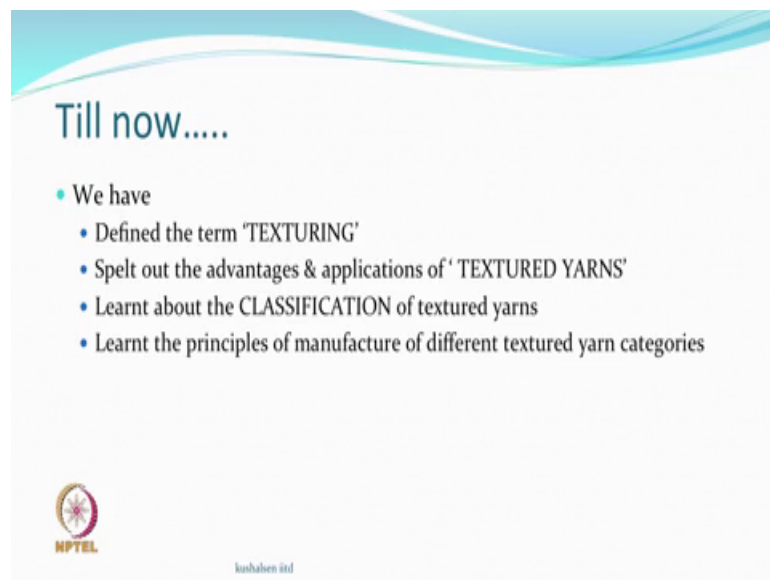


Textured Yarn Technology
Prof. Kushal Sen
Department of Textile Technology
Indian Institute of Technology, Delhi

Twist texturing
Lecture – 05
Mechanisms of setting and texturing

All right. So, we meet again and we shall discuss something on Twist Texturing.

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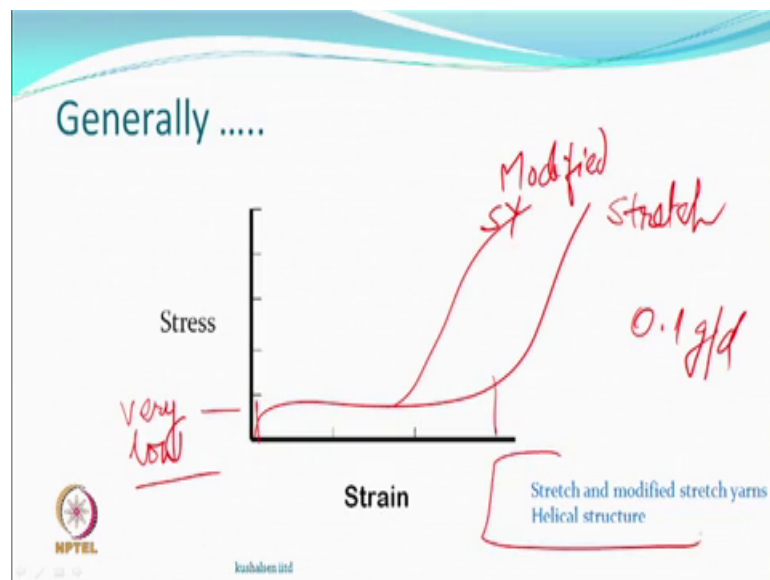
What we have done till now? We have defined texturing, we have also know known about the applications advantages of textured yarns, we have done the classification and also learned some of the principles of manufacture different texture, different types of textured yarn.

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We talk about Twist Texturing and what it means is the three processes ok, helanca, false twist and turbo duo all of them will give us helical structure all right.

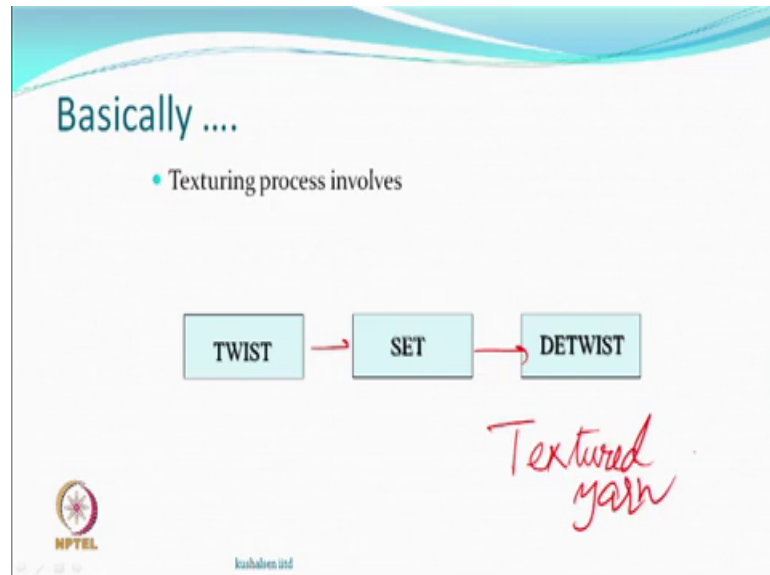
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So, we move further and we believe that because they have helical structure and generally the stress strain curve would be like this, there is a lot of stretch before the stress actually develops and this is very low value. It could be as low as 0.1 grams per denier. So, these type of yarns would have the stress strain behavior of this type and can

be modified in that case you may have reduced stretch. So, you have stretch yarns and modified stretch yarns.

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So, this is what we have already understood. So, this process which we are now calling as twist texturing; obviously, you do some twisting and then some setting and then d twist and we believe that at the end of the day, we should be having a textured yarn which has helical structure and has bulked and stretch.

