Technical Textiles
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Lecture No- 31
Compression Bandage

Hello everyone, so today we are going to start a new topic which is compression bandage. So compression bandage is one area in technical textiles where the technical performances of textile materials are required.

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This performance is including the amount of pressure applied by the compression bandage, retention of this compression pressure along the different body parts, in the body parts and with the time how this pressure get changed is very important. Here what we are going to discuss, first will try to understand the mechanism of Compression therapy, how compression bandage assist them in recovering the diseases, different diseases.

Where the compression continuous compression pressure is required, then we will try to understand how this pressures are measured using different principles, then we will try to see the different types of compression bandage available and finally we will see the different parameters which affect the compressive pressure also the relaxation of pressure in both static and dynamic mode.

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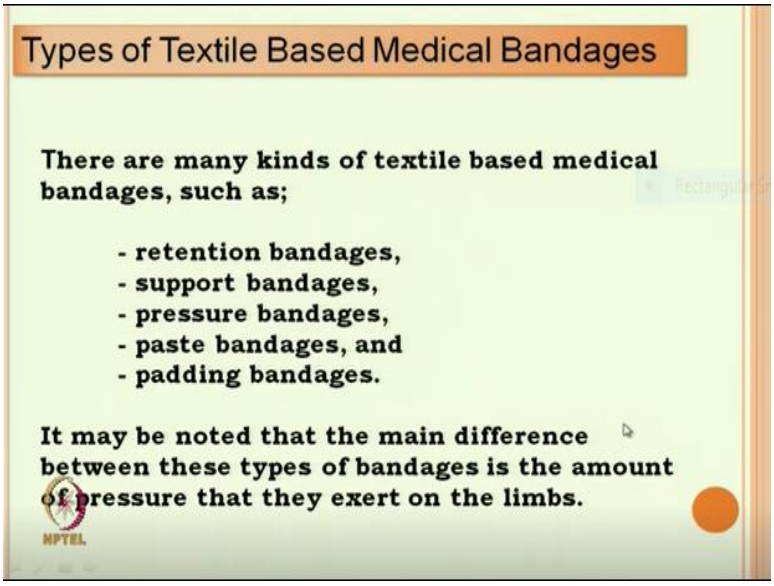

So the types of textile bandages used for medical applications are retention bandage, support bandage, pressure bandage the area we are which we are going to discuss here because for pressure bandage or compression bandage, we need highly technical inputs, then paste bandages and padding bandages. So medical bandages are broadly classified into these categories, so here one thing we should note that the main difference between these types of bandages is the amount of pressure they exert on our body.

So different bandages they insert they impart different level of pressures where pressure bandage or compression bandage, it is main function is to impart different levels of pressure depending on our requirement.

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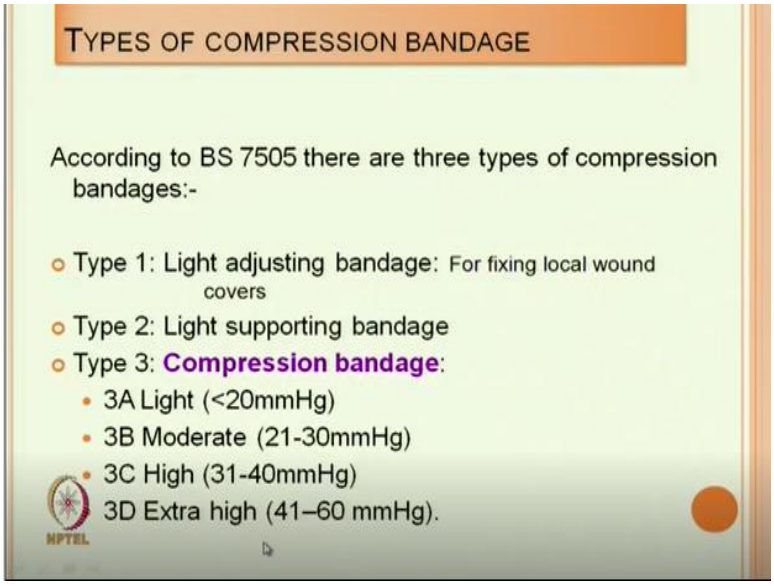

So compression bandages are divided into different categories depending on the type of or level of pressures they insert, they impart on our body. So type 1 which is light adjusting bandage for fixing local wound cover. So here the pressure level it is not that important, here the importance is that that the local wound has to be covered. So this bandage we need very low level of pressure, otherwise it may damage severely the wound area.

