Fundamentals of food Process Engineering
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Lecture - 46
Mixing and Agitation

Hello everyone, welcome to NPTEL online certification course on Fundamentals of Food Process Engineering. Today we will start a new chapter on Mixing and Agitation.

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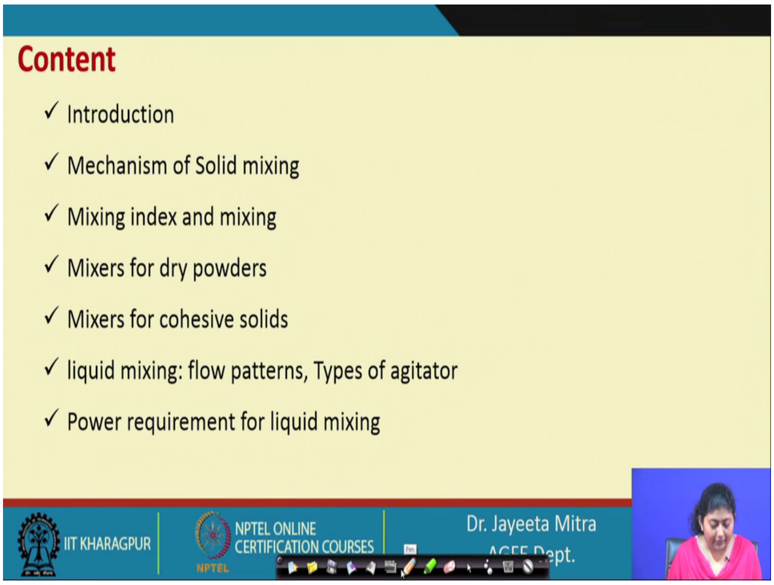

So, mixing is an important unit operation and there are many instances in food process engineering, where mixing of liquid, solid or different 2 different liquid or 2 different solids or even gas and liquid this kind of mixing operations are very important. And we will we will you know differentiate the whole content of this particular chapter in several headings.

First we will tell a bit introduction about the mixing and agitation process; then we will see the mechanism of solid mixing first, followed by the mixing index and mixing process. Mixers for dry powders, then mixers for cohesive solids, after that liquid mixing; in that we will also see the different flow pattern while mixing and the types of agitators. Finally, we will see the power requirement for liquid mixing.

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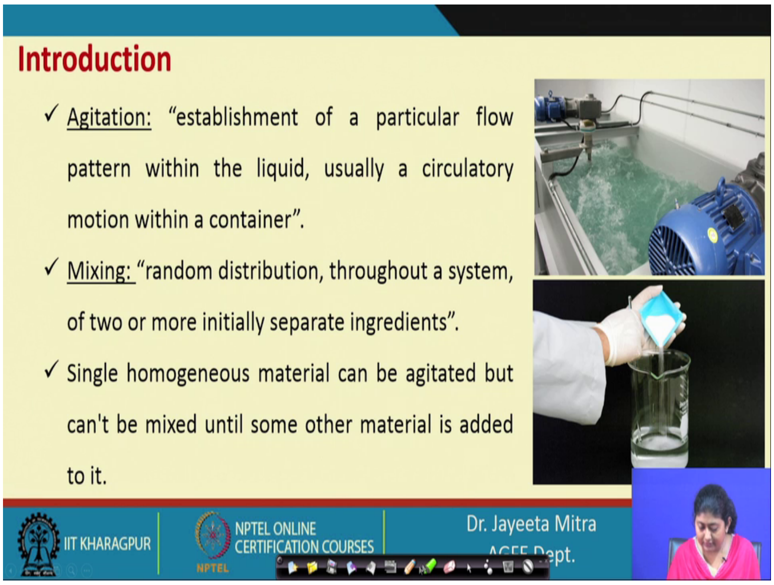

So, let us start with the introduction. So, mixing not merely making a homogeneous sample is the only purpose of it. There are lot more to lot more functions associated with mixing and if it is not done properly, then the texture or the quality of the food process may be hampered.

So, what are the main functions and purpose of this that we will see. If we talk about agitation, agitation is establishment of a particular flow pattern within the liquid. Usually we perform a circulatory motion and agitation may be you know any kind of agitation, any kind of motion we can initiate or a induce in a liquid. And for having agitation one component is also; I mean one component if there in the in the particular liquid then also we can initiate agitation.

Mixing; however, is random distribution throughout a system of 2 or more initially separate ingredients. Therefore, agitation can be done with one liquid, but or one solid sample, but the mixing cannot be done; it is basically may takes place from 2 distinctly sub distinctly separate material when they come and contact and we want to make a homogeneous sample out of that; then the unit operation mixing is to be applied.

