

**Textured Yarn Technology**  
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**Lecture – 31**  
**Hi-bulk yarns**

So, we are continuing the same topic Hi-bulk yarn and we will try to wind it up today the hi-bulk is concerned.

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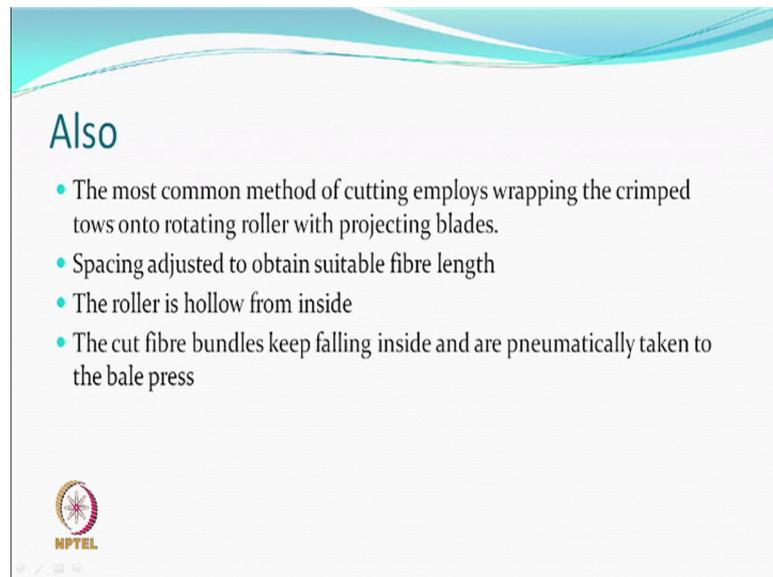
**A step back...**

- We have learnt that
  - Hi-bulk yarns can be produced by mixing two fibres with substantial differential shrinkage
  - Acrylic hi-bulk yarns are a commercial success
  - Amorphous orientation can be frozen in acrylic fibres enabling production of shrinkable fibres
- Principles of cutting filament tows into staple fibres of desired length

 NPTEL

So, what we have learnt is that the hi-bulk yarns can be produced by mixing two fibers which have substantial differential shrinkage. So, the difference between the two should be high close to 25 percent more. Acrylic hi-bulk yarns are commercial success from this principle and reason that the amorphous orientation can be frozen in acrylic fibers enabling the production of shrinkable fibers. Then we did learn how normally cutting of filaments is done particularly for producing staple fibers of desired staple length.

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**Also**

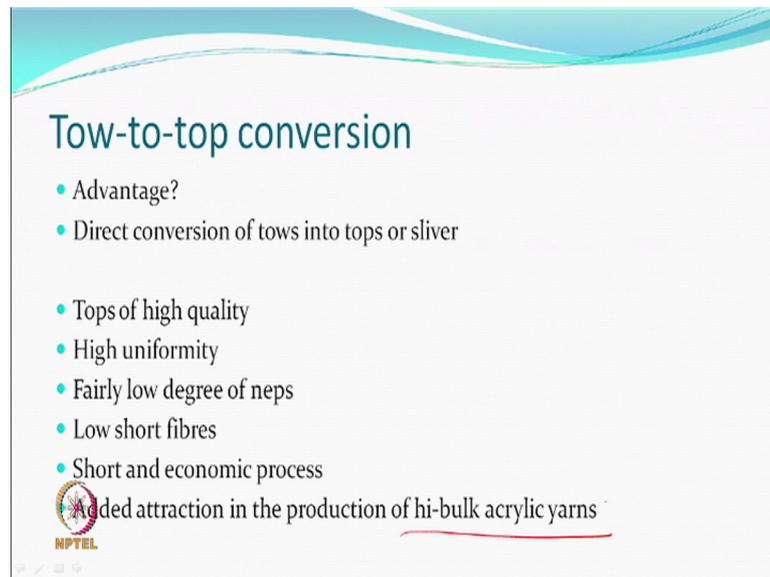
- The most common method of cutting employs wrapping the crimped tows onto rotating roller with projecting blades.
- Spacing adjusted to obtain suitable fibre length
- The roller is hollow from inside
- The cut fibre bundles keep falling inside and are pneumatically taken to the bale press

  
NPTEL

Also in this we understood that the common method of cutting to staple fiber is basically wrapping, the crimped tows onto a rotating roller with projecting knife or blades and the spacing can be adjusted to suit the suitable length based on whether you are a woolen system or a cordon system. The roller is hollow from inside, so the cut bundles keep falling inside which can be pneumatically taken to the bale press and that is how you can take the thing.

But then it was understood that a multi filament yarn which is already parallel we need not lose if possible the paralyzed fibers. So, that some of the steps could be avoided that is why the total top conversion was considered.