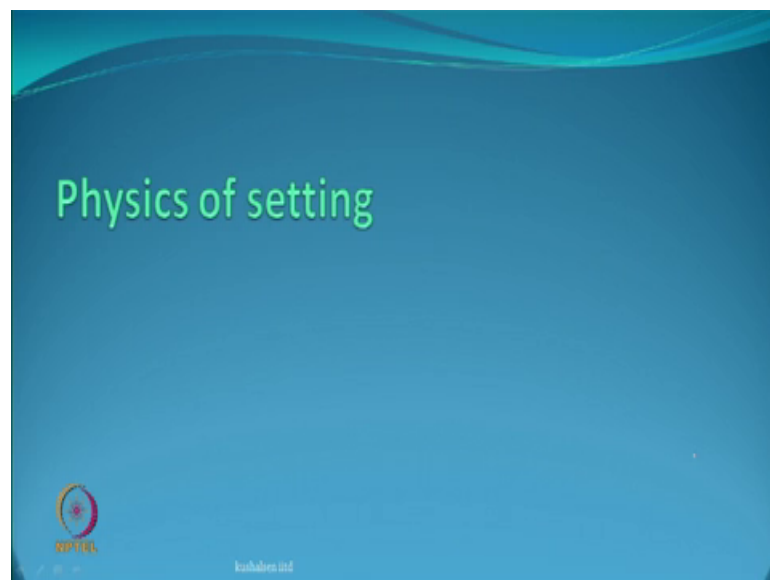
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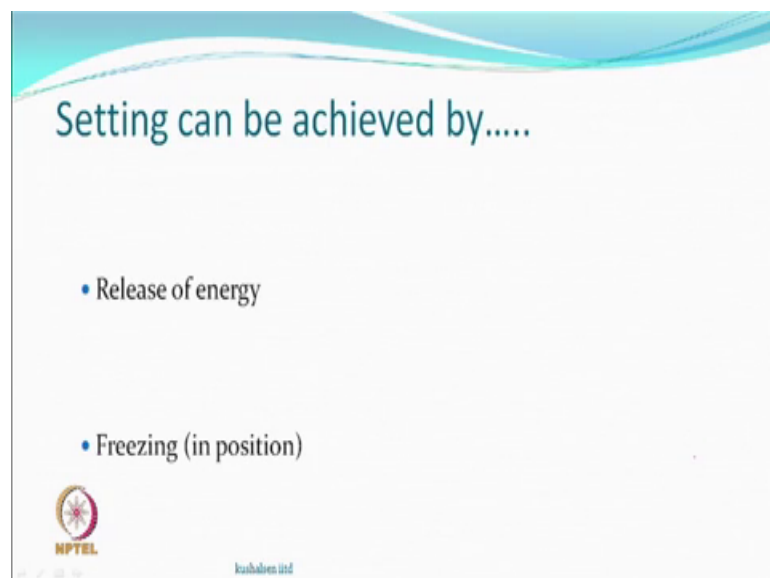
In this lecture, we would try to concentrate on the physics of setting and mechanism of stretched generation and bulk formation, in the twist texturing mechanism. It does not matter whether it is duo, turbo duo or false twist or helenca they should cover all these type of processes;

So, physics of setting mechanism of stretch generation and bulk formation in twist texturing. So, we try to understand how does the setting take place and what exactly it involves.

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So, setting can be achieved by two basic mechanisms. One is that you do something; so, that the energy of the system is released. So, whatever is the energy in the system it is released and therefore, you can achieve a stable, structure and which we can call as a setting. The other could be not release of energy, but freeze everything in position like for example, you have a molten polymer solution, you immediately put it let us say into liquid nitrogen; the molecular chains have no scope for any arrangement or rearrangement, they just freeze wherever they are; and so, that also means they will stay in that position. Now, this is what we mean by freezing in and a release of energy.

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Setting via release of energy

- It helps to make the system more STABLE
- FREE ENERGY should be as low as possible

$$\Delta G = \Delta E - T \Delta S$$

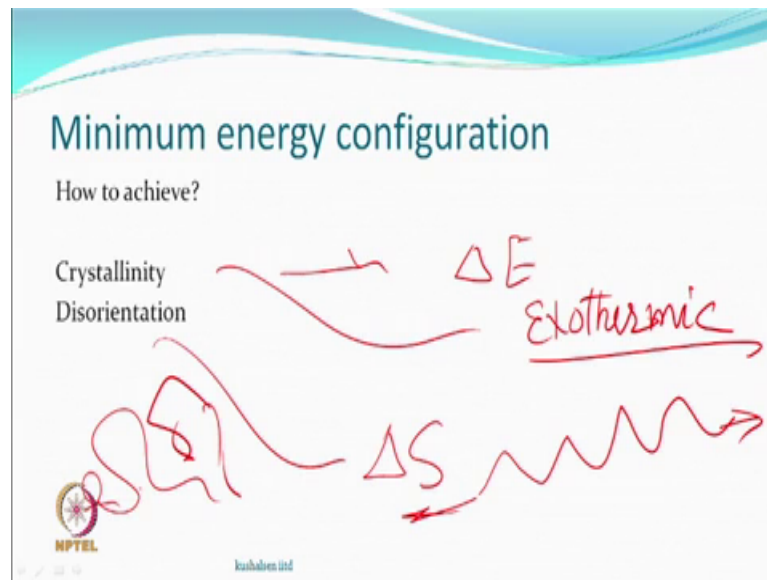
Internal Energy (under ΔE) *Entropy* (under ΔS)

NPTEL IIT Kharagpur

So, let us say what do we mean by release of energy? Obviously, the purpose is that we want to make the system as much stable as possible; that means, it will not change its position and why are we interested because we are going to be deforming the yarn. Once we deform the yarn, there is a purpose for deformation and that deformation should be stable; so, simple equation that you have already gone through the free energy equation. So, we have this delta G is equal to delta E and minus T delta S. So, we understand one term called the entropy and this is the internal energy.

So, now we have to see in our terms, in the fiber term, in the yarn terms, what do they mean? What it obviously means is that, if you want these any state to be more stable the delta G should be negative; that means, release. So, whatever was the energy level, if delta G is negative; so, we can be quite assured that, we are going towards a stable state.

