Evaluation of Textile Materials
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Lecture – 14
Evaluation of Cotton Fibre Maturity

Hello everyone so now we will discuss one characteristic of fibre or textile material which is not that important for most of the fibres. Like synthetic fibres and most of the majority of fibres is not that important but it is extremely important for cotton. So the characteristic is the maturity.

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So it is primarily associated with the cotton fibre testing, for manmade fibre there is no reason there is no reason for measuring the maturity. But for even for other natural fibre, we do not measure the maturity. But for cotton fibre it is extremely important. It has many adverse effects, if the fibre is immature. It directly or indirectly affects the characteristics and quality of product.

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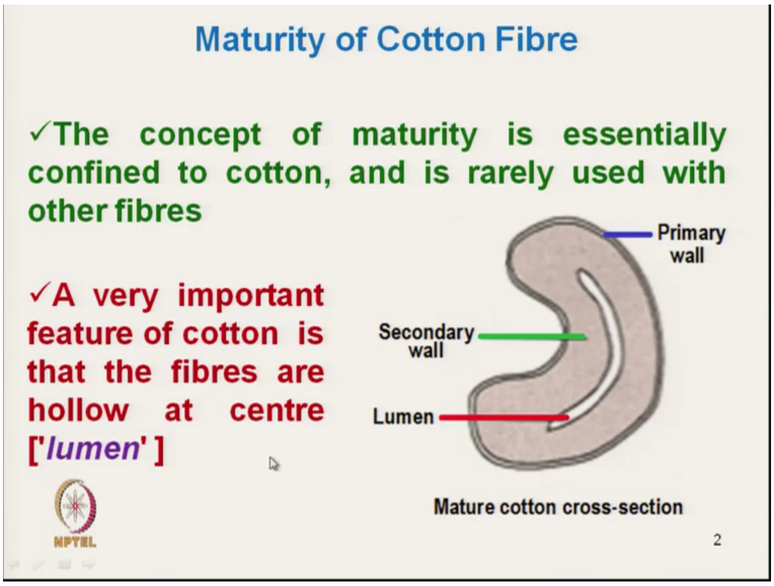

Now the concept of maturity is essentially confined to cotton, and rarely used with other fibres. So for other natural fibres like jute, Lenin, we normally do not talk about maturity and this is the cross section of cotton fibre and it has got three distinct layer. Outer layer is known as the primary one which actually keeps the total perimeter of the fibre. And after the primary layer it is called the secondary wall, which is the actually consist of the majority of bulk in the cross section and then the lumen which is hollow in nature.

So, this is the unique nature of cotton fibre where this centre it is inside is the hollow ok. Now the maturity depends on the; that thickness of the secondary one, as compared to the thickness of the lumen and when the fibre grows and it is getting matured, so that secondary wall thickness increases it is a very important feature of cotton is that the fibres are hollow in lumen. So that is the important feature here.

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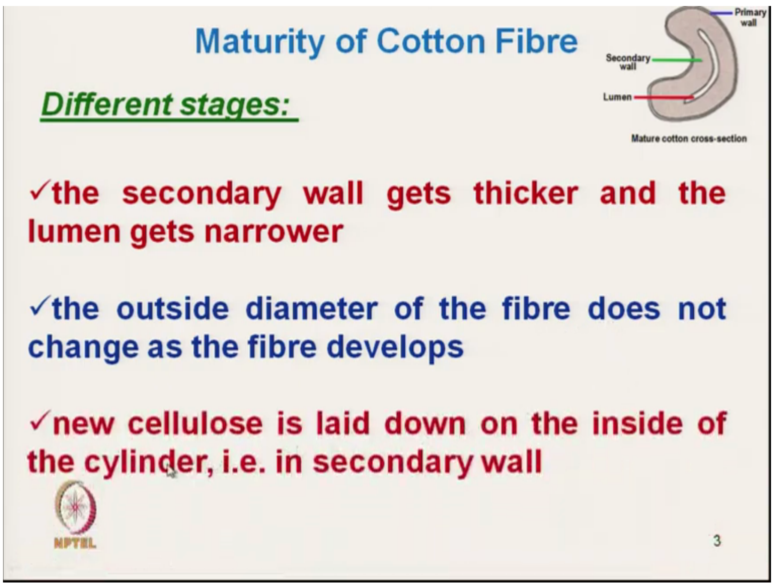

So, now at different stage let us see how the cotton fibre grows. The secondary wall gradually it becomes thicker and lumen gets narrower. Initially the lumen was wider as the lumen dip was wider but as the secondary wall gets matured it gets thicker and the lumen gradually it becomes narrower the outside diameter of the fibre does not change that is very important. That is the perimeter of the fibre in the primary wall it does not change during the whole actual development that it is it remains almost constant.

So, only the change is that this; if it is getting matured that means the secondary wall gets thicker and the lumen gets smaller ok. The outside diameter of the fibre does not change. The new cellulose is laid down on the inside of the cylinder that is secondary wall the new cellulose is laid down, ok.

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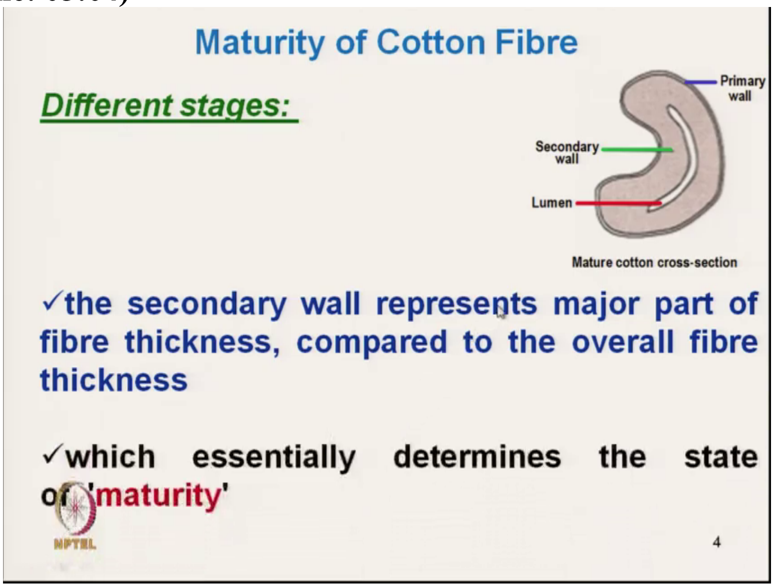

The secondary wall represents the major part of the fibre compared to the overall fibre thickness ok that is the major part. That is actually shows the maturity which essentially determines the state of maturity. So the secondary wall, growth of secondary wall is not proper then the fibre will be immature.

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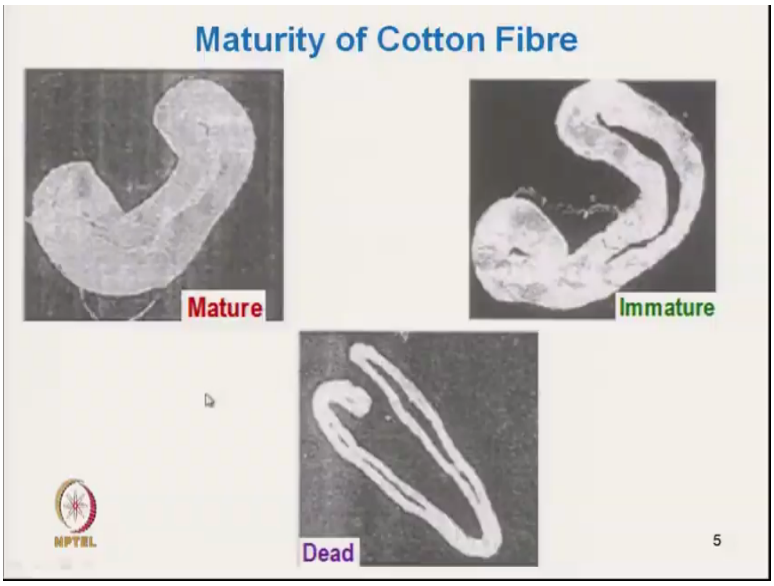

If the growth is very good then it will be matured. Now this is the picture which shows the three different types of maturity. So this was this matured fibre where secondary wall thickness is very thick. And the lumen is almost fenced it is very thin lumen. This is fully matured fibre. And this one is immature fibre where secondary wall thickness is very small and proper lumen is there.

And now this one is dead fibre where secondary wall thickness is very small, it is not there only lumen is there. Now this fibre this immature or dead fibre they have problem of actually of neps formation this fibre there have they have flexural rigidity is very small very low that is why they easily get bent and they get entangled and form the neps ok.