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**Tow-to-top conversion**

- Advantage?
- Direct conversion of tows into tops or sliver
  
- Tops of high quality
- High uniformity
- Fairly low degree of neps
- Low short fibres
- Short and economic process

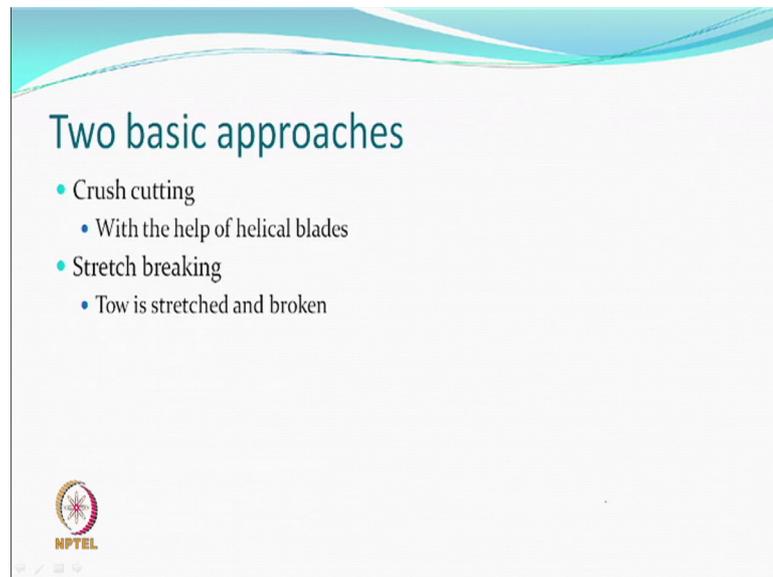
Added attraction in the production of hi-bulk acrylic yarns

**NPTEL**

So, the advantage if you think about it that is one of the direct conversion of tow into top or a sliver, in between we do not have to do much if we can do it, so the carding and other drafting processes could be avoided. It is expected that the tops of high quality will be there because very parallel a uniformity is likely to be high, low degree of naps because during carding although tailing ends and trailing and those kind of things may not be there.

Low short fibers because after this there is no breakage in during carding another process there can be breakage of fibers also you can get short fibers also and the process is economic and short. And the added attraction is that this process has become popular for production of hi-bulk acrylic yarns. Although you can make tow to top of polyester, you can make tow to top of polypropylene or whatever you want. But somehow acrylic fiber industry could find good use of this in fact, large number of them use this method.

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So, for this tow to top conversion they use two basic approaches one is crush cutting, like crush is the word because there is a blade which cuts the fiber, but before cutting; obviously, there is a crushing, so this term says crush and cut. So, even if it is a fine blade, but still it is there is the thickness involved, so the cutting is by crushing with the help of blades which are helical we will just see why they are helical. Other is the technique which is called stretch breaking that like you keep extending till breaks

So, the difference between the two is the one of the first one; obviously, the staple length can be more or less fixed, in the other case the break can take place in some zone and therefore, the lengths of each of fiber may not be same. But both the principles and machines based on these two are available and which people use.

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**Crush – cut converters**

- Basic elements
  - Inlet guide frame in which tows are spread and properly levelled ✓
  - Stretching zone (optional)
  - Cutting system
    - Drafting and drawing section to produce sliver or top
    - Crimping system for increasing cohesiveness
    - Coiling head for delivering slivers in to cans

 NPTEL

So, a crush and cut converters so called converters right. So, the whole machine may have many elements other than the cutting system. So, important thing is after guiding there are tows they are supposed to be spread see you have so, many tows are coming you spread them on a plate like so as if only single filament, but it may not be true they may be more than one, but it should it cannot be a rope kind of a thing you do not cut into rope, so you will flatten it out. So, on a plate you flat it down generally level it before cutting.

So, after that is done you may have a stretching zone is optional means that if you are doing a polyester tow you are not interested in producing a shrinkable, non shrinkable kind of environment, so you may not use it. So, normally what will happen is there you have a system, but you may not stretch like you do not give the differential speed. So you may not stretch, if there is a heating element you may not heat and so just passes, so that is one thing.

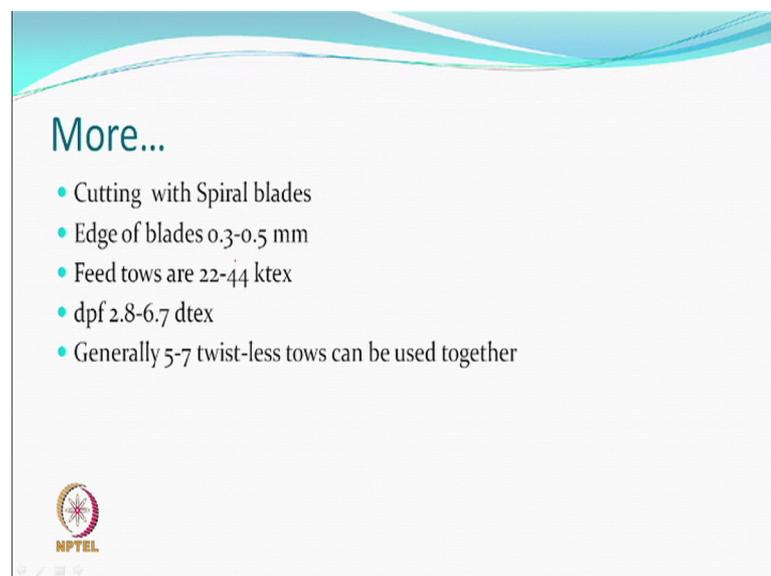
Then of course, there is a cutting system which is based on this principle of crash and cut. And after that once you think it is done then you have to collect it grafting drawing sections could be to produce slivers or top as they call in woolen industry, they may be further crimping for any process some cohesiveness of the thing.