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So, how do we achieve our goals? So, we have to go to what we call as a Minimum energy configuration? That is, a fiber is made of a large number of polymer molecules. And we have understood, why a polymer molecule is required, what kind of a characteristic of a private polymeric molecules should be, but now in terms of that the molecule is there and we believe there is a fiber forming polymer and we have a polymer like polyester or a nylon or a polypropylene we understand all that.

Now, how do we take it to minimum energy configuration? So, there are two things that can happen; one is a phase which we call it a crystalline phase and the other is called the amorphous phase. An amorphous phase means the order in which the molecules have been put is not defined all right. So, in some sense we can say one is crystallinity and the other is disorientation. If you say, crystallinity is similar to let us say ΔE , if you change crystallinity ΔE will change ok. Now, if somebody ask a question, when crystallization takes place is the energy released or produced.

Student: Released.

Released. So, in some sense we can say crystallization is an exothermic reaction, can we say that? So, this process is exothermic; that means, whenever you facilitate crystallization, then energy will go down ΔE will go down, that will; it will become negative, is that right? And if you go above what it means is if this is negative it is helping, the ΔG also to go towards the negative.

Then, there is other component which is called the entropy. The entropy must increase if suppose, entropy of a system whenever you see whatever thing happens the randomization is preferred, that is what the thermodynamic part of it. And so, if ΔS is positive then it helps; if ΔS is negative then we are not sure. If suppose ΔS is negative then, this term may become positive and based on the value absolute value you may actually be landing somewhere else.

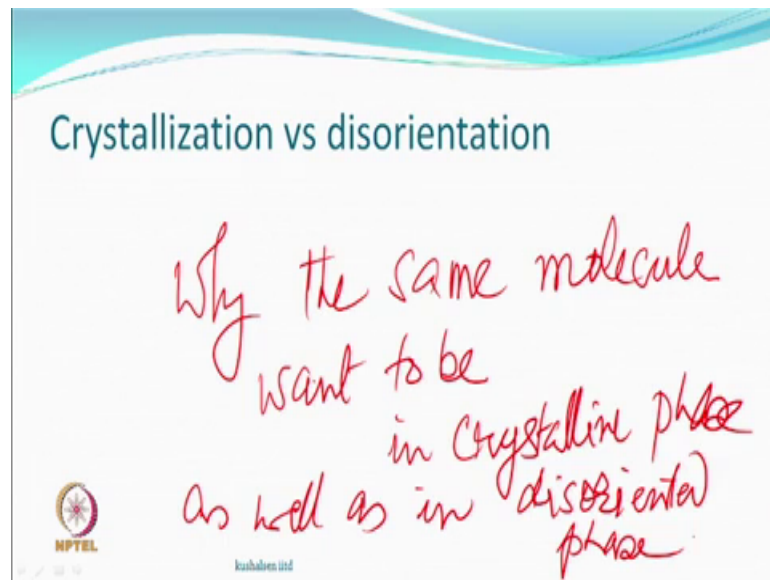
So, theoretically from this equation what we are saying is, ΔE should be negative and ΔS can be positive and should be positive, the more positive it is the better for us; that means, this may be representing the entropy. So, more is a disorientation in a system entropy is increasing and therefore, finally, ΔG may be negative. Now if you look at daily life also anything and material or even persons would like to be disordered; that is, the thermodynamics direction like for example, in this class at the movement looks like very ordered class. So, there is something happening and suddenly the teacher goes out, so, there is disorder and that is natural.

So, if we take the polymer molecule and pull it, let us say I have drawn it because you put force; the molecule can remain in a extended conditioned configuration. For example, let us say this is a molecule you can stretch, very simple molecule it could be $\text{CH}_2\text{CH}_2\text{CH}_2$, but if you remove the stress this molecule may like to take up some shape which may not be your desire that is thermodynamics. So, a molecule when given a freedom would like to take a shape which is not oriented, which is not aligned and that is the reason, why the textile material is a synthetic fibers as compared to any other material; when you heat them they shrink.

You have seen that, you believe it, if you have a metal when you heat it expands, but this is a very difficult, different material where there are molecules long chain molecules and they have all to take a random position; that means whenever you do some action, where the change would be allowed if the molecule wants to change if is a favorable kind of a condition, then there will be automatic tendency to go to a random configuration.

If it is oriented then you are actually working on it, you have put energy, you give energy pull it out which obviously, you are reducing the entropy. When the crystallization also spontaneous process it happens automatically because the molecules want to be there. So, these two processes both are thermodynamically acceptable processes first thing.

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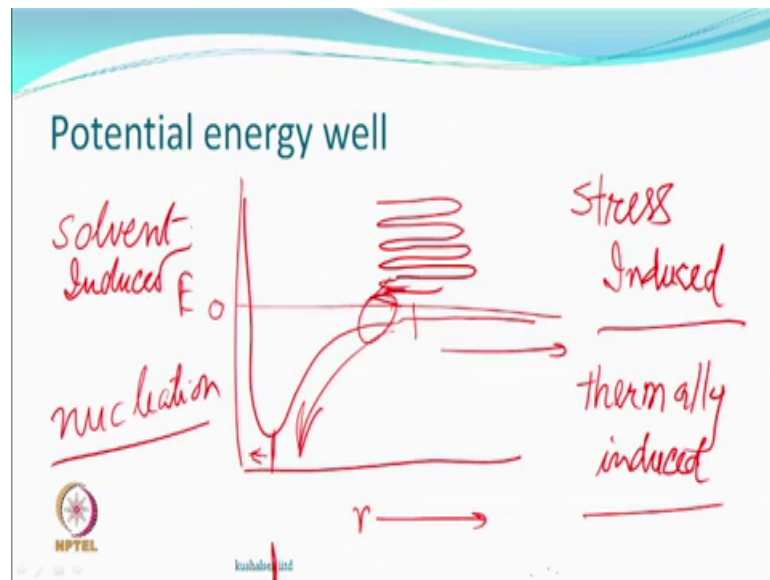


If suppose somebody asks a question, the same polyester molecule in a fiber also is available present in the crystalline part and also in the amorphous part and if you understand correctly, crystallization also is favored and randomization is also favored. So, how the same molecule can go to a perfect order which is the crystal and also go to another order which is random and both are thermodynamically favorable.