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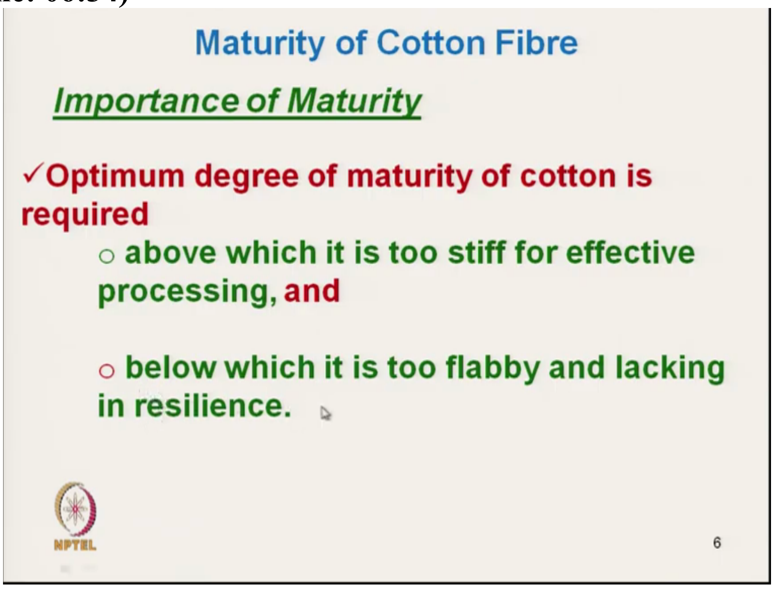

So, let us see what are the importances of maturity? The optimum degree of maturity of cotton is required ok that if it is not matured, maturity is not there above which, if it is a fully matured, so optimum maturity is required, but if the fibre is the fibre's maturity is more than the required maturity then the fibre may be too stiff for effective processing. So it is, that is also not required; if it is a highly matured fibre, that a very thick secondary wall that will result the thicker stiffer fibre and the spinability will be poor. Spinability sometimes it will be poor and below maturity low maturity, below which it is too flabby and lack of resilience.

So that means it is resilience means after bending it should come back ok. But if it is the maturity is very low that means if it is bent it will not come back. So it will it will 10d to form the napes.

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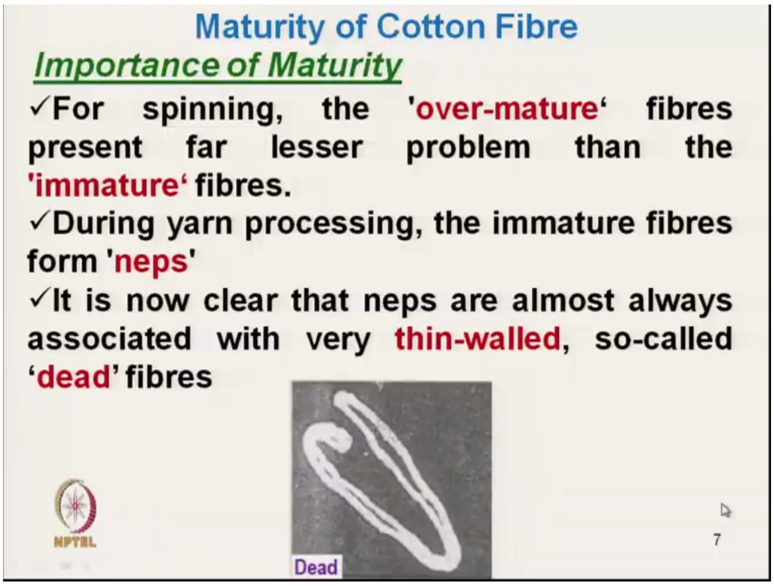

So, over maturity although it is a problem but not tact problem, its problem is less ok but spinning the over mature fibres present far lesser problem than the immature fibres. Only problem with the over matured fibres is the stiffness, that can be handled by applying different level of twist or we can handle or we can use for say coarser count or but handling the immature fibre is very difficult. The tool is that; it can break easily or it is a neps formation and it is a proof that most of the napes generation, napes formation or cotton fibre is basically due to the immature fibre.

So, during yarn processing, the immature fibre of neps and it is now clear that neps are almost always associated with thin walled and so called dead fibres. So, if we can actually test the neps you can take the neps and test the maturity these are the dead fibres. These are the dead fibres it actually get it is bale it is rolled very easily during the process in cadding process in blow room process, this can get rolled and form neps.

And this neps create problem everywhere. This neps we cannot remove most of them if it goes beyond the carding, this neps cannot be removed this will remain in the; up to the yarn stage, ok, because this is very small neps ok.

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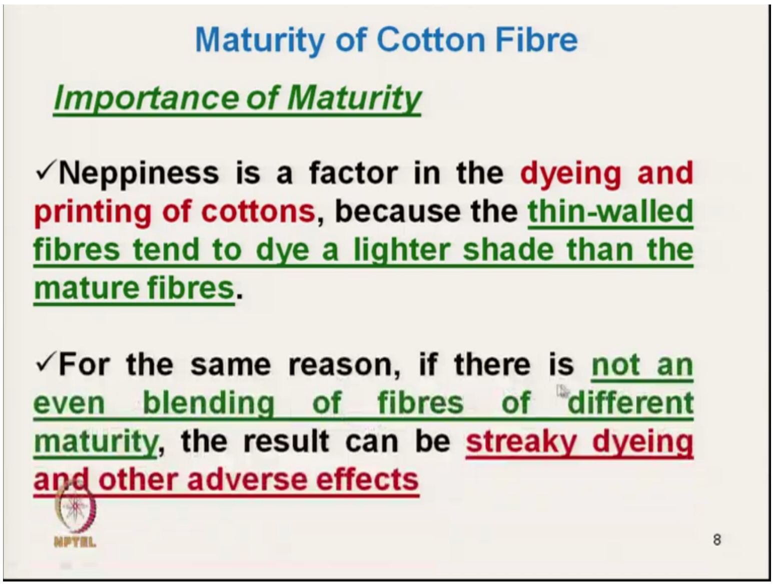

So, importance of maturity, the neppiness is a factor in the dyeing and printing of cottons so cotton in cotton fabric dye and printing the neppiness creates problem that means that the nape the neps which consist of the immature fibre does not get dyed does not absorb dye ok, that is because the thin walled fibre 10d to dye in lighter shade than mature fibres. Because here the dye aspect is less because of the absence of secondary wall ok and that is why it gets lighter shade. And it ultimately the appearance of fabric gets adversely affected.

For the same result if there is not an even blending of fibres of different maturity, the result can be streaky dyeing and other adverse effects ok. So, that blending has to be at all there is some immature fibre the blending has be proper otherwise there will be sticky dye.

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So, we can see this is the direct fabric and the neps are clearly visible. And this neps this they are not actually absorbing dye they are not and dyed in the lighter shade and create problem. And even this annealing dye due to immature fibre also. And this we cannot; if we; if it mean other methods like different types of dyeing method chemical method we cannot remove this. Wherever the immature fibres are there we cannot do anything. It will actually decide the annealing dye.

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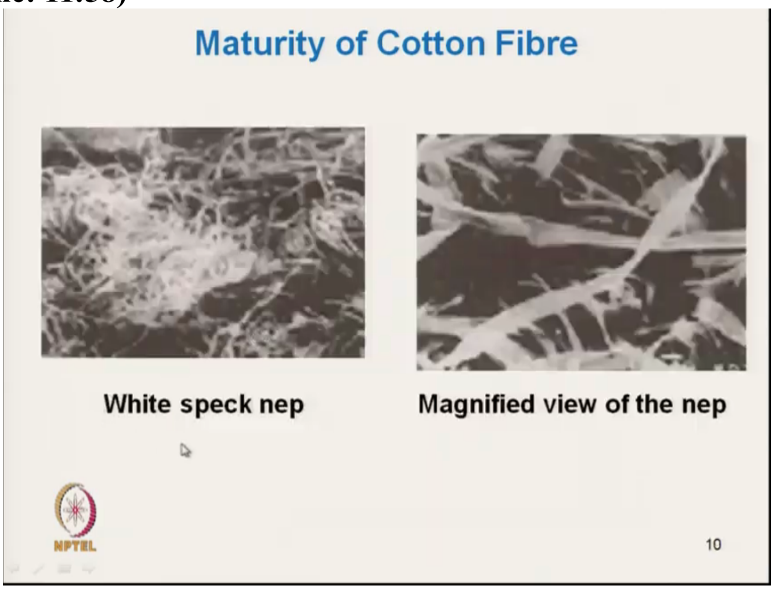

Like white speck nep, this is because of the neps ok, and this will be actually visible like white speck ok. These are all immature fibre. Now after knowing the importance of maturity, now we will discuss the various parameter how to express the maturity.

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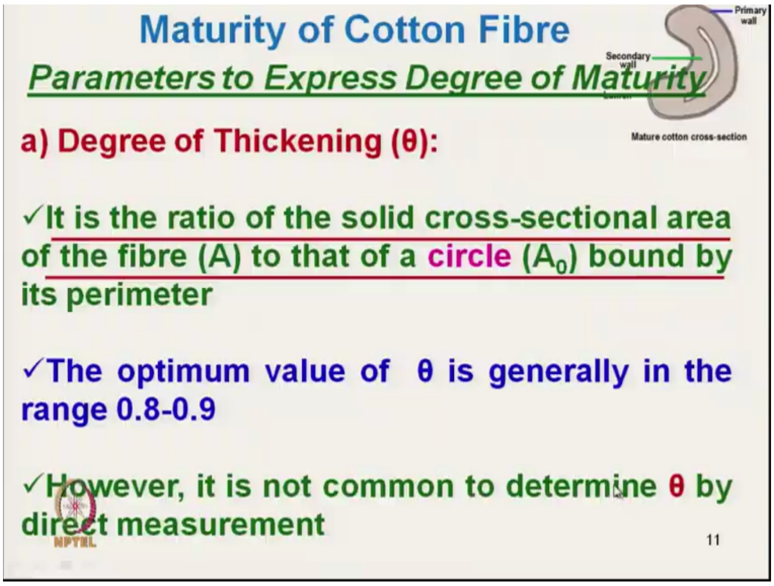

So, parameters to express the degree of maturity are one is the degree of thickening. It is expressed in terms of theta. Degree of thickening is that it is a ratio it is a ratio of the solid cross sectional area of fibre the actual cross sectional area of fibre, this is the actual cross sectional area of the fibre divided by the circle with the same perimeter. So, if we can unfold this one unfold this one and make it circular, that cross section and with the actual cross section, the ratio is the degree of thickening.

