{D}{2}$ plus from the centre it has to go to point A. So, it will be $F_1 \frac{D}{2} \cos\phi$, that is what we are writing here.

So, because it is inclined this plus W; W is being applied vertically so, if it is to be coming to point A, it will be $W \frac{D}{2} \cos\phi$ this will be resisted by this moment which will be in the clockwise direction because F_1 is producing that moment, W is producing that moment which will be resisted by something which will be coming anti-clockwise and the anti-clockwise it is coming as N_1; N_1 will be coming to the centre and then to this point A.

So, this will be from the point where N_1 is being applied to the point A, it will be $N_1 \frac{D}{2} \sin\phi$. This is another equation of all moments around the point A. Now, we have these three equations, here ϕ is the hopper wall angle and D is the diameter so, $\frac{D}{2}$ is the radius. Now, we will take from this equation the value of W and put in equation, let us say 4.1. Let us say this is 4.1, this is equation 4.2 and this is equation 4.3.

So, from 4.3, we will take the value of W and we will put that value in here, here we have the W. So, after rearrangement what will be getting is this, let me show it to you how it is getting.

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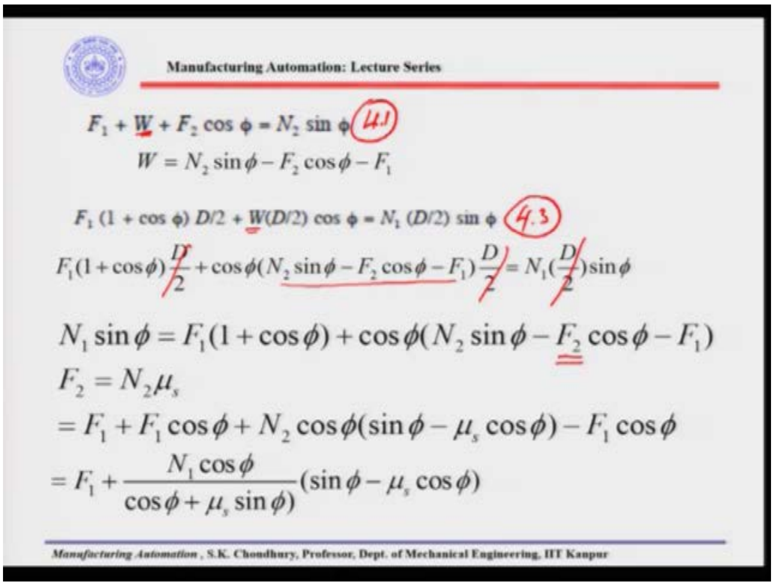

So, we have the equation 4.1 here; and from here, we will find out the W is equal to this, we have the equation 4.3 here. So, we take the value of W from the equation 4.1 and that value will be putting in the equation of 4.3.

It will be like this. Since, $W = N_2 \sin\phi - F_2 \cos\phi - F_1$, this value we are putting it here in place of W. If you solve this equation it will be in this form: $N_1 \sin\phi$ we are taking it from here $\frac{D}{2}$ we are cancelling from all this.

So, we are getting, $N_1 \sin\phi = F_1(1+\cos\phi) + \cos\phi\left(N_2 \sin\phi - F_2 \cos\phi - F_1\right)$. Now, $F_2 = N_2\mu_s$. Let us see this, what we are saying is that F_2 is the friction force because of the N_2 which is the normal force. Therefore, $F_2 = N_2\mu_s$. We are putting that value of F 2 to get: $F_2 = N_2\mu_s = F_1 + F_1 \cos\phi + N_2 \cos\phi(\sin\phi - \mu_s \cos\phi) - F_1 \cos\phi$ and after simplifying we are getting this equation: $F_2 = F_1 + \frac{N_1 \cos\phi}{\cos\phi + \mu_s \sin\phi}\left(\sin\phi - \mu_s \cos\phi\right)$.

So, how this is getting affected and from these three equations, how you are getting into the design aspect that I will discuss in the next class.

Thank you very much.