Then coiling head and cans where you actually stored them. So, what would happen is that people who are doing this conversion may be the people who are making acrylic hi-

bulk yarns may not be. So, this may be happening somewhere else and then you have to supply the top, so you have a canned top. So, it has to be done nicely, so that when you are able to take it out up and down, so like we do.

So, it is possible that you may be transporting this also depending upon who has interest, somebody may have interest only in blending with let us say wool or polyester they may not be wanting to do any hi-bulk shrinkage. But this is how you will be supplying, so the cans or other packages which may be supplied so that you can take the sliver out and then do further mixing blending whenever you want.

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So, cutting is spiral blades. So, the blade at the moment whenever you seen in the normal cutting system you have a blade either as blade which is a flat blade arranged in overall the circumference of a roll, but here we are looking at a spiral blade. So, maybe one blade which is moving like this the edge of the blades are fine, but this kind of dimensions 0.3, 0.5 mm what it means is that will be some crushing will take place.

So, when crushing takes place maybe the edge is not as sharply cut, maybe it is slightly flat and cut this is possible, but this could be true with any kind of cutting systems. So, here the tows are not of those big deniers these are the tows which are finally, going to be converted to right kind of a slab or a top, so this will be lesser in that sense. The filament deniers could be anything, but generally three to six denier or something similar in this it x maybe there.

The way the tows are also carried and brought to the machine, it is expected maybe they are in the can or any kind of a pack that when you take them out there should be no twisting happening because then you would not be able to spread properly. So, there should not be any twisting they should remain a twist less material which would be able to be spread and then you can cut it.

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**Spiral (helical) blades....**

- Cutting roller has helical blade embedded in synthetic rubber
- Rubber surface gives gentle treatment and restricts slippage
- Avoids double cut
- Spiral blade ensures continuity of the web
- This is stationed above an anvil roller
- Cut tow is passed through shuffling and deboning sections before crimping and canning

The slide includes a hand-drawn diagram in red ink showing a cutting roller with a helical blade and an anvil roller below it. The word 'Anvil' is written in red next to the lower roller. The NPTEL logo is visible in the bottom left corner of the slide.

So, the helical or spiral blades, so the cutting roller has helical blades embedded in a synthetic rubber system. So, if this is the roll the blades may be appearing, but this whole thing is embedded. So, you have all over let us say a rubber which is, so the projection is very small. So, it is not like the blade of this is just jutting out because it can bend it is the support of the thing there is a matrix. The matrix is rubber which is also flexible then you press it can support.

But the rubber surface is supposed to give it to the rest of the thing where it is not being cut a gentle treatment and also restricts slippage because this tow is passing through some rollers and if because of some tension of course, a little bit or anything else if there is a slippage. Then you can have double cuts you just cut it again and the cut can come in so very short systems can we say. So, this does a frictional kind of a work as well.

The spiral blade ensures continuity of the web, if they were not spiral and if they were arranged like this they were also cut, so remember do you remember we saw another

roller in time. The blade could be arranged like this on the circumference and the rubber is here, if that happens then you will have the cut fibers just falling down.

So, if they fall down then you are actually again collecting as if you are doing your bale formation, but you are not interested in that. So, in that if you are not then this spiral one helps to maintain the continuity of the web. So, the web can actually pass like you have a sheet of the tows spread tows moving when you cut it would appear as the web is moving right.

So, it is not going to fall down because each one is overlapping with the other one. Then this kind of a roller; obviously, would have another roller which may be hard roller. So, that the cut takes place which may be called the anvil roll and so things will pass through this support it and the finally, the cut row or the tow will pass through the shuffling, d bonding because sections before crimping and caning.

So, shuffling etcetera or d bonding may be required because in case you have because of spin finish. So, the spin finish are three functions other than the lubrication static, but also cohesiveness if there is too much of cohesiveness maybe few fibers are always getting cut together well you would be happy as all the fibers are separated out alright. So, therefore, you may do some shuffling, so that if there is a loose bonding between the fiber they just get loose. So, that when you make a sliver out of it and do any kind of a twisting later it gives you a good result.

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So, the spread tow is moving in this direction and here you get a cut and the cut therefore, is going to be not perpendicular to the fibers based on this stable length. So, when the fiber etcetera are getting cut. So, this fiber if it is near; obviously, I have just drawn it further, but basically you can see if they were perpendicular then the cut would have been here, so you have some overlapping area.