So, actual cross section to the; so degree thickening will be less than one. That means if this fibre is perfectly circular, suppose this is the bean shaped, if it is perfectly circular, then the degree of thickening will be one ok. So cotton fibre is normally not circular so degree of thickening we can get. The optimum value of degree of thickening is generally .8 to .9 that is the highly matured fibre is the .8 to .9.

So, because it will form little bit in bean shape it will never be circular. However this method of measurement is not common. Because cross section; measurement of cross section and measurement of perimeter is very difficult but nowadays we can measure we can measure by using different photo electric technique, photographic technique that we will discuss. In AFIS technique we can measure directly, the degree of thickening but for other methods we cannot measure.

We cannot do that it is not. But indirectly we can measure the thickness the degree of thickening by some empirical equation, so that we will discuss here.

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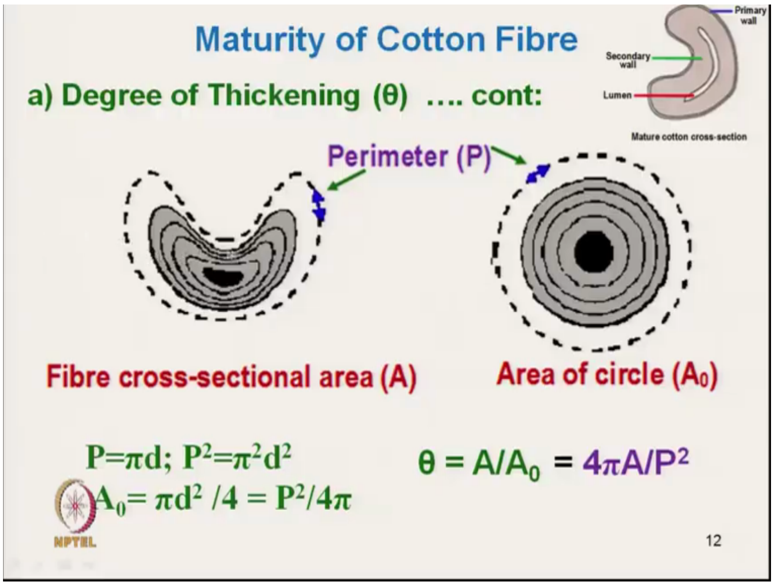

So, as we have discussed here, this is the actual fibre, actual fibre of cross sectional area of A. Now this perimeter; this is the perimeter P here this perimeter we have formed converted into circle whose area is A0 ok. The perimeter P is Pi d here it is the Pi d so from there we can calculate A0. A0 is the perimeter squared divided by 4Pi ok. Now theta is A this cross sectional area divided by this cross sectional area that is it is the A / P 2 / 4 Pi ultimately 4 Pi A / P 2, perimeter squared.

This is the degree of thickening so if we want to get the degree of thickening, we have to measure two parameters one is the area of cross section of fibre actual area of cross section of fibre and the perimeter of fibre. The both; measurement of both the parameters are very difficult. In normal case we cannot measure, but we will discuss in other methods some methods we can measure this degree of thickness.

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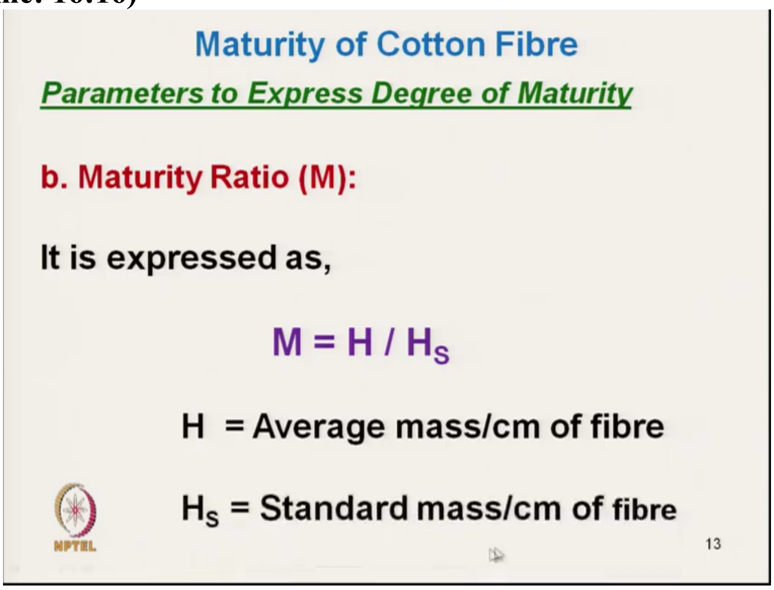

Next parameter is that maturity ratio, it is expressed in terms of M where maturity ratio is the nothing but the ratio between the average mass per centimetre of fibre to the standard mass per centimetre of fibre. So, that for a particular fibre we have we know the standard for particular variety particular cotton fibre we know the targeted standard mass per unit length and if we measure the mass per unit length of the fibre say in micronaire or some other method. So, the ratio is known as the maturity ratio ok.

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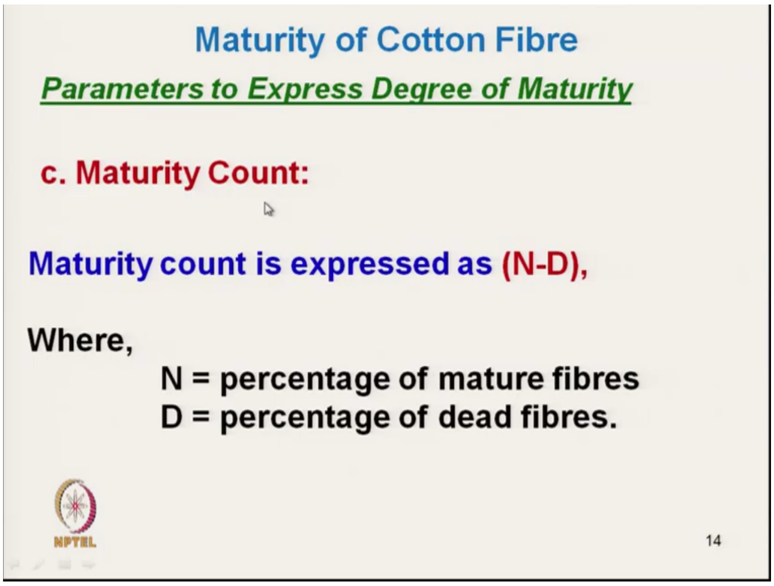

Next is the maturity count, what is that? It is the difference between the percent of matured fibre to percent of dead fibre. So, there are typically three different types of fibres are there. One is the mature fibre second one is the dead fibre another parameter type of fibre which is in between which is the semi matured fibre ok. And in this measurement, maturity count we take two parameters one is the matured fibre N and dead fibre ok. And this maturity count we can use for various calculations that we will discuss.

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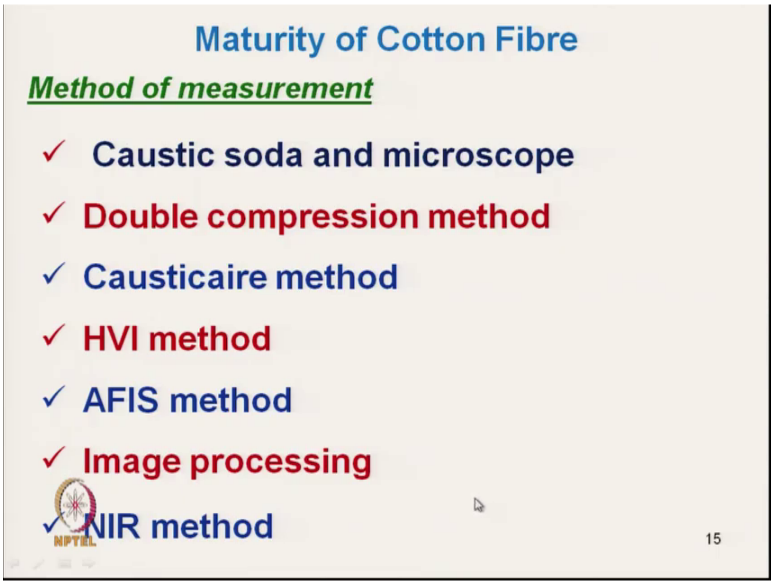

Now coming to the methods of measurement there are different methods of measurement, they are first is caustic soda and microscopic method. We will discuss one by one. Second one is double compression method. Then causticaire method, here also we use caustic soda but the technique is little bit different. Fourth one is high volume instrument method. Then in by AFIS method we measure the maturity by degree of thickening as I mention that we will discuss. Then image processing method and NIR near infra red method. These are the methods of measurement of fibre fineness.