So, how does it happen it is a contradictory; I mean either a molecule would like to go to one state or would remain the other state; why would they do it? That means, this is the question, why? The same molecule polymeric air wants to be in crystalline phase as well as in disoriented phase because we are talking about thermodynamics.

Therefore, all the process are automatic; I mean this is not that well we are directing one part of a molecule to go there, other part of the molecule to go there and therefore, they are molecules are following your instructions. It just happens automatically. So, how can that happen automatically? Both the things are possible and they happen spontaneously well these two phenomena are totally different, in one case the space between each atom is fixed, in the other case randomness and both are good.

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I hope you can recall this kind of a curve and this let us say is inter atomic distance between two atoms the distance in two atoms. And, what this curve is showing is? That if the distance is large then the energy levels are close to 0 let us say, when the distance is large infinite level distances they are large, but when you do something with the atoms start coming closer then, after a certain time or a distance this process happens automatically the gravitational reasons forces would bring them together the masses attract. So, automatically they want to come together.

If you bring them more close after this point, if you bring them more close, beyond this then, what happens? There is a repulsion. So, the electron clouds are there and they repel each other too so much that you really have to work very hard to bring them closer. So, automatically the atoms take a position, different atoms will take different positions. So, this process of coming close is automatic spontaneous, only if the distance is let us say below a certain critical distance.

If the distance is more, then you find that there is no attraction between the two is not good enough to bring them close, why? Well, you see the nature of the atoms. So, they are away and there is enough, kinetic energy available for them to just randomly move wherever they want to move. Let us say at room temperature some of the polymers for example, let us say rubber has glass transition temperature very very low, much below

the room temperature itself, much below 0 degree also; they are flexible there are lot of vibration.

So, there is no that that just dynamic condition and the energy is enough for them not to come very close right. So, they stay away; so that means, the same molecule if normally is a way would like to stay disoriented stay away, and that is more comfortable position. But, if you do something for example, you draw, take polymer melt from the melt of the fiber has come out, it is just solidified and you are drawing. So, what drawing you are doing is, of course you are putting energy, but simultaneously you might be doing an exercise to bring some molecules together. And once they come together then they know what to do, they are also connected with each other, they will pull the other molecule, there other part of the atom also come near.

So, finally, sometimes we see if that is what happens. So, this is what we call it a stress induced crystallization. Stress induced crystallization, that you have done something and therefore, the molecules have come together now and hopefully, if they happen to be somewhere here, then this process will be automatic. They will finally, themselves want to be there, but if suppose the temperature is very low, then you say well do the drawing at a little higher temperature, allow mobility; that means you facilitate or then we had another thing called heat setting.

Thermally induced crystallization, stress thermal inputs, that is you are given enough vibrations, but before that something has happened which we sometimes also know as nucleation. You must have heard about those things that if you have a saturated solution of let us say sodium chloride, if you want to start crystallization you let us say put a crystal of sodium chloride and suddenly everything starts along that the crystal growth starts. So, you can initiate this process.

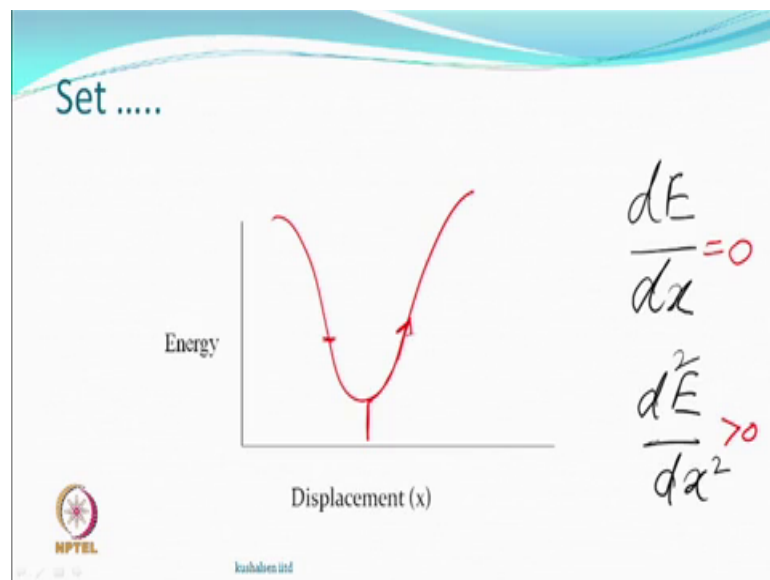
So, by stress you initiate the process; once this process initiated then you heat, then the molecules may say well it is not a bad idea to because it is possible to come close. And therefore, in polymeric systems sometimes you see, what we call as a chain folding, the crystallization happens the chains start folding over each other because you gave them enough opportunity to do the folding also and that becomes a crystalline region.

And whenever it is not possible for the molecular chain to pull the other part very close to itself, then they remain far away and then they remain far away and so they would like

to then prefer disoriented structure or a state; that means, by giving a right opportunity either stress induced, thermally induced and theoretically, another one which we also know as solvent induced. There is it put the fiber or whatever the material polymeric in a proper solvent which also does the same thing as the thermal energy may do and that can also give you solvent induced crystallization ok.

So, crystallization can be done which we believe is now, favorable to us because it will reduce the free energy and if some part of the molecule cannot be brought together, then they would like to remain a randomized form that also helps in the thing; that means, both the things are helpful and stable states can be achieved.