Single homogeneous material can be agitated, but can be mixed until some other material will be added to it. For example, if you see in this figure that some solid sample salt or some chemical that need to be dissolved in the liquid. So, we are we can put it in the in that and then we stare it with a glass stare glass rod to make it a uniform sample.

So, here mixing may be there; however, the agitation in the in that upper figure we can see that agitation simply; we can we can make in a one component system.

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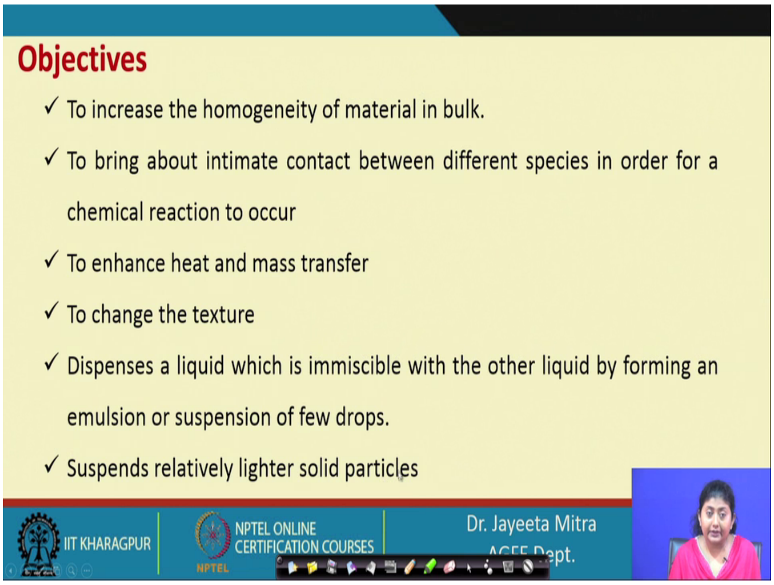

Now, what are the objective? As I have mentioned that homogenate homogenous mixer preparation is one part one important part of or aim of mixing. So, first is to increase the homogeneity of the bulk material, the other purpose is to bring about intimate contact between different spaces in order for a chemical reaction to occur.

Now, sometime we want this 2 component mixing so that every molecule will come in contact with the other molecules so, that the reaction will be proper. However, this may not be limited to only the reaction process, it may happened that for extraction also if the component which the solvent; let us say which we are using for extract extraction of some bioactive from the other micelle kind of thing and if proper agitation is done then the extraction will be even better.

So, that is one function of the mixing operation. Now to enhance the heat and mass transfer many food processing operation is such that to initiate or to increase the rate of heat transfer or mass transfer, we need to give some agitation. For example if we want to cool glass of milk, if we agitate it and then we you know blow air over the glass then it will be cool faster.

So, there are many operations where to increase the heat transfer; for example, if suppose you are heating a food a liquid food and there may be some deposition or sedimentation may takes place at the bottom of the pan. So, if you agitate this continuously; so, no deposition may be there at the bottom and then it will increase the heat transfer. So, these are the functions then to change the texture. So, if the 2 component that we want to mix properly when the homogenous sample will be prepared so that may help improving the texture.

And in other way you can say like suppose you want to make a those sample and for leavening proper leavening you are giving some ingredient to it. Now if the proper mixing does not take place with the; with the floor material. So, the texture of the final product will not be good.

So, the proper you know the expansion will not be proper; the quality of the final product will not be proper. So, because of that the purpose of mixing and agitation is to change the texture also. Then it dispenses a liquid which is immiscible with the other liquid by forming an emulsion or suspension of few drops.

So, this is another function if you want make an emulsion of one liquid which is immiscible in the other liquid. So, there also we can you know we can use this unit operation to make a uniform suspension. And to suspends relatively lighter solid particle; so this is also for example, if the suspends relatively lighter solid particles if the particles are lighter and we need to make it in a suspended situation.

So, we need to agitate it continuously so that it will be you know disperse properly in the liquid sample. So, these are functions; these are the objectives or aims that we full fill by using the agitation or mixing operation.