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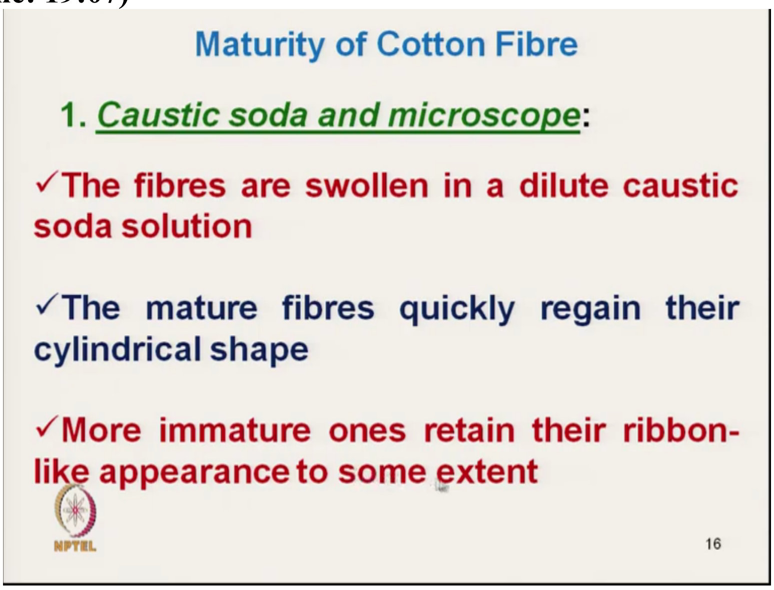

First let us discuss caustic soda method and microscope so for caustic soda method we need microscope. So, fibres are swollen in dilute caustic soda solution. So, we actually use the dilute caustic soda solution and matured fibres they will quickly regain quickly absorb the soda solution and will become cylindrical in shape. More immature ones ok retain their ribbon like so immature fibre will not change their shape they will retain their immature that is their ribbon like shape ok.

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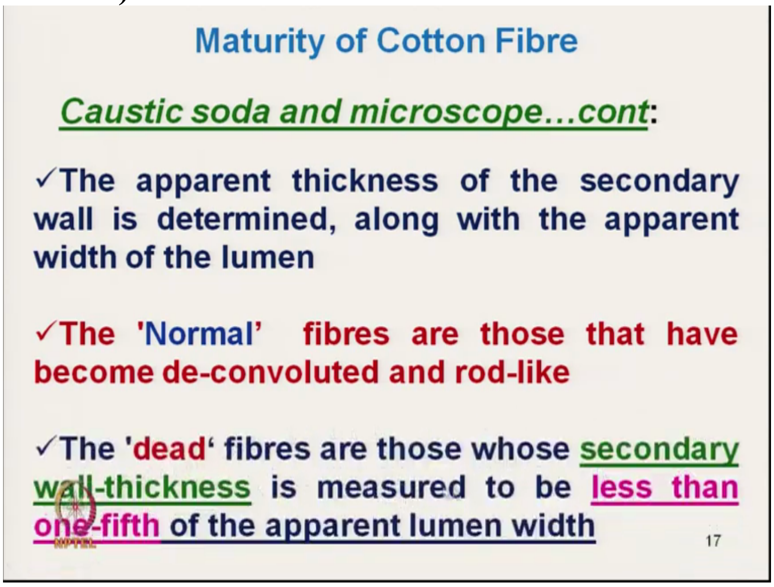

The apparent thickness of secondary wall is determined, so from the microscope we can clearly make we can clearly see the apparent thickness ok.

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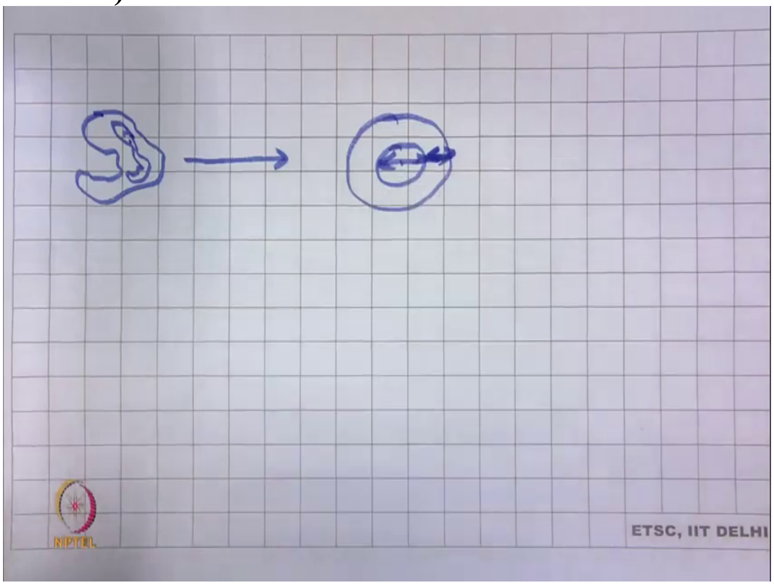

So, if we see this is the lumen and after that when it is; this is the lumen it has become circular. Now this thickness we can measure. This is the secondary the thickness of secondary wall and as compared to the thickness of the lumen ok. And allow with the apparent width of the lumen, that we can measure here under the microscope it is a; it will give clear picture. And the normal fibres are those that have become de convoluted and rod like that we can see clearly it has been de convoluted and rod like.

And the dead fibres are those whose secondary wall thickness is measured to be less than one fifth of the apparent lumen width so that we can measure because and normal fibre we can see clearly make out that it will be rod like and there will be many fibres there will be fibre which are not rod like but those cannot be termed as the dead fibre. And depending on the thickness of the secondary one, if the secondary one thickness is less than the one fifth of the apparent lumen width so then we can tell it; call it as the dead fibres.

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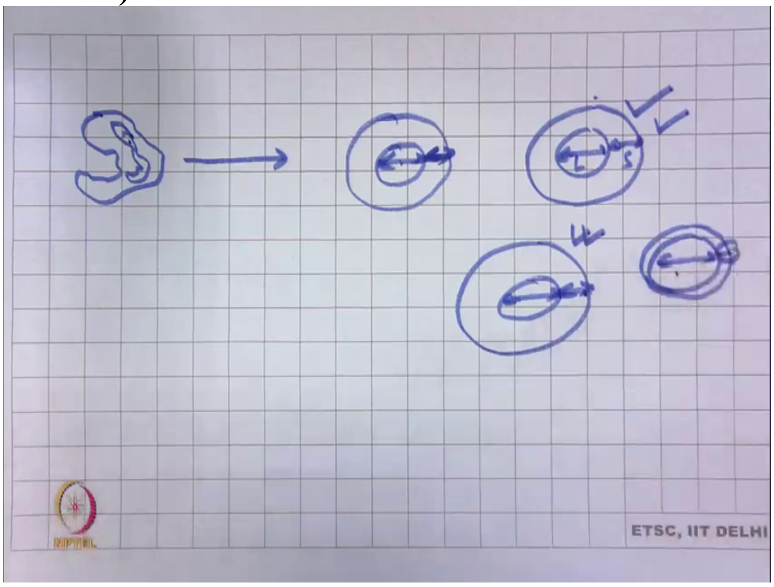

Now again there will be another fibre here this is the width of the lumen and this is the width of the secondary thickness. So, this is L this is S. Now this S, here this will; cannot tell it is a dead fibre this is not dead fibre this is also not dead fibre because this secondary wall thickness is also less than the thickness of the lumen. But it is not less than one fifth of the lumen. But here if you see this is the actually it is the one fifth less than one fifth of the lumen.

That we can directly measure and from there we can tell which one is dead or which one is; that partially matured. Fully matured it is a normal fibre in and this dead fibre we can target it as D, ok.

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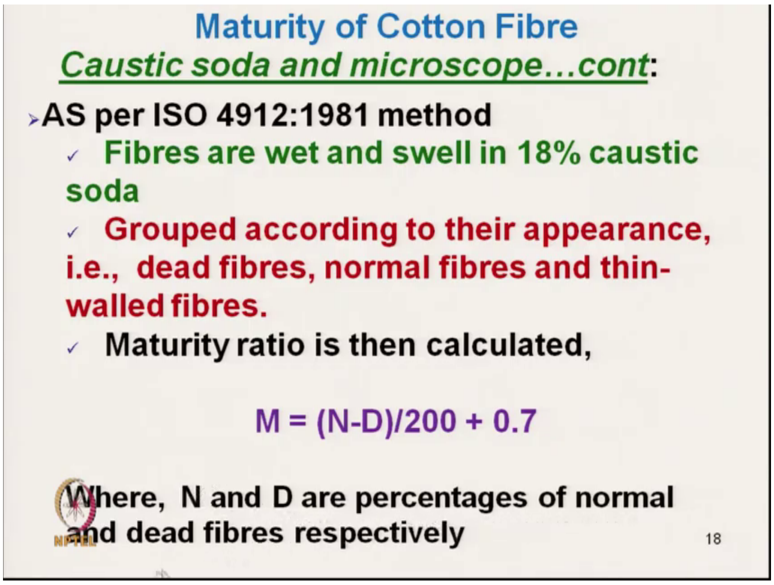

As per ISO method fibres are wet and swollen in 18% of caustic soda. So, that is the standard method ISO 4912, ok. Grouped according to their appearance, ok so there are three fibres that we are using, dead fibres, normal fibres and thin walled fibres, ok which is dead fibre, dead fibre normal fibre and thin walled fibre. Thin walled fibres are in between dead and normal fibres ok.

