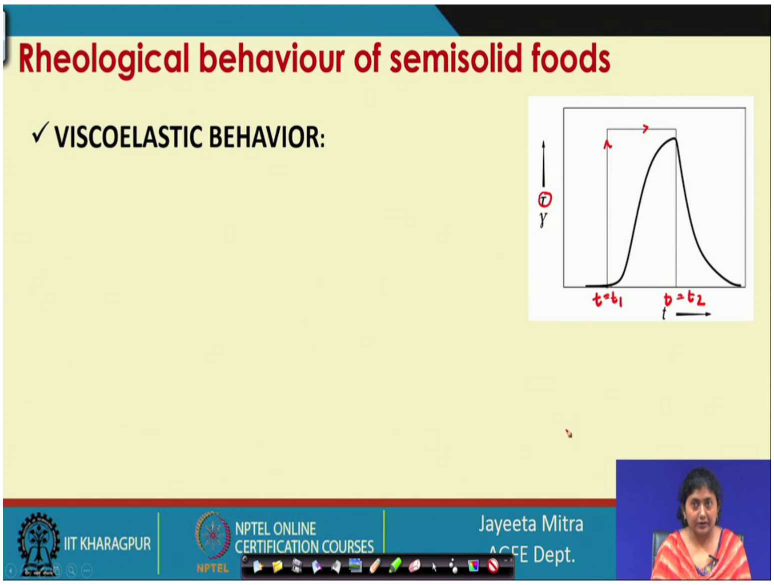
Fundamentals of Food Process Engineering
Prof. Jayeeta Mitra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture – 08
Measurements of Rheological Properties (Contd.)

Hello everyone, welcome to another class of Fundamentals of Food Process Engineering., we are in the first chapter that is food Rheology and we will continue today with the problem, that we should do on measurement of Rheology. So, regarding measurement what are the different methods and what are the principle behind that, we have learned it in our last class. Today, we will continue.

(Refer Slide Time: 00:51)



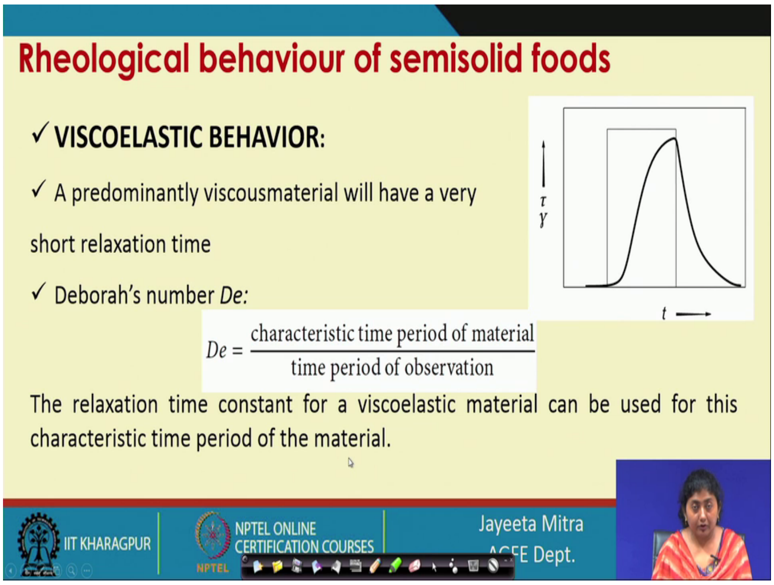
So, next we will cover the rheological behavior of semisolid food. So, semisolid food, which is also called the viscoelastic food. So, we will see first the viscoelastic behavior and then we will see that what are the different kinds of model that can well explain the viscoelastic behavior and the main characteristics, features of viscoelastic behavior; so, first we will see that why it is different from the solid and viscous behavior, we have learnt so, far. So, as the name suggests that viscoelastic material, they must have viscous property that is the flow property and the elastic property which is the characteristics of solid material.