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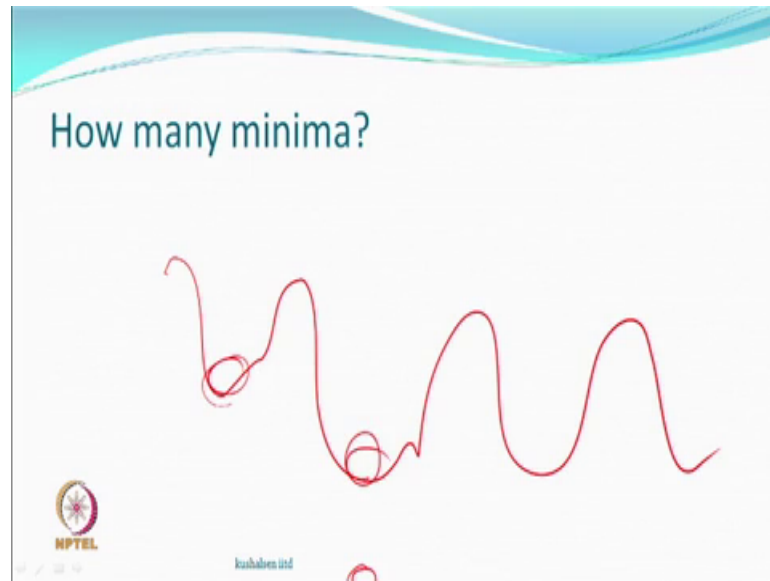


So, we have a minima and energy. If suppose, this displacement you can understand correlate in a manner, we say that something at the molecular level is happening, when you stress, you twist, you deform something is happening. So, molecules at one given point are in certain position in space and they have certain energy which is must be at a minimum level.

For example, this paper stays in this position and is not fragmenting and going all over because is stable; this state is stable. If I bend it, it still comes back. What it means is, that you are trying to displace some atoms some molecules which are very comfortable here in this position and if you do anything they may go there, if you leave the stress they will come back.

So; that means, you can change this displacement in one way or the other in any direction, but it will still come back to the same position and that is, what is settings. So, ΔG must be doing something like that, all right. So, if you want to express dE by dx should be 0 and this d^2E by dx^2 . So, some conditions are being fulfilled and you can always find a minima in the energy levels and so setting can be achieved.

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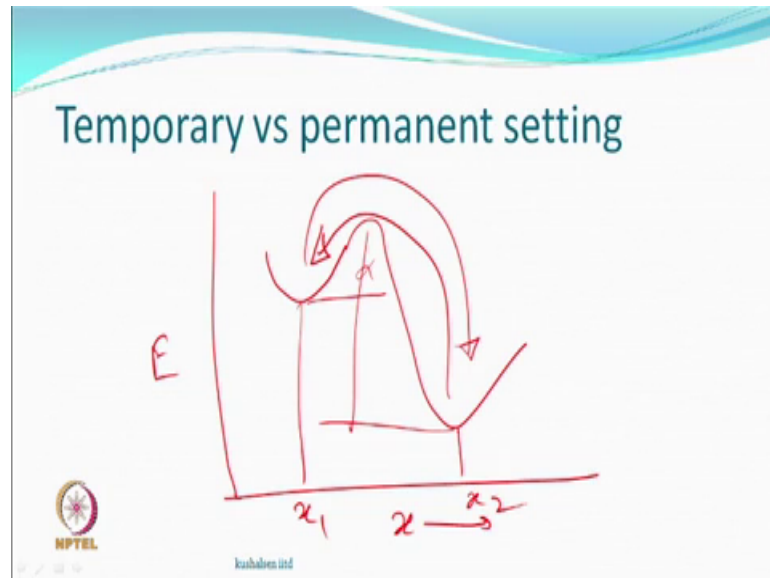


Now, does a system for example, like a fiber which has large number of molecules and very long chain and so many atoms branches all kinds of things is not something like a simple string of atoms. So, do we believe that a minima is only one possibly no in a random system, you may actually have one configuration also stable, the other configuration also stable, some is more stable, some is less stable; for example, I am just giving when you get up from sleep and you see there are some creases which are formed because of whatever reasons they were the fabric was under some stress.

And we start walking and you find the crease is vanishing after some time; that means, you have created a minimum for a thing, but there was another minimum, that is if something happened here and you are seeing watching this, but after sometime you might find it has gone here which may have been more stable because lower energy state. So, there is something called temporary set and a permanent set, but remember in this world there is nothing permanent, it is all relative, it is relative compared to one state the other state.

So, one is if this kind of a configuration is there and you can appreciate that well something happening in the x direction, something happening in the y direction, something happening in z direction also are part of the minimum could be anywhere because the product is a three dimensional structure and molecules are all over and they are not following any path; although, we would like we may like them to do that.

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So, let us say there was let us say a fiber, it remained the way it is; it remains the way it is because it is in a stable form. And what do I do? I help it, by heating let us say and you find thermally induced crystallization taking place or something may be disorientation also taking place and it comes to from a state called x_1 to a state called x_2 Now, this change from state x_1 to state x_2 can be considered as a permanent change; relatively permanent change, why? Because there is an energy barrier which was crossed and it went down all the way till this point ok.