So second type is that light supporting bandage where we need little bit higher level of pressure but here pressure application is not that important and third type is that compression bandage where we need higher level of pressure for recovery of different type of diseases. This compression bandage's main function is to apply pressure. So depending on the requirement we can apply different level of pressure.

So for that this type 3 bandage they are divided into 4 different categories 3A, 3B, 3C, 3D. 3A means the bandages where we need to apply very low level of pressure, the pressure range below 20 millimeter Hg. 3B, we require little bit higher moderate pressure, so the range is 21 to 30 millimeter Hg. 3C is high it is 31 to 40 millimeter Hg and 3D with extra high. For some diseases we need very high pressure to be exerted on our limb. So 3D is 41 to 60 millimeter Hg.

So main function of this type of compression bandages are to insert pressure on our limb and to retain pressure for long time because our body parts hand, leg, knee always in motion. So these

bandages will undergo different load, loading and relaxation cycle continuously at different level, so this bandage they are supposed to maintain the compressive pressure but the main problem with all these compression bandages, they are typically viscoelastic in nature.

So gradually there will be stress relaxation and due to this stress relaxation there will be drop in compression pressure. So we must know what is the relationship between this structure and the level of pressure which this compression bandage, they are inserting on our body over long time during different activities.

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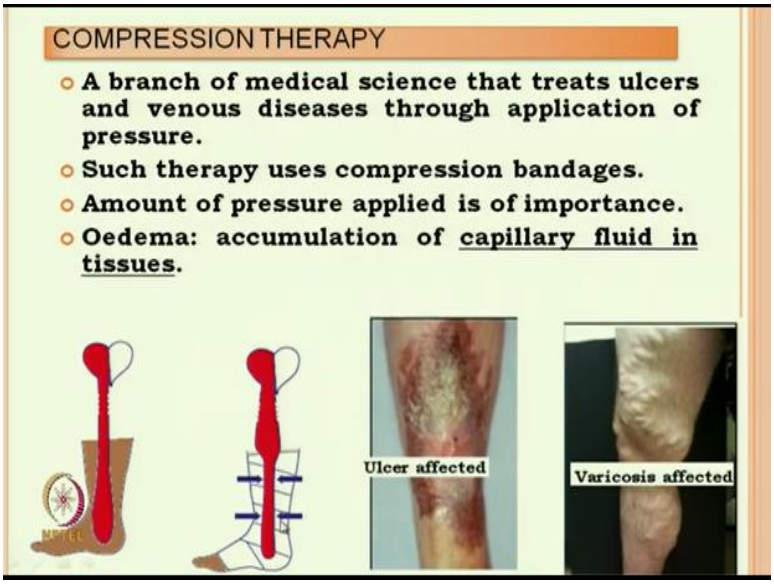

Now compression bandage is mainly used to assist the compression therapy. So we must first understand what is compression therapy? So it is a branch of medical science that treats ulcers and venous diseases through application of pressure. So these are this ulcer affected area, here it is a varicosis affected area. So by applying compression continuously in this area this type of diseases we can recover.

So this actually therapy, compression therapy can be done using compression bandages, so this is the simplest way to treat this type of diseases, so where amount of pressure applied is important. So depending on our pressure requirement we can select the type of bandage. So if we require lower amount of pressure then we can use type A, 3A type accordingly if we require higher pressure we can change our bandage.