Every fiber with the next one will have some overlapping area and so they will hold each other and the web will be formed and it will not just drop down which would be in a normal cut because the blade is as the blade is rooting the position part is shifting because this is continuously moving the roller is consciously moving right. So, this is the principle of the helical blades which; obviously, in the there is a rubber they are embedded in the rubber those thing.

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The slide is titled "Quality characteristics of tows" and lists several bullet points. A handwritten note in red ink says "Fused, undrawn". At the bottom left, there is a logo for "Example Pacific converter" and "NPTEL".

- Tow shape
  - Uniform continuous filaments
  - No loose ends
  - Even tension
- Tow cleanliness?
- Tow lubrication? Spin finish
- Tow packing?

*Fused, undrawn*

Example Pacific converter  
NPTEL

So, the input quality also people say well if you helical input quality is bad that the tows are overlapping with each other and they are not parallel and they are not spread properly, there the one is going in this way the other is going the other way, after cutting you will get whatever you get. So, it is important that tow shape whatever they mean is that continuous filament should be uniformly fed. So, this spreading also although looks simple, but it may not be simply or to spread it properly.

They may not be broken ends because invariably there may be broken ends that can cause either entanglements or push the things out and then you do not know what you are

doing. And tension should also be even if half the because sometimes you may be mixing more than one tow because the platform is big and if all of them are going in different tension levels, then you can expect something else happening somewhere else.

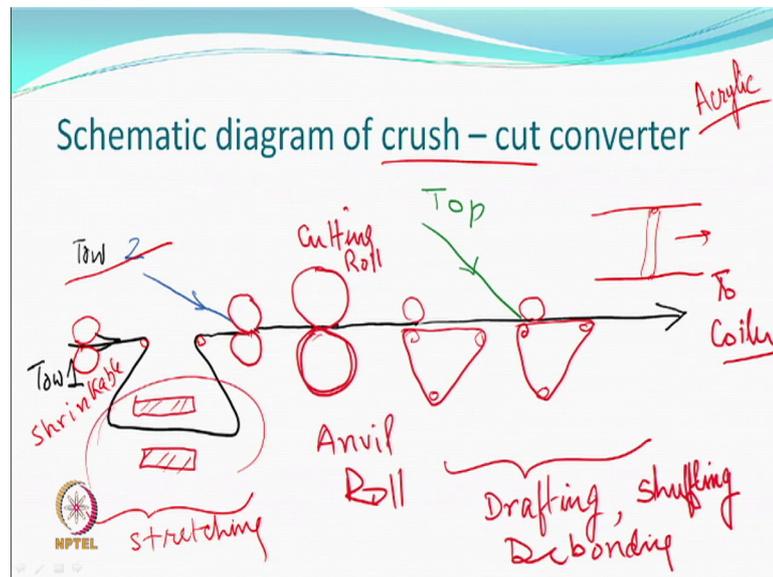
Cleanliness what it means normally is that there are no fused filaments, undrawn. So, melt spinning with a polyester for example, your POY, if whatever reason if the filaments are stuck somewhere in that situation you would have those things coming together it is not just the spin finish part of it or because of not the presenting of the thing in a right way you may not have fully drawn and so these scales also get cut and at high temperature they can diffuse or the dimensions may be different.

So, that is the final top if it has to be good this also is expected. See you may appreciate the normal staple fiber which is cut is cheaper than the filament fibers because people believe that even if there are variations they will get mixed and then you will get a uniform shape. In this case you are finally, getting the yarn without any other mixing and so if you have things are not so clean, then there can be problems.

The lubrication means that whatever spin finish was added it should if it is you; obviously, want the friction to be less so that it just moves on. But if you add too much then you may had cohesiveness is so much that the bundles are actually getting cut together and the bundles are being passed. If the bundles keep getting passed then the sliver is not going to be as good that is why they do d bonding is an important power portion which will do.

Tow packing means that when you take the tow out from whichever bundle that you have you should be able to take out without inserting any twist say even if somebody is done a coiled thing, then suddenly if you take it out automatically some twist gets inbuilt. So, you have to ensure that the tow as it is coming does not get any pre twist during the before cutting. One of the examples is a pacific converter from the US which makes this type of machine as well there are others also, creator also I believe make total top conversion converters.

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So, a line diagram may look like this, so you have a tow 1 this let us say in the case of acrylic because we are were interested in this, can pass through a zone which is stretching we are in crash cut. So, it is not stretching for breaking, it is stretching to produce finally, a material which is shrinkable, say you stretch there is heater, so there is a heating element.

So, between this and maybe another set of a roll you have stretch being given whatever level of stretch that you want to get. And to ensure that this stretch actually has those changes which were said that dipole; dipole interaction will take place it molecules get stretched after that degree and then you cool. So, this can therefore, this tow can be considered as the one which is likely to be shrinkable type.

So, one is that you take this tow cut it and send it, this shrink will fiber you mix it whenever you want to mix it. Other is that if I have the one who actually making hi bulky and say well I will take the other one also which is not been stretched. So, you can have a tow 2 which is not been stretched to have a stretch tow and tow of an unstretched type of a fiber also and then you can mix them here, in the ratio then what one makes four of this six of that whichever way you want right.