So then after knowing after dividing this three into three parts we can calculate the maturity ratio what is that maturity ratio? This is maturity ratio is expressed in terms of M which is calculated by N - D / 200 + .7 that is the maturity ratio.

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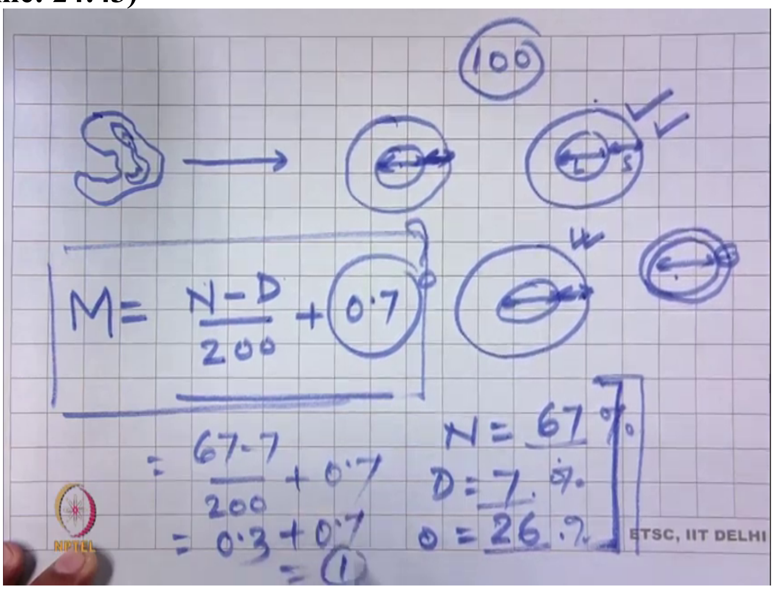

And this formula is typically maturity ratio is the N -D / 200 + 0.7. And the question comes how this 0.7 has come. Now it has been observed experimentally based on large number of data large number of reading that most of the fibres most of the normal fibres the quantity is that if you test 100 fibre the normal fibre if you see the normal fibre is typically it is the 67 normal fibre ok. And dead fibre 7 and in between fibre other fibres will be 100 - 74 it will be 26. If this is the combination, the fibres are said to be normal fibre.

And the data this equation is said this is the empirical equation. Empirical equation is said in that in such a fashion that for this type of ratio 67, 7 and 26 because one normal fibre which is producing normal yarn most of the cases they found that this is the typical value this is percent ok for 100%, this is 67, 7 and this N and D they are in they are also in percent.
Now try to see if we put this value here, if we replace this value 67 - 7 / 200 + 0.7. So, it will become 0.3, 60/200 it will become 0.3 + 0.7 so it will be 1.
So, maturity ratio of these combination has become 1 ok, that is why the 7 this value 7 comes it is arbitrary it is not that it has no logic. There is no scientific logic but as most of the fibres normal fibres, it has been observed with that proportion that is why it has come in becomes maturity ratio becomes 1, ok. Here, so it is so where N and D are percentage of normal and dead fibre respectively and one get normally confused here that N and D will be always try to get confused with.

N is the actual number of fibre it is not the actual number of fibre it is the percentage fibre percentage of N and suppose we test take 150 fibre or 1000 fibre N we have to convert it to in terms of percent ok percent N and D.
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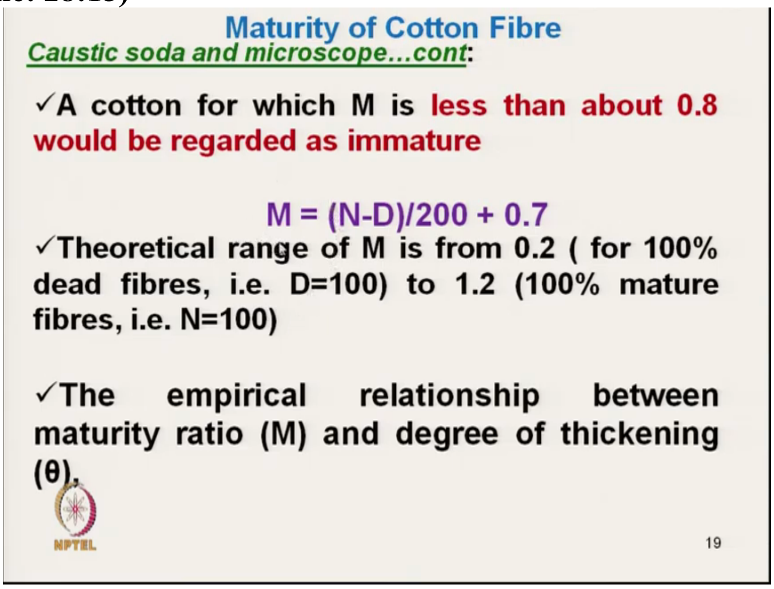

So, a cotton is M is less than .8 will be regarded as immature cotton ok and N – D. Now can we calculate what will be the maximum value of the maturity ratio? Maximum value of maturity ratio theoretically it is; when all the fibres are matured, 100% of fibres are matured that means N will be 100 then what will be the D value? D value will be 0 ok, so D is 0 so what is the value then, it is a 100/ 200 it will be .5, so .5 + .7 it is 1.2.

That means when all the fibres are matured 100% matured in that case maturity ratio is be will be 1.2. Now in the extreme case all theoretically all the fibres are immature dead fibre, 100% dead fibre. In that case N will be 0 D will be 100 so this portion will be - .5. So, - .5 + .7 that will be .2. That means the range of maturity ratio is from .2 to 1.2, ok so that is the range. The theoretical range of M is from .2 for 100% dead fibres, that is D = 100 to 1.2 that is 100% matured fibres where N is 100 ok.

And the empirical relationship; so if we know the this calculation of maturity ratio is very simple, using the microscopic technique using the caustic soda technique we can calculate the measure the maturity ratio and from there using the empirical relationship we can calculate the maturity that is the degree of thickening ok. This is based on large number of data we can get the this one 0.577 * M this is purely empirical equation.

So, if it is asked that if the degree of thickening is related with the maturity ratio of this equated 0.577 * M what is the range of theta value will be .1158 to .6927 because M is range is .2 to 1.2. if we use if we replace M by .2 we will get .1154 and then if we replace the M value with 1.2 we will get .6924 so this is the range ok.

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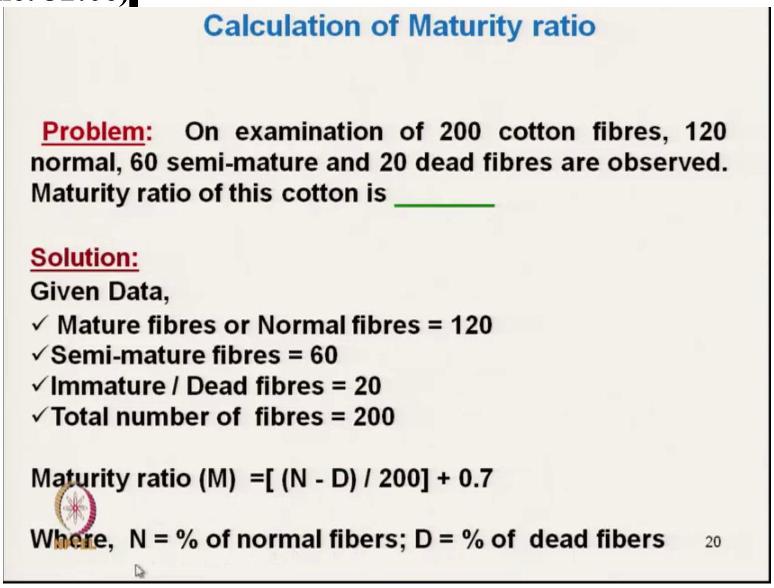

Now let us see one numerical. On examining 200 cotton fibres so we are experimenting on 200 cotton fibre 120 cotton fibre are normal fibre 60 fibres are semi matured fibre, 20 dead fibre, 120 normal fibre 60 semi matured fibre and 20 dead fibre. So, what is the maturity ratio, what we have to do we have to first convert this value in percent. We cannot directly take, students normally make mistake they use direct value of 120 and 20.

Then it will give wrong result so this is we have to convert into percentage. So, mature fibres or normal fibres this is 120 so if we convert into and semi matured is 60 and dead fibre is 20 so if we convert into percentage so total number of fibres 20 so this is the equation relationship and percentage normal fibre and percentage dead fibre we have to calculate.

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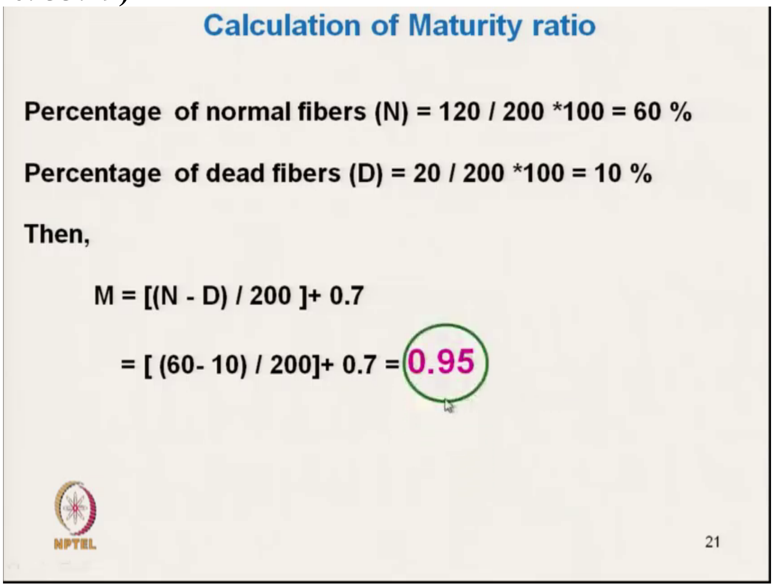

So, percent normal fibre N is 60, percent dead fibre is 10. Then if we use this equation it will become .95 that is the 60 - 10 / 200 if we use 120 and 20 then the; we will get wrong result. So, this .95 is the actual maturity ratio, ok. And from there if we know these things we can calculate the degree of thickening by last earlier formula, ok.