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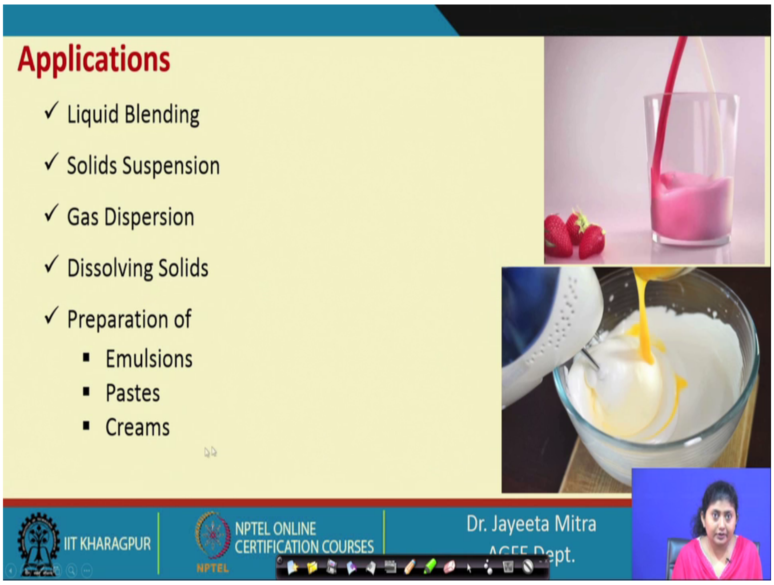

So, liquid blending this is one operation where we use the unit operation mixing, where 2 different liquid are mixed together to make some different food product. Then solid suspension, gas dispersion sometimes we want that you know to disperse the oxygen gas in a liquid sample.

So, then we use this operation; then dissolving solids, preparation of emulsion or paste or creams. So, we know that for weeping of creams we need to mix it thoroughly and then that the texture the creamy texture will also develop, the proper paste can make out of this method.

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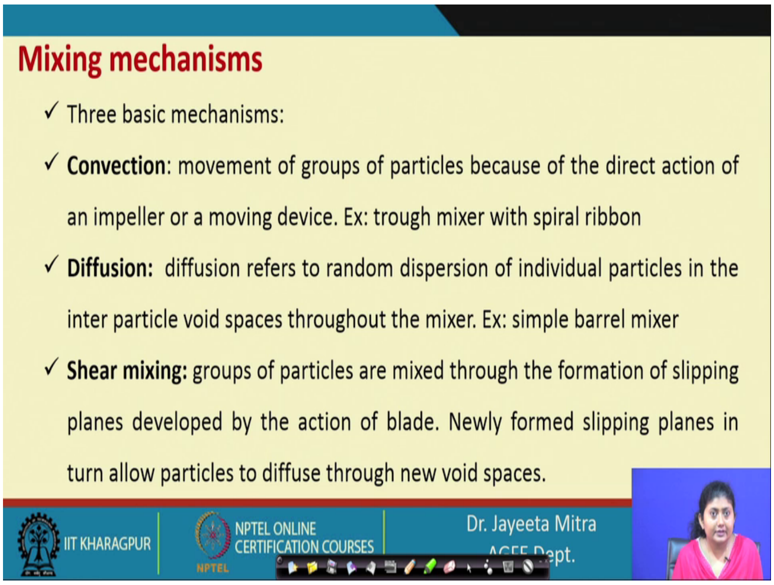

So, various applications are there in food processing specially; now let us see the different mixing mechanism. So, there are my different methods by which the mixing of two different component or solid or two different solid fractions will take place.

So, the three mechanisms are there for mixing, first one is the convection. So, convection as the name suggest that there must be positional displacement of the solid particle in the whole mixer; so movement of groups of particle because of the direct action of an impeller or a moving device.

So, what is what it says that movement of group of particle; that means, a group of particle or section of the particle is moving towards the another section in the inner front. Because of the spiral action of the ribbon; so, the material is conveyed from the one location to the other and there by this process is continuously performs; so, this is called the convection mixing.

Now next is diffusion mechanism; so, diffusion refers to random dispersion of individual particle in the inter particle void spaces throughout the mixer. So, simple barrel mixers, so; these are comes under this diffusion mechanism. So, if you visualize this, in case of convection there is a trough and there is a central ribbon is there, some kind of a metal ribbon or mixer special kind of mixer blade are there.

So, what it does actually; what it does actually it is rotating continuously this ribbon is rotating continuously. And because its movement the particle will move from one place to the other and eventually get mixed up properly and also propagate towards the forward direction where as in the diffusion if you see that suppose barrel is there, a barrel mixer.

So, here it is it is rotating; there is the there is the shaft will be there and there are the blades with it. So, when it rotates if we if you see the front view; so, it takes the particle with it and because of angle of (Refer Time: 13:47) of this particle at one point it will again try to fall down and again it is you know mixing as the rotation will continue. So, diffusion refers to random dispersion of individual particles in the inter particle void spaces throughout the mixer. So, this continuous rotation takes place and because of that the particle will move to the inter particle space again it will moves.