So, if you do that uniformly then you do the all the spreading etcetera at this portion and then you do a cutting. So, when you are cutting, so you actually have a mix tow coming where one of or some of the tows have been stretched and others have not been stretched.

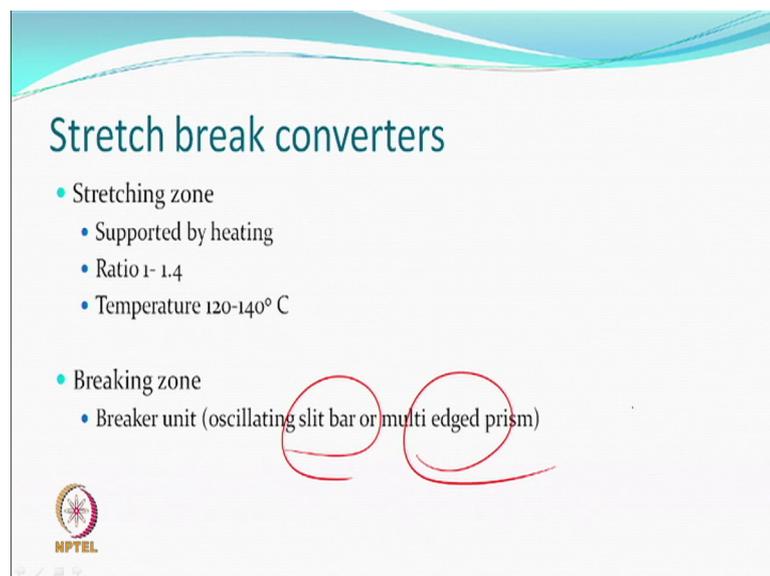
So, if this is situation then you go and cut, so your so called web that is coming has got mixture of them.

Then you do various types of apron, drafting systems could be attached which may have a shuffling system also d bonding you may have a little bit of vibrations also so that anything any fiber which as sticking to each other they may just get d bonded. There can be another way sometimes when a tow comes on the web comes you can if the web is passing in this direction.

And on the top if you have a roller which is oblique in the direction and it keeps rotating in this way this also can do a bit of a d bonding because it gives a shear, so that this kind thing happened. And after that you do whatever drafting you have satisfy the ticks and you can do certain things. So, you have an anvil roll and a cutting roll.

In case after this you have two types of things you may have may not have to and you want to blend with polyester. So, you can I have another top coming from somewhere else and it can get mixed and then you can get the drafting rolling and then mixing and you get sliver which have got other fibers also. So, these machines would allow all this to happen.

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**Stretch break converters**

- Stretching zone
  - Supported by heating
  - Ratio 1- 1.4
  - Temperature 120-140° C
- Breaking zone
  - Breaker unit (oscillating slit bar or multi edged prism)



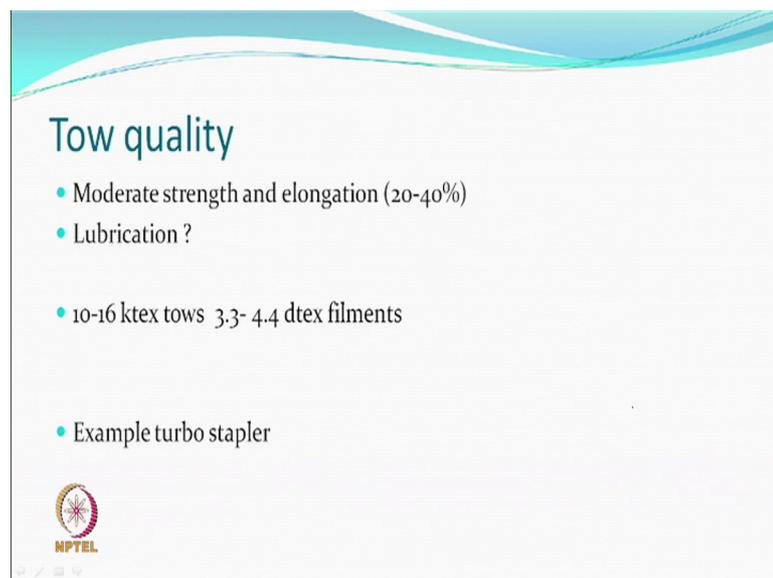
The slide features a title 'Stretch break converters' in blue. Below it are two main bullet points: 'Stretching zone' and 'Breaking zone'. The 'Stretching zone' has three sub-bullets: 'Supported by heating', 'Ratio 1- 1.4', and 'Temperature 120-140° C'. The 'Breaking zone' has one sub-bullet: 'Breaker unit (oscillating slit bar or multi edged prism)'. There are two red hand-drawn circles on the slide, one around the text 'oscillating slit bar' and another around 'multi edged prism'. In the bottom left corner, there is a logo for NPTEL.