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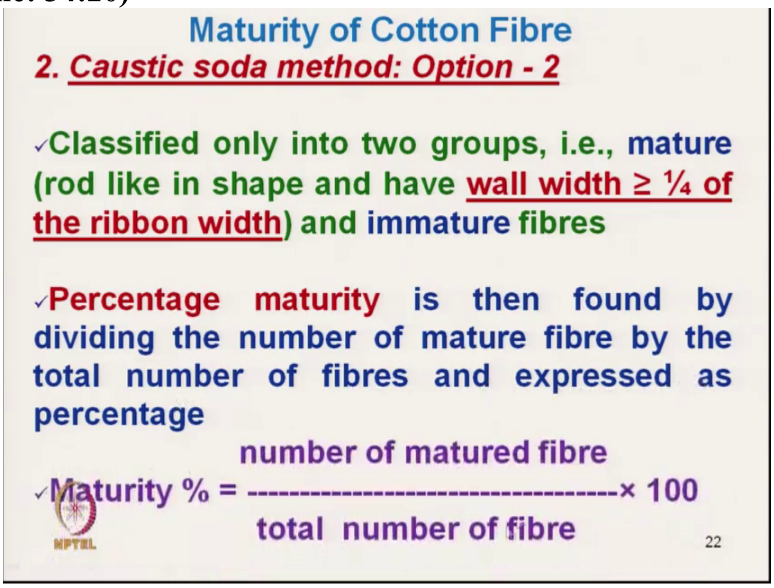

Next is the caustic soda method with option 2, second caustic soda method. Classified only in two groups of matured fibre rod like fibre and with a width of actually a wall width greater than equal to one fourth of ribbon width that is the way and immature fibre so, it is a simple method. In industry we normally use this method. This is quick method what we have to do we have to know the matured fibre and immature fibre.

So, matured fibre is a rod like structure with wall width which is more than equal to one fourth of the ribbon width. Total width, if we know the total width, and with the total width we just we do not; we are not concerned about the measurement of the lumen. Here total width and the width of the wall so that way if it is more than one fourth then it is mature and rest all other fibres we can term it as immature fibres.

And percent mature maturity can be calculated by dividing the number of matured fibres by the total number of fibres. So, this is the maturity percent we can calculate here, so total number of matured fibre which is having wall thick width more than one fourth of total width ribbon width divided by total number of fibre.

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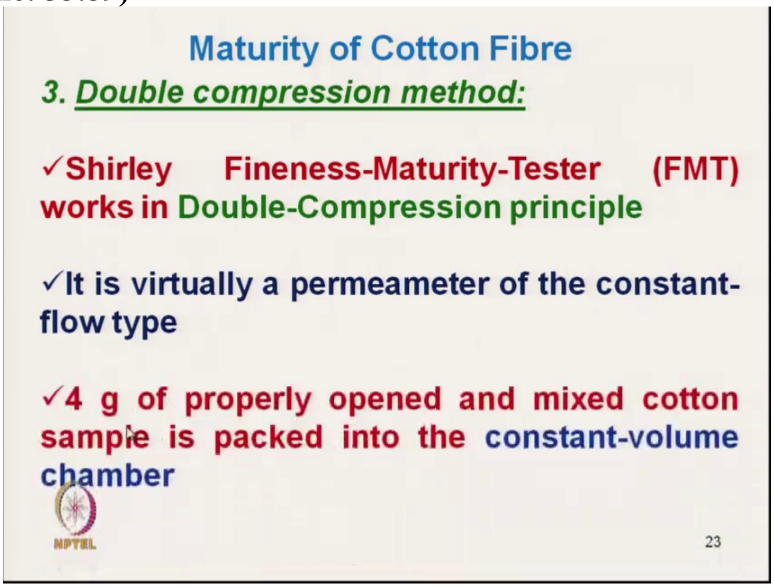

Next is that it is a double compression method. In double compression method, it is a; this principle is used in Shirley FMT fibre fineness maturity tester, ok. In that case the same fineness instrument is used where we measure the fibre fineness by air flow ok. But in normal fineness method what we do we measure the air flow by single compression. We compress the fibre mass in a particular volume ok.

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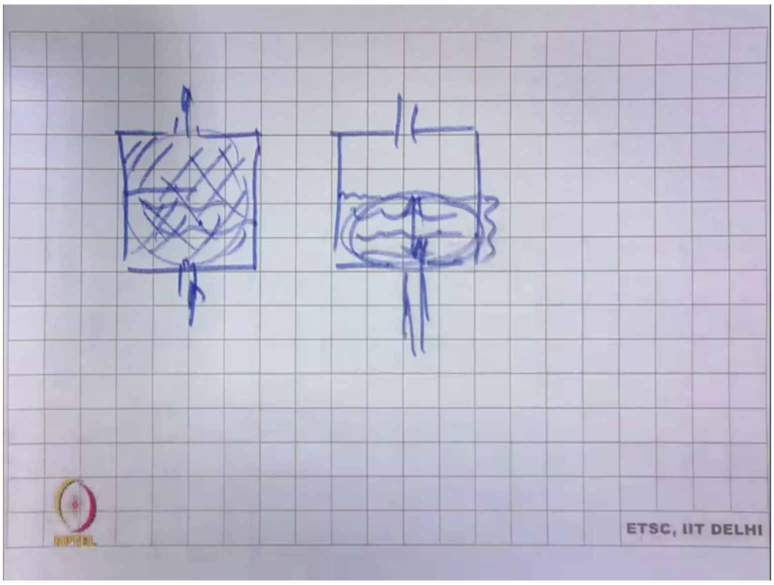

So, in normal measurement as we have discussed earlier so we take the fibre and we compress it up to a certain volume ok and then we measure the air flow and in this method for same fibre same quantity of fibre, we compress half of the volume this is one volume and this is same fibre with the half of the volume ok. So, it is a double, it is compactness has become double. But here what happens here the fibre surface area specific surface area is same. Both the fibre both the fibre because quantity of fibre is same specific surface area will be same.

But due to the maturity, maturity of the fibre this fibre ultimately will give the different flow rate ok. So, double compression principle is there. It is virtually a parameter of constant flow type ok. So, constant flow type measurement that we have seen in the fibre fineness measurement, 4 gram of properly opened and mixed cotton sample is packed into the constant volume as we have done in fibre fineness tester.

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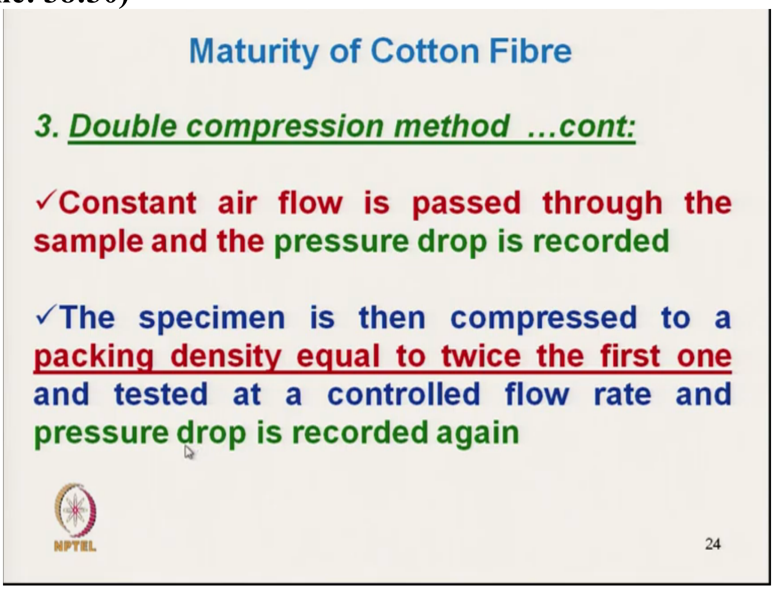

Then constant air flow is passed through the sample and the pressure drop is recorded. So, we measure the constant air flow ok. Constant air flow and pressure drop is recorded. Now the specimen is then compressed to a packing density equal to twice the first one that means we are compressing into half of the bulk ok. And the test at the control flow rate same flow rate and the pressure drop is recorded again. We record the pressure drop again ok.