So, this process will goes on and the diffusion phenomena takes place by that the mixing will takes place and example is the simple barrel mixer. Then shear mixing, groups of particle are mixed through the formation of slipping plane develop by the action of the blade. So, groups of particles are mixed through the formation of slipping planes, develop by the action of blade. Newly formed slipping planes in turn allow particles to diffuse through new void spaces. So, continuously this sharing will take place and continuously the formation of slipping plane will be there.

And again it will be you know disrupted, the particle will defuse new void space will created and again the shearing action of the blade will continue. So, because of that the shear mixing will takes place. So, we have seen the convection mechanism, diffusion mechanism and shear mixing.

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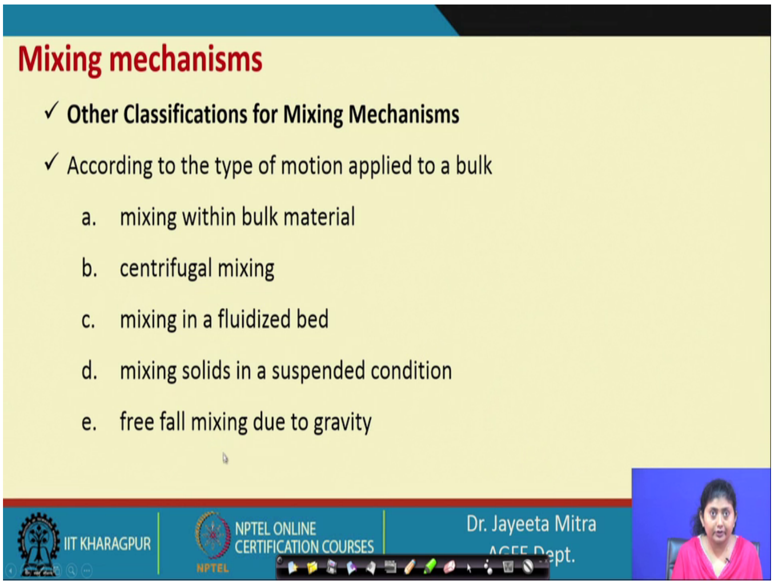

Now some other classification for mixing mechanisms. So, according to the type of motion applied to a bulk; we can categorized them as first is the mixing with bulk material, then centrifugal mixing, then mixing in a fluidized bed, mixing solids in a suspended condition.

So, mixing with bulk material that this is also one case the different kind of specific impellers are used for mixing the bulk material. And centrifugal mixing is that by using the centrifugal force when we want to mix two different two or more different components. In a fluidized bed that means, we are making the particle in a suspended condition and because of that it will be getting mixed with the other component or other fraction of the composition. And in a suspend mixing solids in a suspended condition that is another category and free fall mixing due to gravity.

So, when applying the gravitational force; different component of the mixtures are you know freely fall from a from a measure height and they will getting mixed. So, and this is again repeated the; those process; so, by that we can also have the mixing operation.

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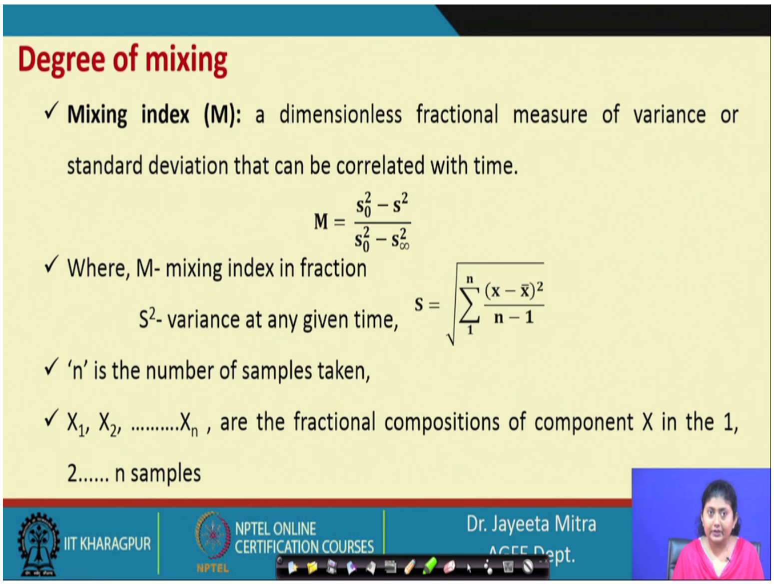

Now, to what extend mixing has been done? Whether we have achieve the final desired uniformity or homogeneity in the sample? That can be assessed by degree of mixing.

And the degree of mixing is also depends on the sampling procedure. So, since we want to measure the random samples from the; from the whole bulk of the material. And those random sampling we will measure the fraction of the component one component fraction and from that we can measure the other component as well so, from all such small fraction or sampling that will collect will measure their you know distribution. And also from that we will calculate that what is the desired composition and how far we have reached to that desired mixing and in what time.