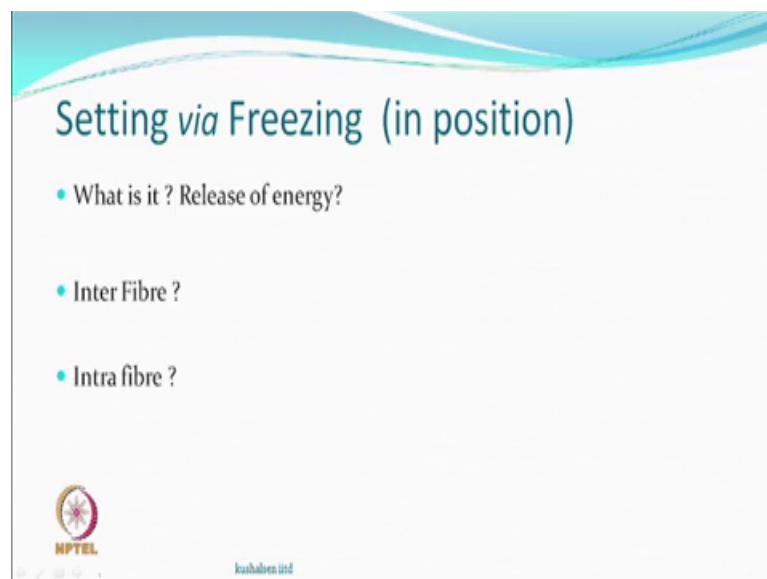
Now if it has to go back, you have to give a good amount of energy for it to go back. So, that is not in favor, that is not a favorable situation; but so, if the change takes place from a higher minimum to a lower minimum, when a change takes place from a higher minimum to a lower minimum we can say it is a permanent set. If the change takes place from the lower minimum to higher minimum, then you can say it is possibly a temporary like, let us say tomorrow you have a textured yarn, itself is a beautiful yarn. You have kept it in a package for three months as you know winding tension may be good enough

to keep the fiber in fully flat state because 0.1 gram per denier is a very small amount of stress required to completely you know remove the crimps.

And so, you have wound under this and kept it for three months and then you open the package, you may find oh just opening as if it was a flat yarn and you see where is the whole setting gone, all texturing finished and the package was stored at room temperature, you do not see it and then you remember, it is a textured yarn. And, then you do one thing, just take it and just shake, it give a mechanical stress or give a thermal shock you certainly find they all remember where to go and finally will go back.

So, from a temporary set which was created, they will remember the permanent position, if given a little favorable condition and suddenly they will remember and go there. So, that is the way permanent and temporary set could be defined. The other way of setting is freezing.

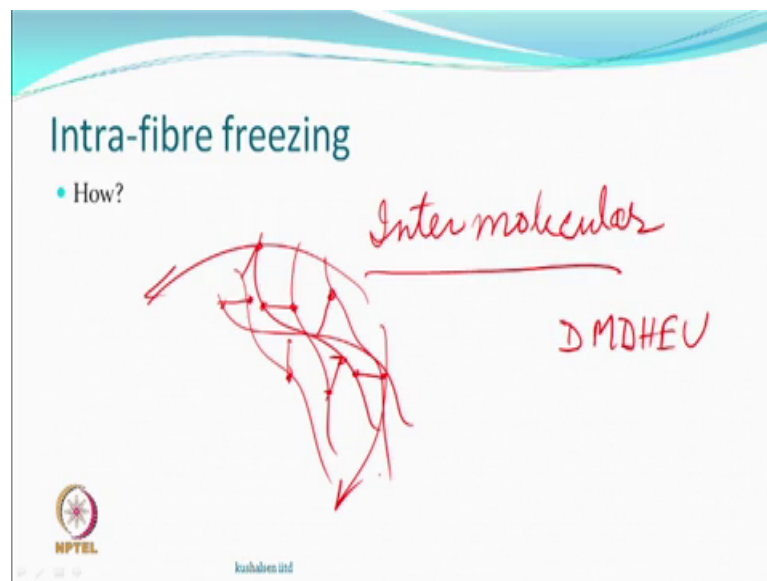
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So, this is not thermodynamically driven process, this is an external source; for example, I bend this fiber it wants to go back, but I put a glue it cannot go back. So, you are freezing this deformation, against the will of this material, you have not released any energy it may be under stress, but you say well we want this type of a configuration. So, you better be there that is freezing. So, you require something else, some external entity to keep a new configuration stable.

For example, you take a fabric apply starch. So, fabric may want to drape, you put a starch and iron it fabric becomes like a board cannot change the position because the starch molecules are holding it down. The other thing is, you can put other polymeric material which can polymerize and make sure that does not move anywhere, you bend it in a position and put something outside and then it remained the bend remains the bend as it is. So, you can do that.

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So, do we need inter fiber freezing, my interest of course is texturing, that is yarn has got many fibers, fabric has got many yarns and you are bonding inter fiber. So, two fibers are getting bonded whichever way temporary bonds, permanent bonds whatever. Then you get material where everything is stuck that probably could be done as I said by starch or any other material like a PVA or anything cross linking type of materials, you can use which will completely cover the whole thing.

So, inter fiber freezing you can actually keep any state which can stay there as long as that the external material is there. The other thing could be intrafiber. Intrafiber means it is within the fiber and or outside it; that means, it can also be said as intermolecular; that means if you heard about, have you heard about cross linking right; cross linking have you heard.

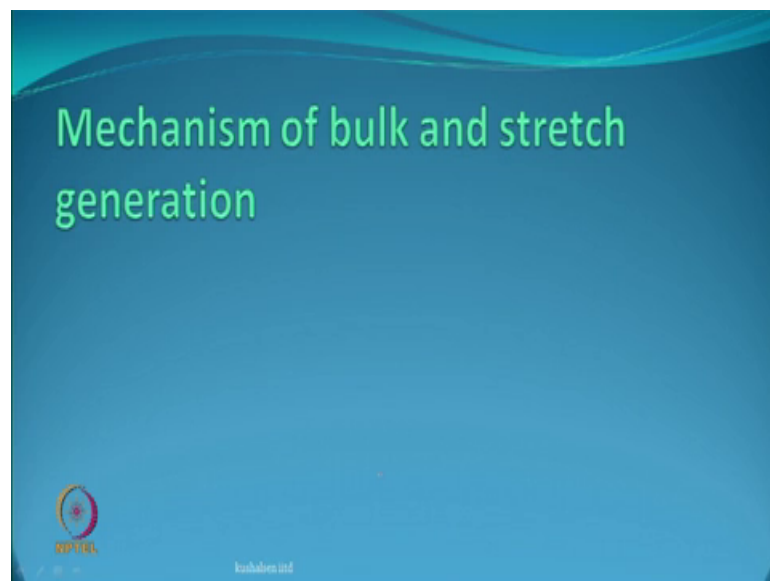
So, if I put a chemical cross linking by a covalent bond another molecule which goes and reacts like this and makes bonds of this type with the functional groups, that are there

remember Dimethyl on Dihydroxy Ethylene Urea, DMDHEU; it can make cross links with cotton, cellulose then you have any other kind of cross linking agent, we can do this type of job for different fibers. So, the chemistry would depend on, what is the chemistry of the fiber. So, if you do that.