That means they show both the elastic as well as viscous property, at the same time say, they possess some to, some degree of elasticity and also they flow, some degree. So, the full recovery of the initial condition may not be possible in this case. Let us see that, what happen when a constant stress applies on a viscoelastic material. Here we have a plot where a constant stress tau has been given here, according to this line and it is maintained at that condition at a particular. Shear stress is being maintained for certain time and then it has been withdrawn ok.

So let us say if t equal to t 1, we are giving this constant stress and then t equal to t 2, it has been withdrawn. Now, what happened to the elastic material that since, stress is proportional to strain in pure elastic material; it directly come to the, come to the condition of the stress, proportional to the stress and then instantly again come back to the initial condition; if it is purely elastic material. However, if it is purely viscous material; so as the stress comes on the material; so, a constant stress.

So, it will start flowing continuously but for a viscoelastic material, it starts increasing the strain and may not be reaching to the exactly similar degree of the applied stress. And then, when we withdraw the stress it will try to come to its initial condition exponentially, not instantly. And because it has some viscous property as well; that means, it has some, flow properties that is why it cannot fully regain the initial condition, because of this elastic nature it regained, some of it is nature, but not fully. So, this is the nature of strain that will be observed as a result of a fix pulse of stress, which is applied on a viscoelastic material.

(Refer Slide Time: 05:32)

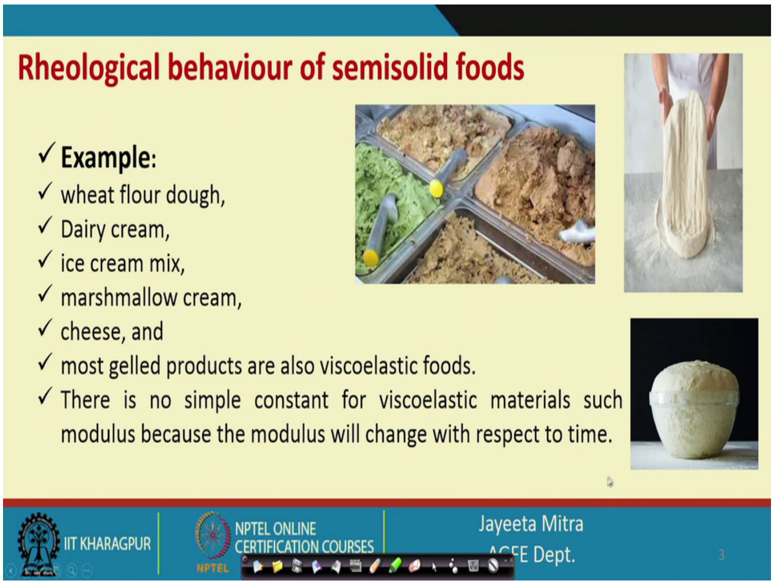


So, now we will see that if the material is having viscous nature to having a higher degree of viscous nature compared to the elastic nature, then it is relaxation time will be very short. And if it is having, more elasticity, more elastic nature compared to the viscous nature, then it will show a longer relaxation time. So, one important characteristics is Deborah number, represented as D suffix e that is the ratio of characteristic time period of material divided by time period of observation.

Now, if the characteristic time period of the material; that means, the time to have the full relaxation will be very low, as the high viscous, material will be I mean in the viscoelastic material, where component of viscous material will be higher. So, they will have very low Deborah number and the reverse will happen in case of the, in case of the material, which is having higher degree of elastic property ok.

So, Deborah number can give us some indication of the nature of the viscoelastic material, that is why this is very important parameter and it also depends on the, the time of observation. So, if the material is having a really-really longer period of, period of the relaxation time. So, we should take the time of observation, accordingly. So, relaxation time constant for a viscoelastic material, can be used for the characteristic time period analysis of the material.