So, mixing index is a dimensionless fractional measure of variance or standard deviation that can be correlated with time; it is a dimensionless fractional measure of variance. So, it is represented as M equal to S 0 square minus S square dived by S 0 square minus S infinity square. So, what are these terms? M is the mixing index in fraction, S square is the variance at any given time. So, S can be signified as root over summation 1 to n x minus x bar whole square by n minus 1. Now x is at one sampling when you take you sample you get the; of the desired component.

So, that is that is the fraction that you are getting and x bar is the mean fraction of the desired fraction of that particular component that is to be there when the complete mixing will be done and n is the number of sample. So, either standard deviation or variance we can calculate based on this. As I said that X 1, X 2 and X n; these are the fractional compositional of component X in 1, 2 and n th sample.

So, you are collecting the sample from the bulk randomly from suppose n number of sampling is done and then the fraction of the particular material that you collect that you measure each time. So, that will vary for the first sample X 1, for the second sample X 2 up to nth sample X n and then we will calculate the S square for putting in to the equation of mixing index.

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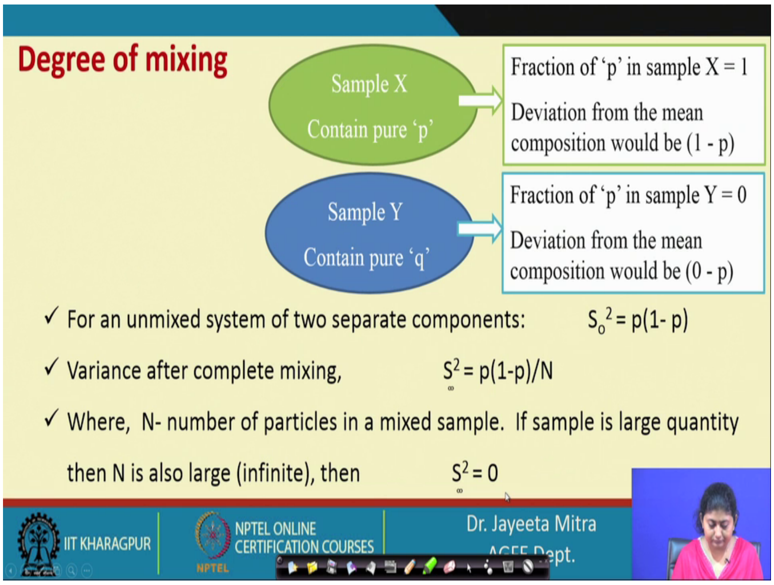

So, let us see the degree of mixing in a bit elaborate way; suppose sample X is there that contain the pure p, where fraction of p in the sample X is 1 because it is the; it is a pure material that has only particular component; so, the fraction will be 1.

Now deviation from the mean composition would be 1 minus p and sample Y, which contents pure q fraction of p in the sample Y will be equal to 0. So, deviation from the mean composition would be 0 minus p. Now for an unmixed system of two separate components S 0 square will be p into 1 minus p.

So, p is the fraction of the component into 1 minus p. Variance after complete mixing that is S infinite square; so, that is p into 1 minus p by N; N is the number of particle in a mix sample. So, when the complete mixing has been done; so in that mix sample the number of particle is capital N and S infinity square is p into 1 minus p; if sample is large quantity, then N is also large or infinite; then we can take S infinity square this is equal to 0.

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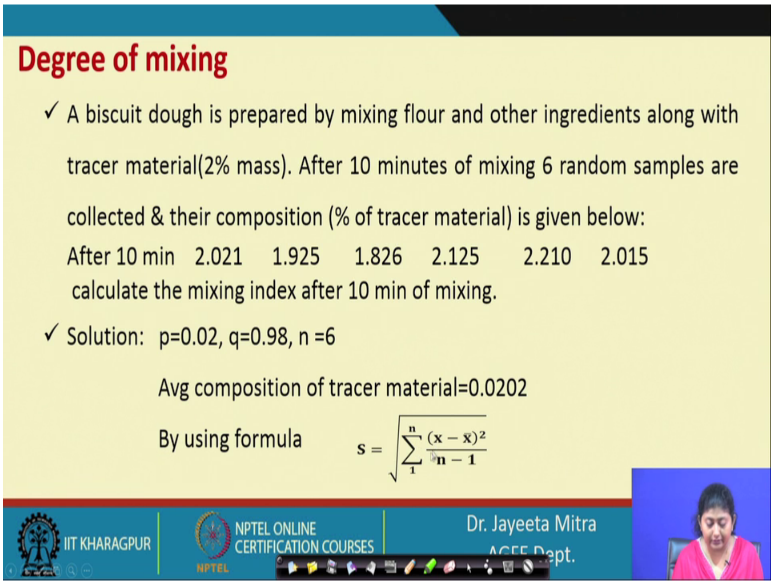

Now, let us see one problem on it; a biscuit dough is prepared by mixing flour and other ingredients along with tracer material 2 percent mass. Tracer we put actually to see that when suppose those material are of same color and then the homogeneity visually measuring is very difficult thing.