And then after doing this, when you try to bend this material or change it's configuration, these bonds will get stretched and when you leave the force, they would like to come back to their own position. So, this is how you can do intrafiber freezing of the position; whichever position you have. So, you deform the material let us say twist, after this you do cross linking, then you will find that the fiber does not untwist on it is own or it remains that position because the cross links would not let it go to the other direction, right.

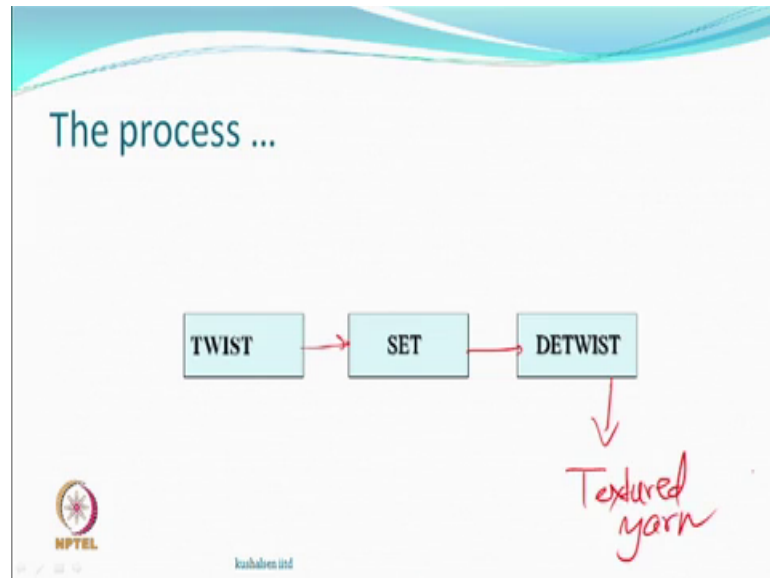
But remember, there is no release of energy if for whatever reason your deformation has put stresses in the fiber, the stresses would remain ok. So, for texturing I may say that we may like to have intrafiber because each fiber of element, we want to behave individually and not get stuck with each other a multifilament yarn, all filaments stuck with each other, how will it give me stretch and I will give me bulk right. So, this is what we may probably be requiring.

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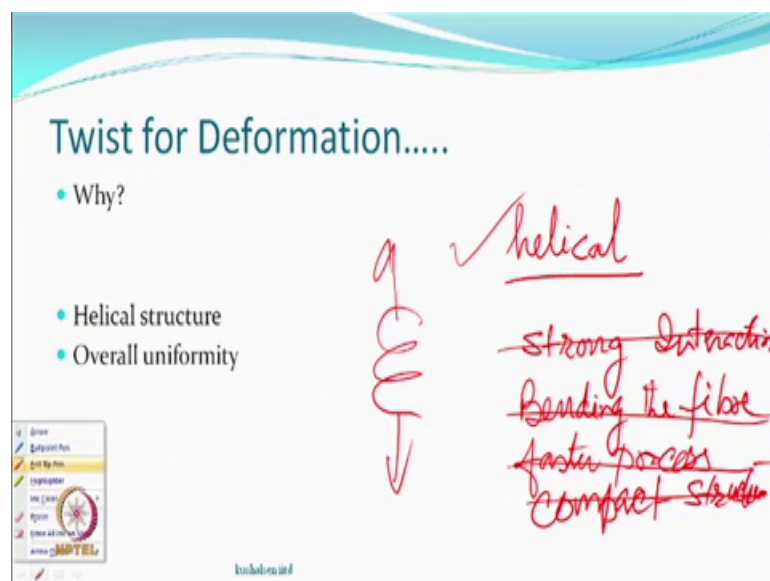
So, let us say now we understand what is setting and now we understand the twist texturing process. So, how this bulk is generated and stretch is generated. So, you have something in your mind a picture let us see if this picture is ok.

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So, yes nothing is changed, process remains the same you have to do twisting, setting de twisting and we say now just do not worry you have a textured yarn; question is how is. So, simple let us see.

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So, we are doing twisting. So, there are three things steps we are doing, important three steps twist for deforming the yarn, right. We have seen there are other methods of deforming the yarn; you can do anything to deform the yarn. So, what is the reason we would like to twist that is the question. Why twist, would you like to guess; why twist, there are other mechanisms why we want to twist?

Student: The helical structure.

Helical structure; so, one is they can give me helical structure that is without any doubt and so, you can produce stretch yarns and modify stretch yarns. So, you get helical structure which is good more extension more stretch can also be achieved; any other reason?

Student: (Refer Time: 40:32).

Yeah.

Student: Strong interaction.

Strong interaction let me just write keep writing down hopefully, strong interaction this is what you said anybody else, anybody?

Student: Bending the fiber (Refer Time: 40:56).

Bending the fiber, anything else?

Student: Faster process.

Faster, faster process anything else?

Student: Compact structure.