Oedema is one such disease where accumulation of capillary fluid is there in the tissue. So this in this tissues there will be accumulation of this capillary fluid and function of compression bandage is to push this fluid again into the capillary so that proper flow of this fluid is there, there should not there is no accumulation of this fluid.

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So compression therapy is the principal treatment for leg ulcers. So there is no other treatment for this type of leg ulcers where accumulations of fluids in the tissues are there and main important factor is that sustainability of the pressure. So once we apply pressure using compression bandage that pressure has to be there for long time otherwise, the effectivity of the compression bandage will not be there.

Along with the sustainability, uniformity of bandage pressure should be there, so if we get sustainability and uniformity of bandage pressure, then we can expect speedy recovery of ailment. So both sustainability and uniformity of pressure they are important and pressure applied should be in desirable range as I have already mentioned we must know what type of pressure is required, accordingly we select bandage and we apply pressure.

There are various factors I will discuss which affect the level of pressure even with the same bandage we can change the level of pressure. So the bandage manufactures need to make best

quality product means they must know that what type of bandage, what are the structural requirement to keep the pressure for long time even after the repeated extension and recovery.

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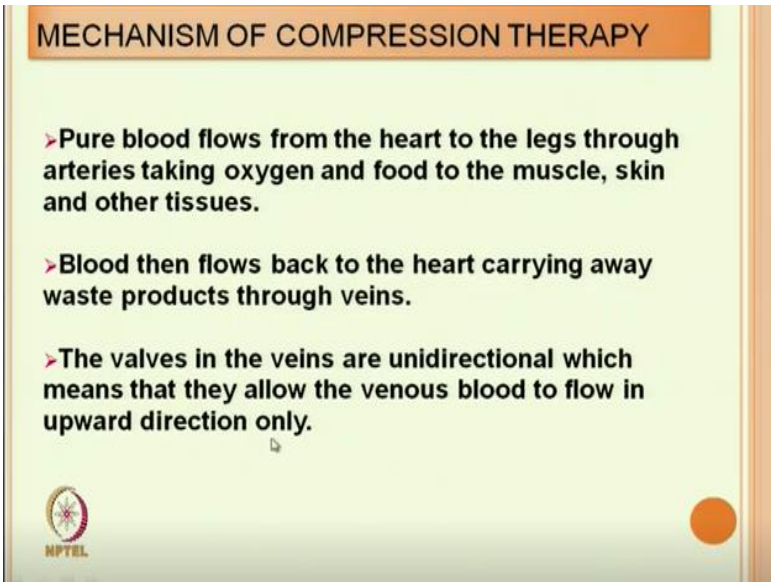

So the mechanism of compression therapy is the pure blood flows from the heart to legs. Basically this type of disease normally takes place in legs, the possibilities are there in other areas also but in legs it is there because with the gravity the fluids are actually accumulated there. So, pure blood flows from the heart to the legs through arteries taking oxygen and food to the muscle, skin and other tissues.

So that they get sufficient oxygen and food and then blood flows back to the heart carrying away waste product through the vein for purification. The valves in the veins are unidirectional as we know which means that they allow the venous blood to flow in upward direction only. So that required pressure has to be there, so that this blood flows in upward direction.

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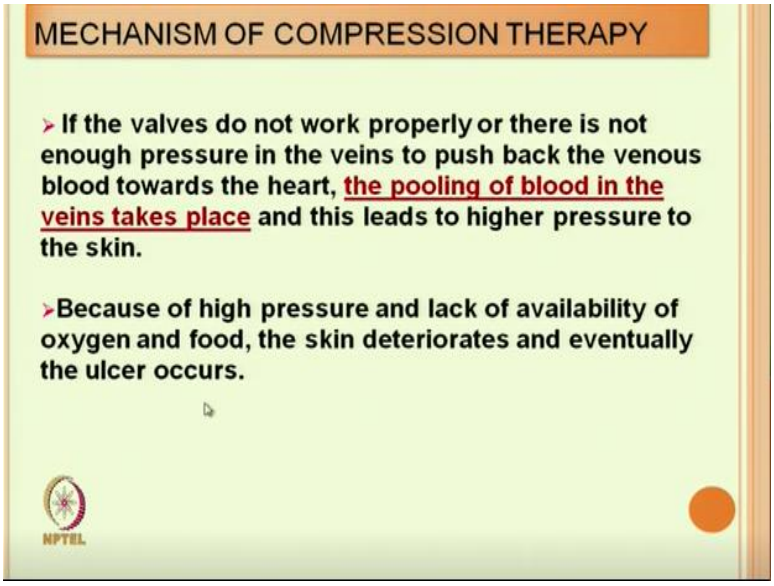