So, some time we added tracer material that is an nth material not reacting with any of the component; just to have an idea that the complete mixing has been done. So, here are ingredients with this ingredients tracer material which is 2 percent of the total mass has been added after 10 minute of mixing 6 random samples are collected and their composition which is the percent of tracer material is given bellow.

So, after 10 minute the fractions the 6 random samples having the fraction of tracer material as 2.021, 1.925, 1.826, 2.125, 2.210 and 2.015. Calculate the mixing index after 10 minute of mixing. So, we need to put the data first calculate the S square; S 0 square and S infinity square, then we need put it in the equation of mixing index. So, p which is the tracer particle that is given added to the system at 2 percent mass. So, fraction of p will be 0.02 and q is 0.98, sample number is 6.

So, average composition of tracer material that is 0.02; now by using the formula if we calculate the standard deviation; that is summation root over summation 1 to n; x minus x bar whole square by n minus 1.

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So, S will come 1.8762 into 10 to power minus 4; so, what we will do is the fraction after 10 minute is given, the desire fraction which will be average of this or the desired that fraction we can consider as this what is given that is 2 percent so that means, 0.02.

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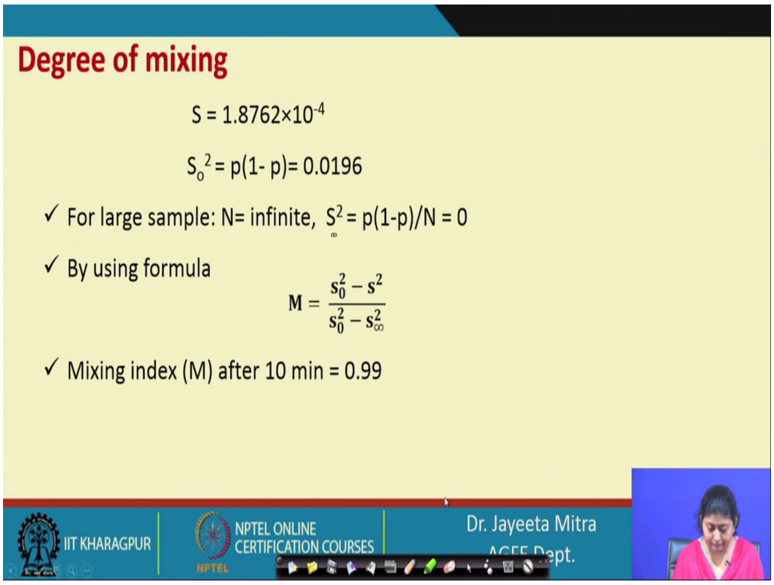

So, using that and n equals to 6; we will calculate this value; that is S will equal to 1.8762 into 10 power minus 4. S 0 square that is p into 1 minus p is coming 0.0196. Now for larger sample as N is infinite S infinity square that is p into 1 minus p by capital N that is equals to 0.

So, using that mixing index will be S 0 square minus S square by S 0 square minus S infinity square. So, putting the value S infinity square this is 0, S 0 square is 0.0196; S square form from this value square we can get. So, finally, in the mixing index after 10 minutes it is coming 0.99; so, we are getting quite high mixing.

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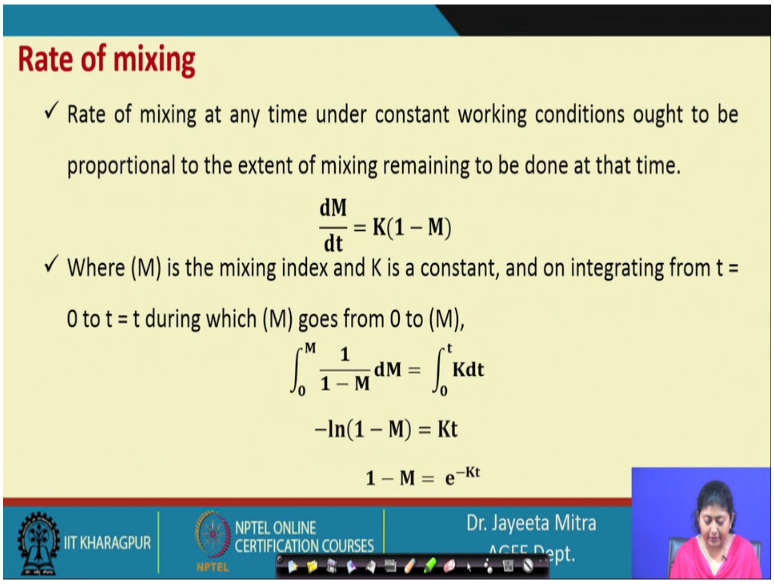