Compact, compact structure let me just stop here. Remember, what is my aim, to produce textured yarn right; and as far as helical structure is concerned I think it is fine twisting does helical structure, you will get something like this. So, you may be able to stretch and it may come back. Now, strong interaction between the fibers, how is it important to us between fibers, very strong interaction twisting is it going to be help me twisting my aim was not this.

So, what I am going to do and it is going to help does not seem so. Bending the fiber, I can bend fiber anyway, why only twist does not make too much of a sense either; faster process yes, but if you just throw the stuffer box keep throwing them, you can keep throwing them as fast as you want may not work.

Compact structure, I mean it could be very interesting if you actually using a twisted structure you are not interested in twisted structure. So, this compact also does not make too much of a sense. So, if I say the twisting gives me an opportunity to give uniform deformation would you agree, helical structure overall uniformity is this statement correct or you think this statement is also wrong, what this is uniform right, you have to tell me something about it uniformity.

How does twisting give uniformity, because we have let us say a yarn got multifilament yarns there are lot of filaments are they being treated uniformly. So, whenever you twist? You have some filaments on the surface some filaments maybe in the core. The filaments in the core, there helical structure will it be similar to the one which is outside, it will not be same, then is it uniform? So, basically you are saying that you are actually doing a bad job, maybe some filaments have some kind of a dimension, the other filaments have other kind of deformity or deformation and so you saying well it is uniform.

Any process which does this kind of a job cannot be considered a good process right, but they still are twisting, why are they twisting? There is one interesting thing about the twist also is, that there is a migration also. So, same filament does not stay always on the surface of the yarn or in the core of the yarn. So, based on the stress level that is exerted on each filament they keep migrating from surface to core and core to surface that is right.

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Twist for Deformation.....

- Why?
- Helical structure
- Overall uniformity

The slide features a hand-drawn red diagram of a helical structure with arrows indicating rotation. To the right of the diagram, the word "MIGRATION" is written in red and underlined. The NPTEL logo is visible in the bottom left corner.

So, they migrate; this is migration. And, what do this migration means this means uniformity. What it means is every filament would be either will also be in the core, will also be the surface, will also in the middle of the yarn and all of them will be assuming all such positions. If all the filaments at some given point of time assume all such position; so, if you measure the uniformity along the length of a yarn, every filament would have the similar kind of experience and that uniformity definitely is there and that is because of migration. Now, therefore, you would like to do twisting. So, it is one good step that you do. What is the next step, setting?

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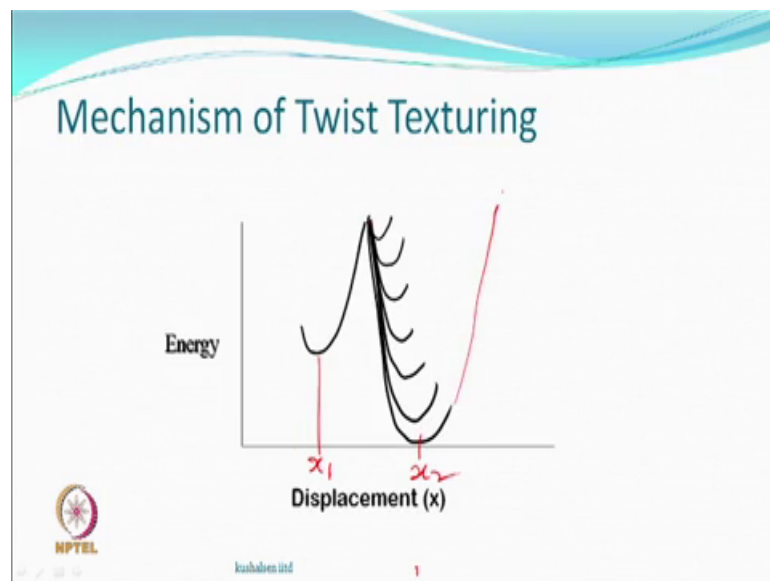
Role of setting

- To ensure that the new geometrical deformation is stable.

The slide features the NPTEL logo in the bottom left corner.

So, we are quite sure setting is important after all you do all the hard work by twisting and you do not want to be undone. Let us say if the thermoplastic material and you are heating, so release of energy may have been the mechanism of setting right. So, role of setting is very clear whether there is a thermal by release or by freezing in some other case or any other mechanism that you want to use, it is very clear you want to get the stable structure there is no problem on that.

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We just spend one's few minutes here and then let us see how far we go because you may have some other engagements in life. Now, this is the energy curve that you saw before, this is state x_1 where the multifilament yarn as it is was stable, it was not changing it's configuration was stable. And what have we do? We have done twisting; when you do twisting, the energy goes high ok, the energy goes high increases. Why? This is the strain energy, deformation energy you are giving; you are make doing an effort to twist it. So, all that effort is stored. So, I going at the higher energy.

So, if you leave that, the twisting forces leave them, it will become it automatically get untwisted true or not, like this paper bend opens because the stable state is x_1 . So, if you just do the twisting nothing will happen because it will come back to the same set. Now, you want to keep in the twisted configuration and then the energy because of crystallization or randomization will keep going down and you come to some state x_2 which energy level may be lower than the previous one. So, that is called optimization,

how much time, what temperatures you may like to work and you can bring down the energy level.

Now, also you said you will cool it also. So, what do you have textured yarn, it is set where actually there is no textured yarn. It is a multi filament twisted yarn which does not want to untwist, that is all; that is all. So, what happens; that means, the third step must be important also.

I am just going to some state and then come back. I do untwisting, now this particular material which is called the twisted yarn is very much stable in the x_2 configuration and now, you are untwisting the energy level again rises up ok. And if you leave this untwisting forces; detwisting forces what will happen, they will come back to the same position called x_2 and x_2 is a twisted yarn. So, what do you do with twisted yarn? So, we will leave it here for you to think that we have done twisting, setting and untwisting and actually I have not got a textured yarn.

So, some point to think we will stop here and we meet next time to see if you have some answer then you go further, all right.

Thank you.