The other one is a stretch break, the stretch break also have two zones one is a stretching zone which would help to make shrinkable fibers, the other would be braking zone where

actually fibers will be broken. So, stretching zone like in the previous case also may be something like this it would be something like that. Draw ratio given stretch ratio 1 to 1.4 depending upon changes, temperatures based on what fiber, but if it is the acrylic you are looking at 120 degrees to 140 degrees heating to help the orientation and of course, as it moves out let cooled.

And then is go to the braking zone, now normally when you just pull all, so many filaments can actually fail at different places. So, it could be so arbitrary that the lengths could be very different, but to ensure that it is not so wild distribution then you may help by some system while it is being stretched to break. So, then if you have this type of thing then it helps to break around the same point to get the staple length close to what you are interested in otherwise it will be there. So, this is the kind of arrangement that you may have.

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**Tow quality**

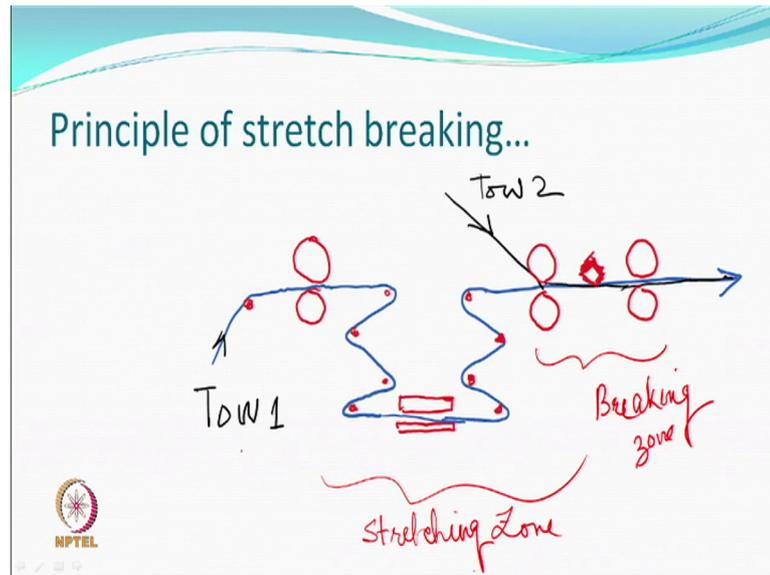
- Moderate strength and elongation (20-40%)
- Lubrication ?
- 10-16 ktex tows 3.3- 4.4 dtex filments
- Example turbo stapler

NPTEL

So, moderate strength elongation of a tow quality means that now you are going to be breaking it. So, if it is a very strong fiber then obviously, require a lot of stretch force and because of that and some non-uniformity you may have more variations. Lubrication again means the same thing that you have enough spin finish which it reduces the general friction which is good for slippage is because they are breaking the filaments are going to slip against each other also. So, that is one and the friction should be less.

This is slightly lower densities could be here compared to the previous one we are just cutting is an old here you have to break, so all the machines, the motors everything else will have to have that much power to do all this because this is not a small filament being broken. So, the example here one of the machine is called turbo stapler which does the stretch braking there are others also.

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So, this is another similar diagram, so tow 1 which is to be stretched is going passing through some heating system and stretching between these two rolls you can add another tow. So, this is the stretching zone and this is the braking zone. So, this is in case you are interested in shrinkable fiber, then you go through this otherwise you do not go through this.

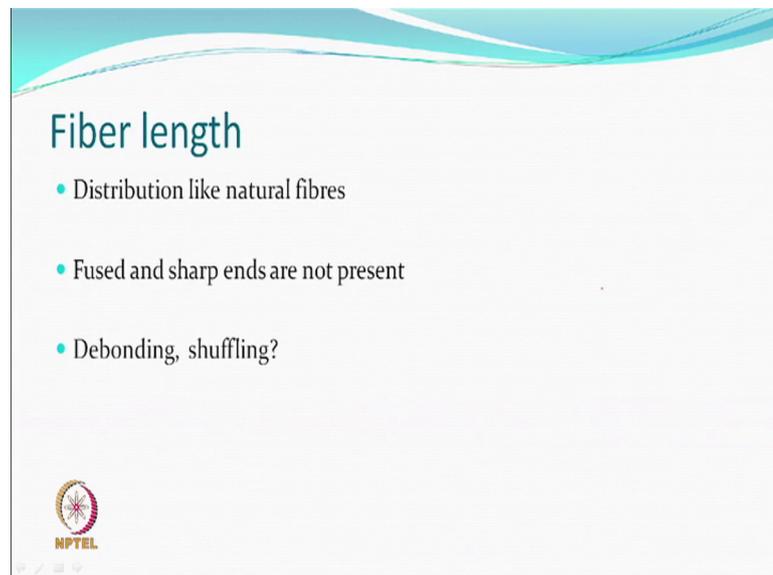
So, all these machines have safety features also if there are two plates in which between which the yarn or tow is moving in case the machine stoppage or something they overturn the face turned, so that it does not get heated. Because there is always heat which is there and so which will keep on radiating and can damage the fiber.