Now, rate of mixing, so how we can define it? Rate of mixing at any time under constant working condition; or to be proportional to the extent of mixing remaining to be done at that time; so, this is almost similar whenever we have you know model the screen analysis or we have model that this kind of cases. Always we are use this concept that at time t whatever reaming thing we have model the rate of change with proportional to that the remaining amount.

So, here also the rate of that is dM by dt at any time has been model as proportional to the extent of mixing remaining to be done at that time. So, 1 minus M that multiplied with K proportionally constant will be equal to d capital M by dt. Capital M is the mixing index and K is the constant and on integrating from t equal to 0; when the mixing starts to t equal to t if we assumed that the mixing has to be completed by that time during which M changes from 0 to certain mixing index.

So, then will get 0 to M 1 by 1 minus M into dM that is equal to 0 to t K dt. So, minus ln of 1 minus M that equals to Kt or 1 minus M is equal to e to the power minus Kt. So, an exponentially dK in carve that will get for 1 minus mixing index right. So, this is how we can calculate the rate of mixing.

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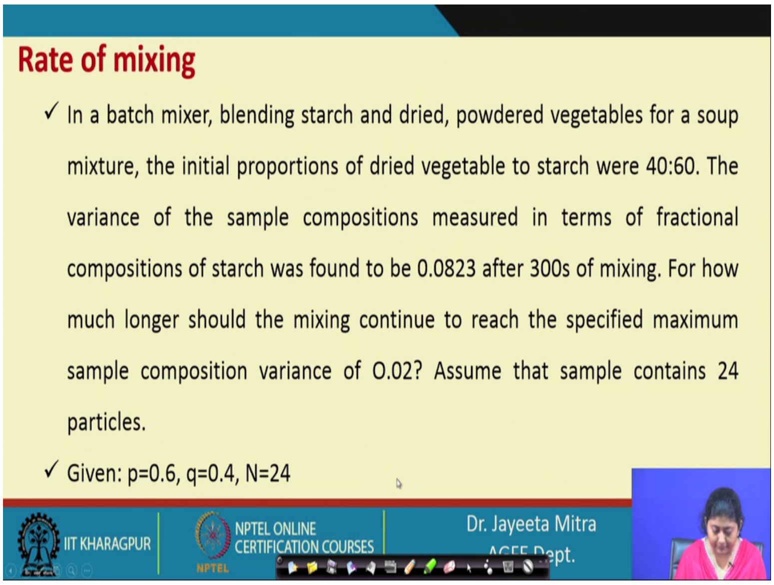

Now, in a batch mixer; blending starch and dried powered vegetable for a soup mixture. The initial proportion of the dried vegetable to starch were 40 is to 60. The variance of the sample composition measured in terms of fractional composition of starch was found to be 0.0823 after 300 second of mixing. For how much longer should the mixing continue to reach the specified maximum sample composition variance of 0.02? Assume that sample contains 24 particle.

So, we have got that time, we have got the number of particle. So and also the proportion of the 2 component that is the starch and the dried powered vegetable those things are given.

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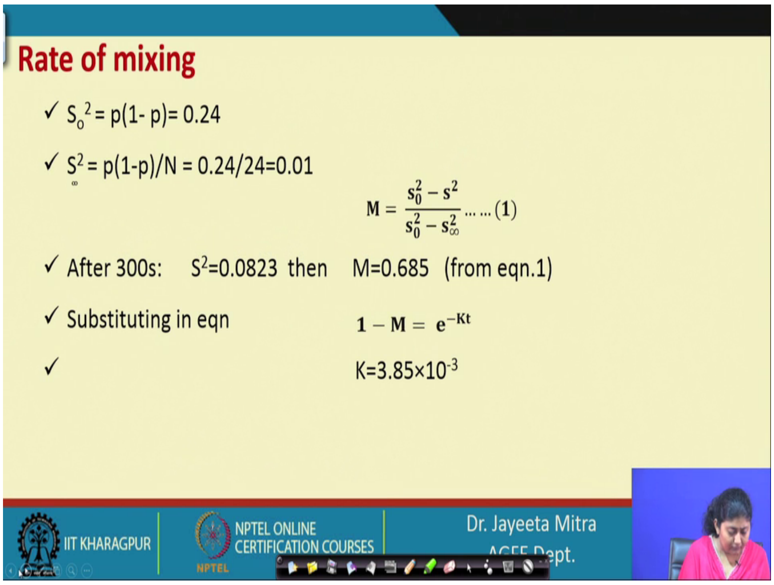

So, then S 0 square that is the p into 1 minus p we will calculate; so p is given 0.4 into 1 minus p; so, 0.24. Then S infinity square that is p into 1 minus p divided by N number of particle; so, that we are getting 0.24 by 24; 0.01.