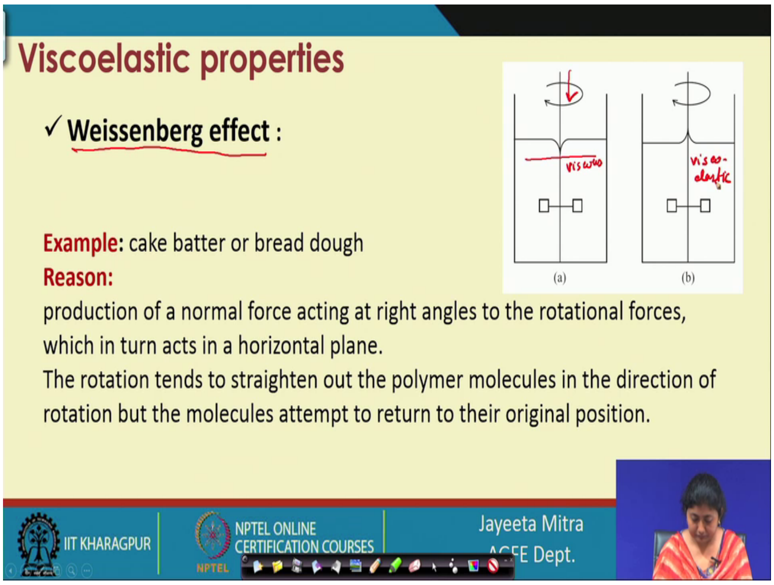
(Refer Slide Time: 08:21)



Now, here are the example of the viscoelastic food like wheat flour dough, dairy cream, ice cream mix, marshmallow cream, cheese, most gelled products. These are viscoelastic food; that means, they possess both the viscous that is flow behavior and, elastic behavior, but the degree of elasticity or degree of the viscous nature may vary depending on the different, molecular construction of the material.

So, therefore, there is no simple constant for viscoelastic material, such as modulus, because the modulus will change with respect to time, because most of the viscoelastic material shows significant deformation behavior with respect to time.

(Refer Slide Time: 09:48)

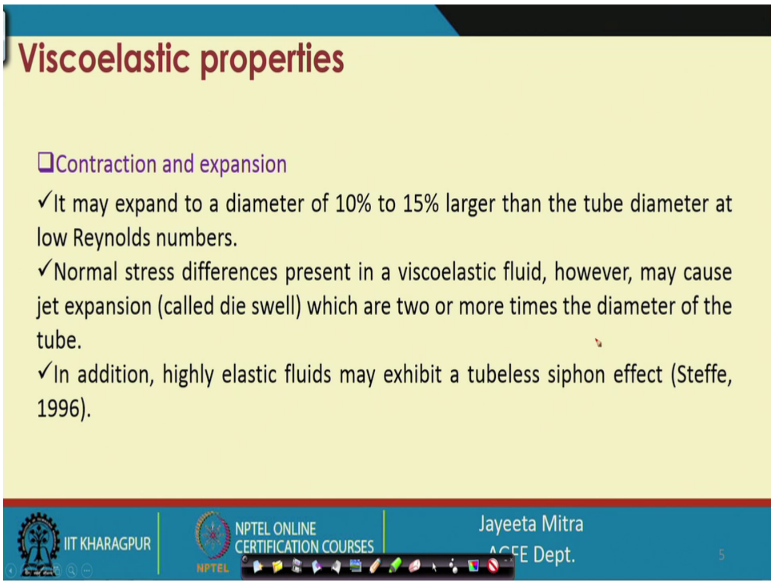


So, we will see an interesting phenomena here, viscoelastic material which is having some special property, which is visible compared to the viscous material. So, if we take a rod, if we dip one rod into a viscous material and give a rotational movement to it then we will observe a vertex in the liquid ok. So, it is clearly visible.

Now, if we take a similar rod and try to agitate the viscoelastic material ok; so take a viscoelastic material then we will find that the material will try to stick to the inner rod and try to come up with the rod. So, this effect is called Weissenberg effect. So, example is, you can see this kind of behavior in cake batter or bread dough.

So, the reason is that, production of a normal force acting at the right angle, with the rotational forces, which in turn acting on the horizontal plane, because the rotation tries to, straighten or break the polymer molecules in the direction of the rotation. However, they have a tendency to come to its initial condition. They try to spring back and put a normal force, because of that, because they want to come to the initial condition and therefore, this kind of effect which is Weissenberg effect is seen in many viscoelastic material.