So, that is what these things will do particularly acrylic if you may like to know very sensitive to heat if everything is not happening right then you can get. So, these features will be there and every machine which could stop, it is not like a center which cannot nothing moves if center stops, then it stops the material that is there inside happens

whatever happens, but here it is not done because you are looking at a another good material.

So, the breaking zone is here if you want to add another tow which is a non shrinkable type which you also want to make it then you can add somewhere here and some equipment of this type a polygonal shaped wedge which is rotating and pressing it. So, when it is stretching and about to break based on this position this becomes like a weak spot or additional stretch, so it starts breaking around this point. So, this is different in that sense that now there is no cutting it is just breaking.

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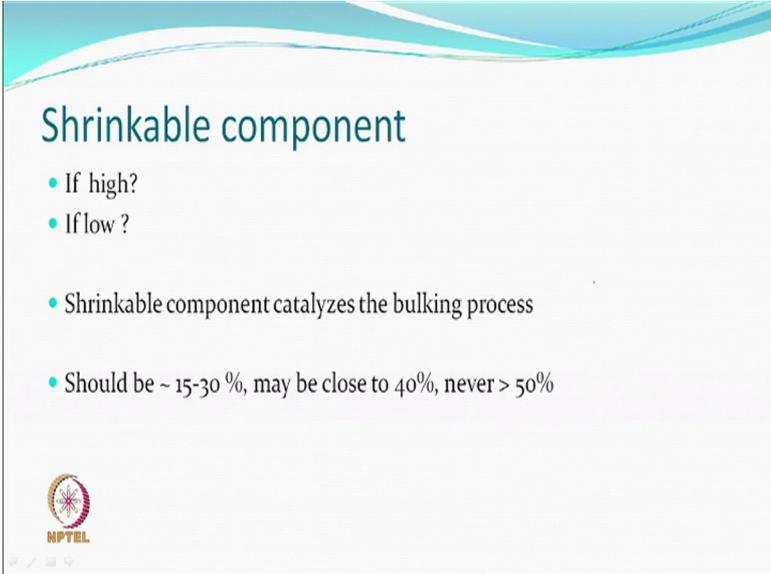


So, these type of manufacturers they say that our distribution of the staple length will be like natural fibers, the natural fibers are not of the same length like you want to blend it with them this is the one of the best ways it not otherwise you; you are blending anyway, but that is what it is. So, this will not be one staple length, so it will be a variation.

The fuse and sharp ends are not present here that is what is because when you cut there is first crushing and then cutting and during that time you may get edges the edges if; obviously, we will have some hindrance and final quality would have. In this case because the stretch breaking it taking place and so much of shear and movement between each fiber filament is going to take place you may not need additional shuffling d bonding arrangements you can directly take this to slab making process condensing and making flowers.

So, you have two different types of principles different companies making based on these principles arrangements to do the total top conversion. So finally, we come back to our hi-bulk acrylic to just revise part of it.

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The slide features a teal and white wavy header. The title 'Shrinkable component' is in a teal font. Below it are four bullet points in teal. At the bottom left is the NPTEL logo, which consists of a circular emblem with a star-like pattern and the text 'NPTEL' underneath.

### Shrinkable component

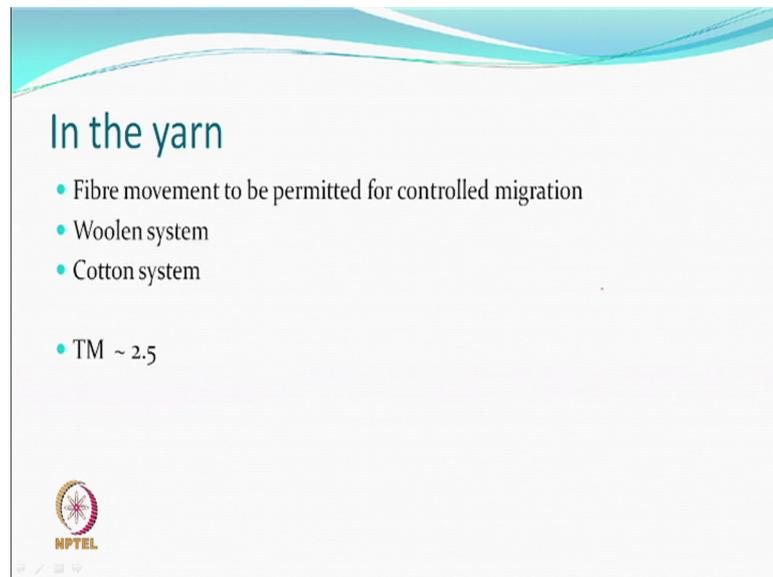
- If high?
- If low ?
- Shrinkable component catalyzes the bulking process
- Should be ~ 15-30 %, may be close to 40%, never > 50%

NPTEL

So, we would be able to produce a shrinkable component and non shrinkable component if the shrinking of bulk component is very high let us say 80 percent shrinkable component in the mixture. So, what will it do? It will only shrink the whole material. If it is too low let us say 15 percent 10 percent it will shrink, but it will not be able to hold the rest of the fibers in place.