So, finally, we will put it here M is equal to S 0 square minus S square by S 0 square minus S infinity square. Now after 30 second S value will be 0.0823; so then M will be this value 0.685. So, putting the value of M in that equation, the mixing rate equation 1 minus M is equal to e to the power minus Kt. Then we are getting K equal to 3.85 into 10 to the power minus 3.

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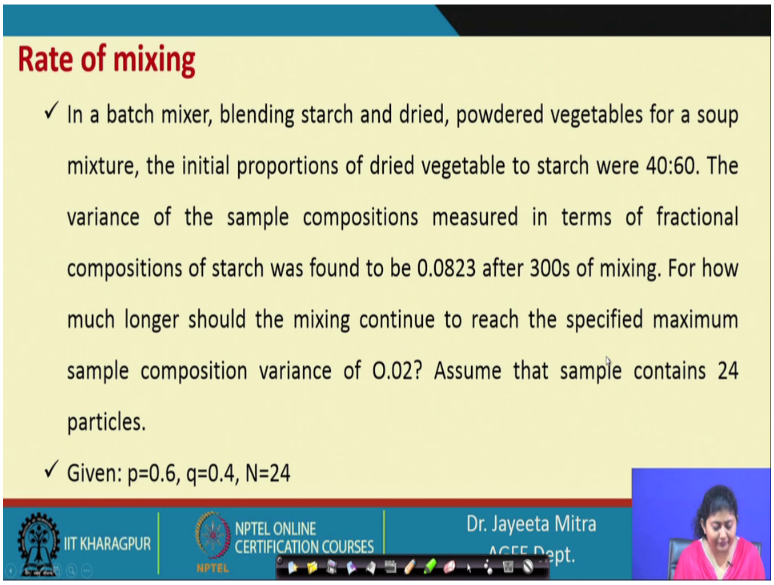

And what else is asked let us see that; p q and N given we are asked that how much longer should the mixing continue to reach the specified maximum sample composition variance of 0.02.

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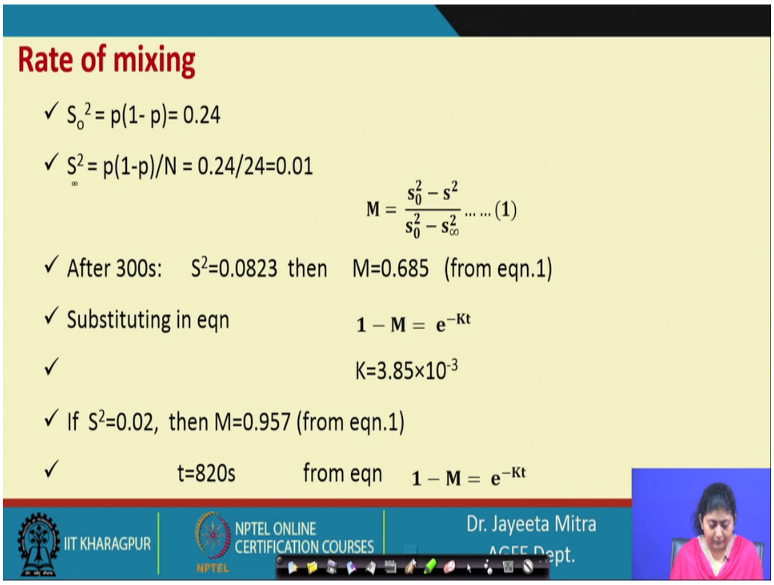

So, S 0 we have calculated based on that S infinity and S also we have calculated for a certain time and then we found K. Now K value 3.85 into 10 to the power minus 3; then variance is given as 0.02. So, then what will be the value of M? So, here we have calculated M as 0.957; if the S value is the 0.02.

So, t will be 820 second from this equation 1 minus M equal to e to the power minus K into t. So, then this will be the required time. So, here we have found out what will be the K that what will be the rate. Now we want to measure that S will be equal to 0.02; so M will be how much? That we will calculate from this equation and then will put it here in that equation K is known to us t we will calculate. So, we will stop here and will continue in the next class.

Thank you.