(Refer Slide Time: 12:07)

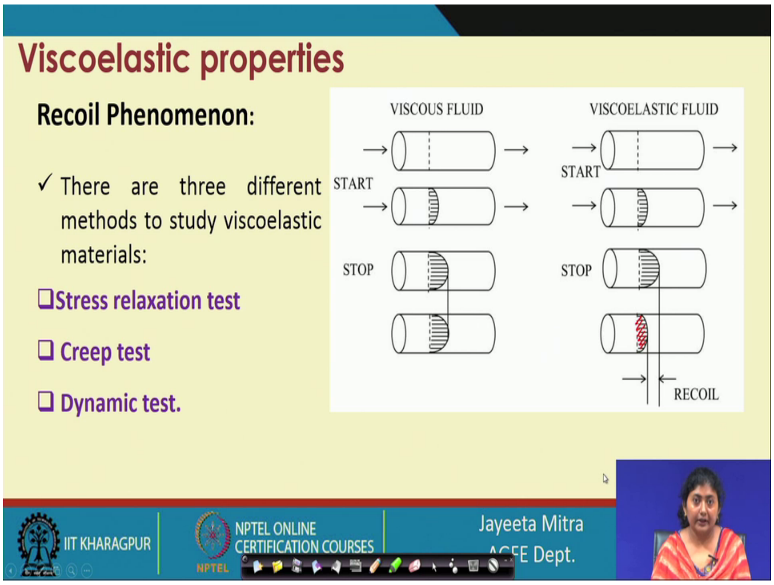


So, another, phenomenon that we can see in case of viscoelastic material that if, let us say some fluid, some viscous fluid, if it comes, through a long tube and when it come, comes out. So, that time contraction happen ok; so, if the diameter is if the diameter is D. So, the the material which comes out to be from the long tube, if it is a viscous material; so, its diameter will be reduced or the material will be contracted a bit. Now, if we see the, in, in case of a, low viscous, low viscous material, then we can see; that means, Reynolds number is low then we can see that 10 percent to 15 percent larger, material may observe when it comes out from the very long tube ok.

So, during flow, so this time we can get 10 percent to 15 percent, higher in the diameter or; that means, we can get a mine a minor amount of expansion in the material; however, if we take viscoelastic material and the stress is released through the, through the pipe flow if, if it comes out to be from a long straight pipe, then almost, almost twice or more times of the diameter the expansion will be visible and also if the material is highly elastic tubeless siphon behavior will be visible ok.

So, this kind of phenomena, you can get it from the, the books as well you can refer the, M A Anand Rao or Steffe book for getting the viscoelastic nature of the material.

(Refer Slide Time: 14:29)



Another more important behavior that is called the Recoil Phenomena; so, what is recoil phenomenon? Let us see, we have viscous fluid flowing inside a pipe as well as, we have a viscoelastic fluid. So, when we start the flow, gradually the flow will start building up in the pipe and eventually fully developed flow, having a parabolic nature will, will be observed and at that time if we stop the flow; that means, if we, if we stop it, it will remain in the same condition; however, if we start the flow in case of viscoelastic material.

So, it will come up to the parabolic condition, but when we stop it, it will again spring back to a stage, which is a, which is a previous condition; that means, it is not coming to fully straight, but not retaining that parabolic behavior that it was during flowing, during the fully developed flow. So, this phenomenon is called the recoil and this is happened, because of the elastic nature of the, viscoelastic material. So, some flow will be observed, because of the viscous nature and some, recovery will be there, because of the elastic nature this phenomenon is called the recoil phenomenon.

Now, the main characteristics of viscoelastic material are stress relaxation. There are method of stress relaxation, test creep test, which is another important phenomenon and lastly the dynamic test. So, this all three test we perform to analyze the viscoelastic nature of food or for that matter any viscoelastic material and this test can very well, give us an indication of the degree of elasticity and degree of viscous behavior of the material. So, we will stop here and we will continue in the next class.

Thank you.