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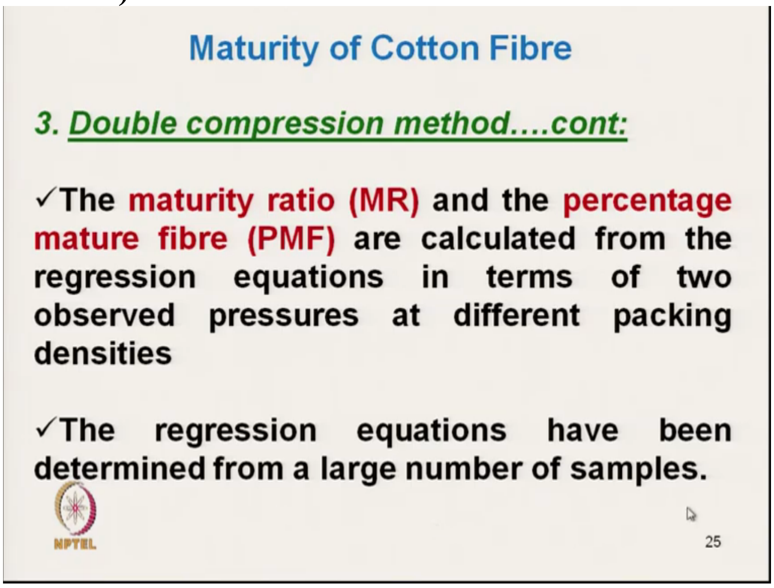

And using the; this, the maturity ratio and percent matured fibre are calculated from the regression equations because in this instrument, regressions equations are already formed ok. From there we can calculate the maturity ratio if we know the pressure drop or a particular flow rate had two different that compression level and using the regression equation we can calculate the maturity ratio and percent matured fibre.

The regression equations have been determined from large number of samples. It has already been formed regression equation. Only thing it keeps the pressure drop value and automatically it will convert into maturity ratio and percent maturity matured fibre. This process is known as double compression technique, ok. Third is the Causticaire method; Causticaire method it is a combination of caustic soda method plus airflow method.

Now as we know that the fibre when absorbed caustic soda absorbed it gets swelled. And swelling depends on the degree of maturity. If the maturity is a dead fibre are there this fibre will not get swelled ok. Now also swelling means the diameter increases. If the diameter increases the air flow rate will increase so the rate of changing airflow after caustic soda treatment will give idea, about the maturity, immature fibre.

Suppose consider there are, the fibres are 100% dead fibre. 100% dead fibre so what we are doing we are actually measuring the air flow before caustic soda treatment. We are getting one particular flow rate so F1 and after treatment, of dead fibre that means it will not swell so the specific surface area will almost remain same and so that it will be almost same value.

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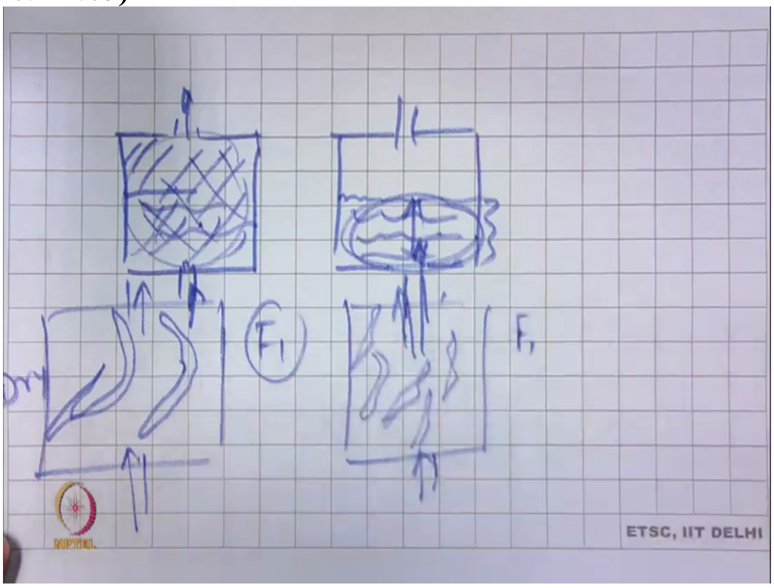

Let us see so these are the dead fibre and the dry fibre we are flowing the air ok and it is giving one flow rate F1. It is a dry fibre and another is after caustic soda treatment it has not been swollen, so it will give another airflow which will be close to F1. Almost equal or close to little bit air so this ratio F1/F1 ideally I am telling this will become here it is one. But on the other hand a normal fibre matured fibre ok.

And after it is getting swollen it will have different air flow rate because it is actually increases the diameter, ok increases the diameter so it is becoming larger. So in that case the fibre airflow through the fibre will be much higher. So that as it is the diameter is more the airflow will be higher or treated fibre than the dry fibre so the ratio will give the idea about the degree of maturity.

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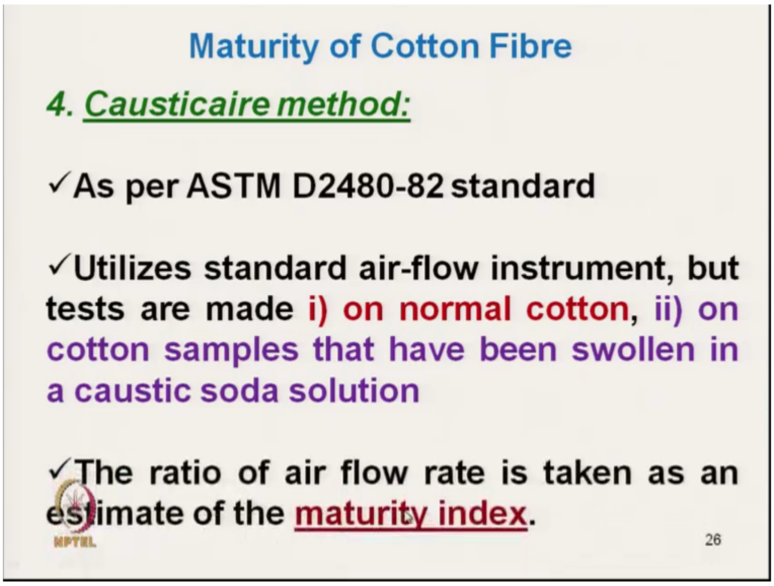

So, it is a; the causticaire method is as per ASTM D2480-82 standard utilizes standard air flow instrument , but tests are made on normal cotton on cotton samples that have been swollen on caustic soda ok, so normal cotton means without treatment another is by treating with the caustic soda. And the ratio of air flow rate is taken as an estimate of the maturity index ok.

So, for 100% dead fibre, maturity index will be one There is no change but for normal fibre the maturity index will be very high because it is total it is diameter has change so air flow rate has increased the ratio of airflow will be changed. This method is known as causticaire method which is as per ASTM standard.

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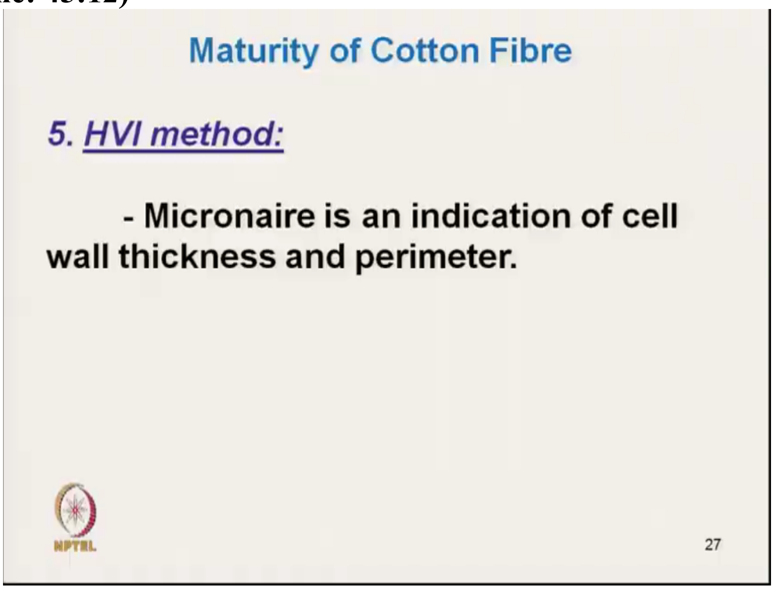

Next is used in HVI method. High value instrument, in high value instrument normally it is the physically is a micronaire value is major ok micronaire is an indicator of cell wall thickening and air perimeter. So micronaire in HVI we use normal airflow method directly measure the micronaire. Now AFIS method, so HVI and AFIS we will discuss separately in next class but here let us see the how maturity is measured in AFIS. AFIS works in the photoelectric principle. It actually capture the total image of the fibre

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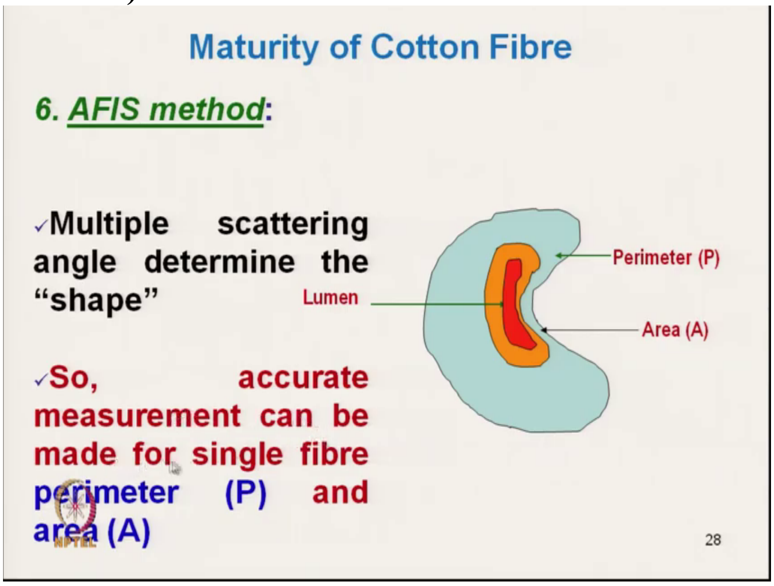

Now this is the fibre here and it is the lumen here. Now this one is the perimeter and here it measures the degree of thickness. What is degree of thickening? Degree of thickening is the ratio of actual cross section to the cross section of circle of same perimeter ok. Now for that as we have seen we need to measure first it is cross sectional area of this fibre and then perimeter.