So, the shrinkable component basically is trying to get the non shrinkable component are bend and make loops. So, it should not be less than 15 to 30 percent could be close to 40 percent, but never more than 50 percent because that does not help bulk is coming from the non shrinkable component and therefore, it cannot have larger percentage.

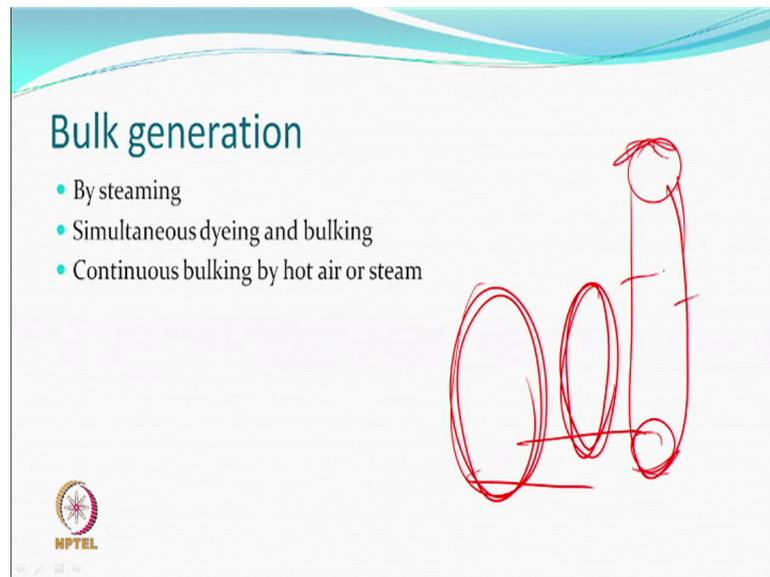
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In the yarn when the yarn has already been made it looks like a normal yarn there is no bulk. So, if it is supplied to a knitter it is supplied as it is alright unless and until somebody wants to make a change. So, this could be made on a woolen or a cotton system, but the twist should not be very high because there is going to be some amount of migration which will take place.

The shrinkable component finally, are likely to come to the core and if it is a very tight yarn, then this motion will not be there despite everything else you may still not be able to do because what you are interested is this shrinks goes to the core, the other one buckles should be able to slip out and get the bulk perfect. So, twist levels have to be relatively you know less, but it cannot be very less otherwise everything will be, so somewhere around 2.5, 2.7 tm could be the one which is used.

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So, finally, the bulk has to be generated in the yarn and for generating the bulk you have to heat, one can use dry heat, but steam could be one of things if independently the yarn in the form of hanks or whatever are to be first bulked, then you separately you can do the steaming in chambers and elga (Refer Time: 35:21) bulk and you see the immediate change in the dimensions.

But people use simultaneous dyeing in bulking you know because dyeing of acrylic fibers is generally done around 90 degrees plus not boil just less than boil above 80-85 degrees where the dye actually rushes, below 80 degrees the dye is almost not going into the fiber there is a very very less diffusion. So, it is a very small window under which an acrylic fiber can be dyed, but that is 85 to 95 96 degrees.

During this portion if during this period if the yarn which are un bulked they not only get dyed, but they will get bulked also simultaneously bulking and dyeing take place. The only thing that will happen is if this was the kind of a hank before dyeing is going to probably become in length it will shrink. So, the margins have to be given in that sense because one thing which is very important is in case during this bulking process any tension, twist, compression is there on the yarn then this will be almost like a permanent change.

The yarn should be very; very free when this bulking takes place, I suppose on the top or at the bottom there is any tension. For example, if somebody says you know I am going

to put the keep the yarn in the stretch condition like this and do the bulking, this portion will be very different from this for very different. So, when you open the you will see there are portions are flat the portion all that happens, but bulking has happened very different ways. It is like crepe fabrics production when you produce the crepe there should not be any non uniformity while the crepe is being developed otherwise that remains permanent very difficult to remove. So, this dyeing anyway is very delicate way of dyeing the acrylic yarns, so that one is done.

So, continuous bulking with hot air or steam means that there is a conveyor belt which is moving through steamer or through a hot air oven and on one side there is a coiler or many coiler which are just putting the loops of the yarn to be bulked as it goes through the conveyor from the other side it gets bulk during the portion less tension and on this side you unwind the coils and make packages right this is the way the bulk can be generated in this hi-bulk yarn. So, it is a very popular method and very useful.

So, one thing which I talked about the tension part is that if somebody says well re dyeing you know in India we do a lot of re-dyeing of garments or anything to that if you tell somebody is a local that this is my acrylic thing from lemon I want to make it deep read re-dye, if the fellow understands the thing we will say I am not doing itself do it yourself. Because, any non-uniformity that comes the structure is very delicate the changes take place and it is not the shade that is there the shape may be different at the end of the time alright we stop here and this topic I think we have covered.