So in AFIS here the principle is the multiple scattering angles determine the shape. So, at multiple scattering of a difference direction it keeps the actual shape of the fibre. So, when fibre flows in air it captures the image by multiple scattering and it gives the actual shape of the fibre cross sectional fibre. And from there we can calculate the area cross sectional area. So, this from this perimeter and also we can measure the length of the perimeter.

Because here it captures individual data at A, each and every point of the perimeter from there it calculates the shape and actual area. So, accurate measurement can be made for single fibre perimeter and area. So, if we capture the data we can capture accurately the perimeter and area.

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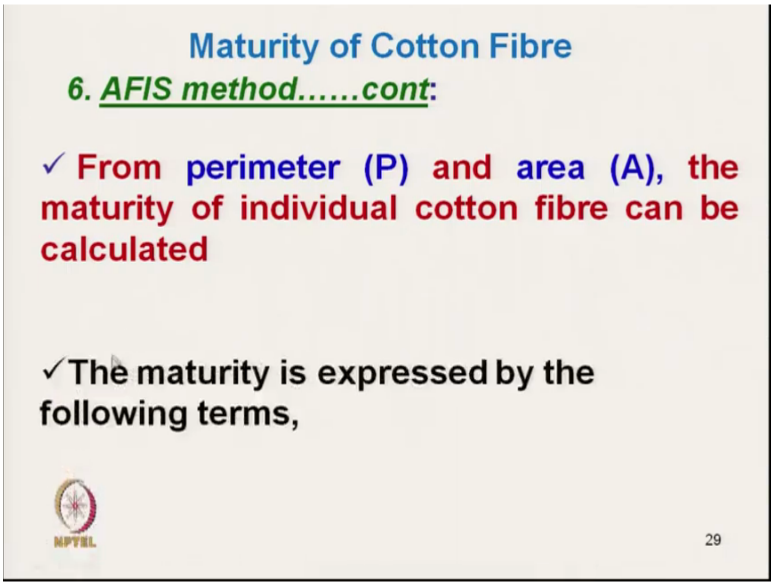

From perimeter and area as we have seen earlier we can calculate the degree of thickening. So, maturity here then is expressed by the following terms, so one can ask question so in AFIS if we get the perimeter and area how can we express the maturity, degree maturity? Here we can express the degree of maturity by the term degree of thickening which is 4Pi A by perimeter squared that we have to seen ok.

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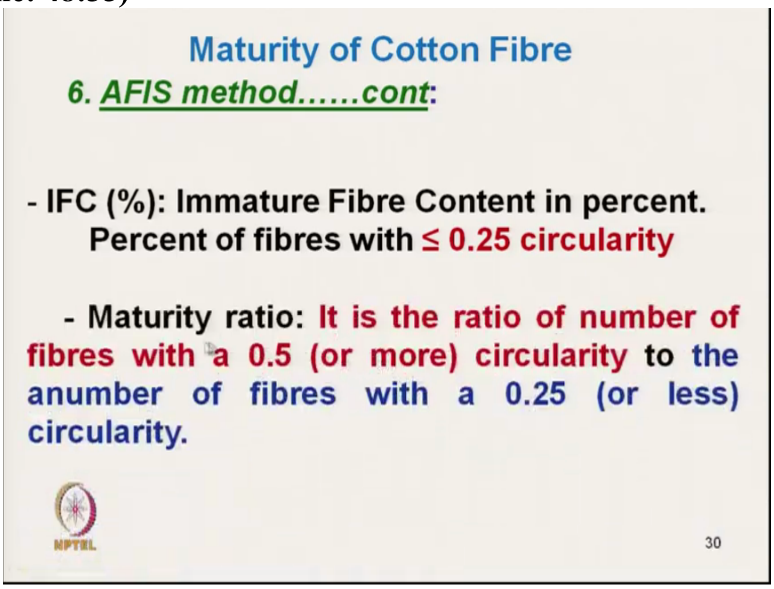

And percent immature percent fibre content in immature fibre content we can also measure percent of fibres with less than .25 circularity. So, as we have data we can calculate the individual data of the perimeter. We can calculate the circularity also. So, less than .25 circularity means called the immature fibre. So, we can calculate the percent of fibre. And maturity ratio, it is the ratio of number of fibres with .5 or more circularity to the fibre of .25, ok to a number of fibre with a .25 or less circularity.

So, that will if we calculate the ratio of circularity then we can calculate the maturity ratio also. But this maturity ratio is entirely different from maturity ratio which we have seen which we have calculated earlier, ok. This is total entirely different here they have in AFIS they have expressed maturity ratio by this by the way of circularity. Because in AFIS the advantage is that they can in that instrument it the actual shape can be predicted ok.

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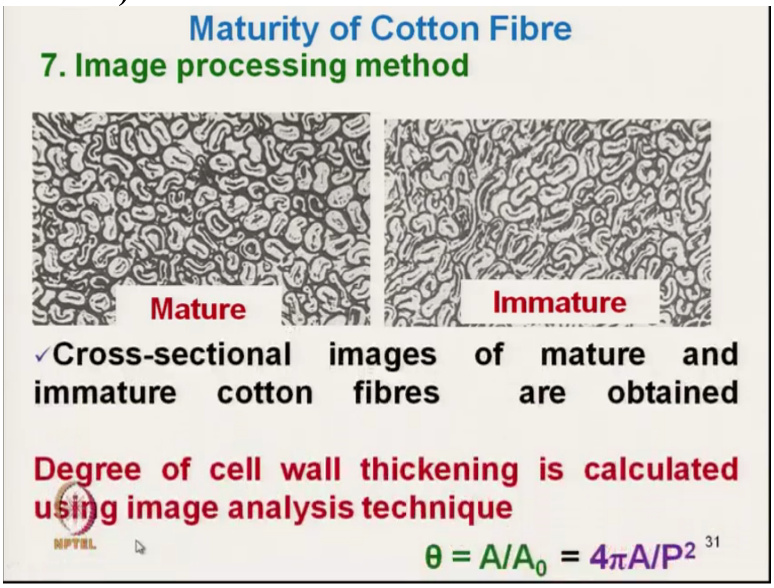

And by image processing technique also one can calculate the maturity. Here it is a individual fibre here image can be grabed and the shape of the fibre can be captured and if we know the shape of the fibre so the cross sectional image of the matured fibre and the immature fibre ok cotton fibre are obtained. And when the actual shape of the fibre can be obtained ,in that case we can calculate the degree of thickening.

Degree of cell wall thickening is calculated using; so it is very clear, you see the degree of cell wall thickening we can calculate we can measure where we use the photographic principle. That means well we use the light principle where we can measure the cross sectional shape of the fibre. So, from there someone say that it mean measure the cross section of fibre which parameter we can measure so that is the degree of cell wall theory ok.

Now another question can be by measuring diameter of fibre or by measuring the cell wall thickness can we measure the degree of thickening. It is not here we have to measure the; because degree of thickening and degree of cell wall thickness people get confused ok. From there we cannot measure. But if we can measure the perimeter and actual area then only we can measure the degree of thickening.

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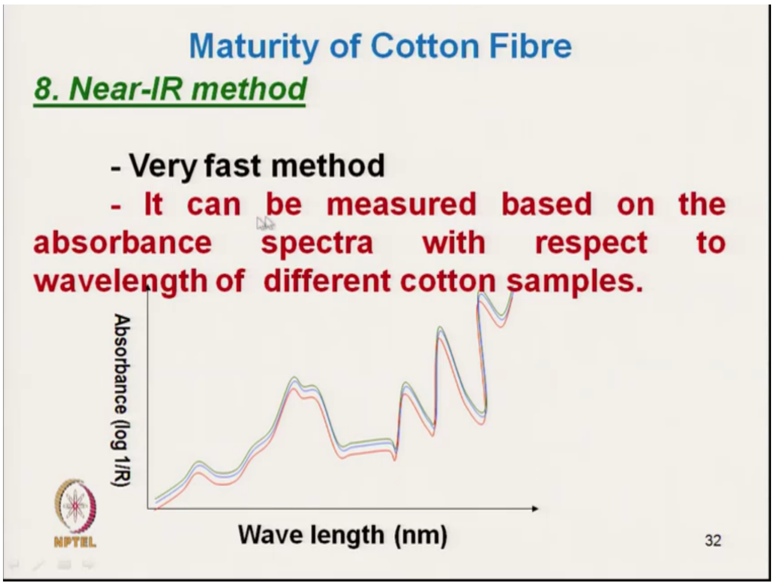

And the last technique is the NIR technique. It can be measured based on the absorbance spectra with respect to wave length of different cotton samples. So, this is the absorbance spectra and wavelength and from there one can actually predict using some specific equation, one can predict the maturity of cotton ok and this all about the maturity of cotton. Thank you.