The problem comes that if the valves do not work properly because they will not be able to retain the fluid, this fluid will actually come back again to the leg, so if the valves do not work properly or there is not enough pressure in the veins to push back the venous blood towards heart, so sometime it may happens the enough pressure is not getting generated. So we need sufficient pressure to push back this blood to the heart for purification.

So if this valve does not work and pressure, sufficient pressure is not there then what will happen? The pooling of blood in the veins takes place around the leg and this leads to higher pressure to the skin. So due to this pooling of blood there will be higher pressure on the skin. So to avoid this pooling of blood we have to have extra pressure, apply extra pressure because if valves do not work, so we cannot do anything with the compression bandage.

But in compression therapy we exert extra pressure on the limbs. So because of high pressure and lack of availability of oxygen and food the skin deteriorates and eventually ulcer occurred. So skin needs oxygen and food and due to this lack of proper blood flow the ulcer occurs.

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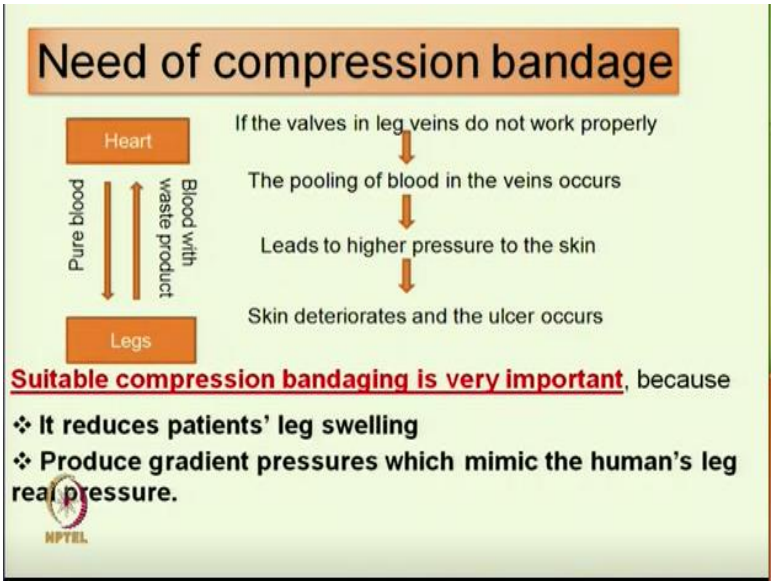

Now if you see the picture that this figure here it is a heart, here it is a leg, pure blood oxygenated blood and the blood with food it comes to leg and various part of the body, we are talking about leg because the ulcer takes place in mainly in the leg and from there for proper functioning blood with waste products it goes back to the heart. If the valve in the leg veins do not work properly the pooling of blood in the veins occur leads to higher pressure to the skin and skin deteriorates and ulcer occurs.

This is the basic principle of ulcer formation. So the treatment is the suitable compression bandaging is required. Because of the reasons, two reasons it reduces patients leg swelling. So, because it is due to pooling of blood leg start swelling, so due to application of compression bandage, so leg swelling reduces and produce gradient pressure which mimic the human legs real pressure.

So normally there will be a real pressure, so that it flows the blood flows back to heart but if that pressure is not there physiologically, so extra pressure if we apply by compression bandage that will mimic the normal pressure.

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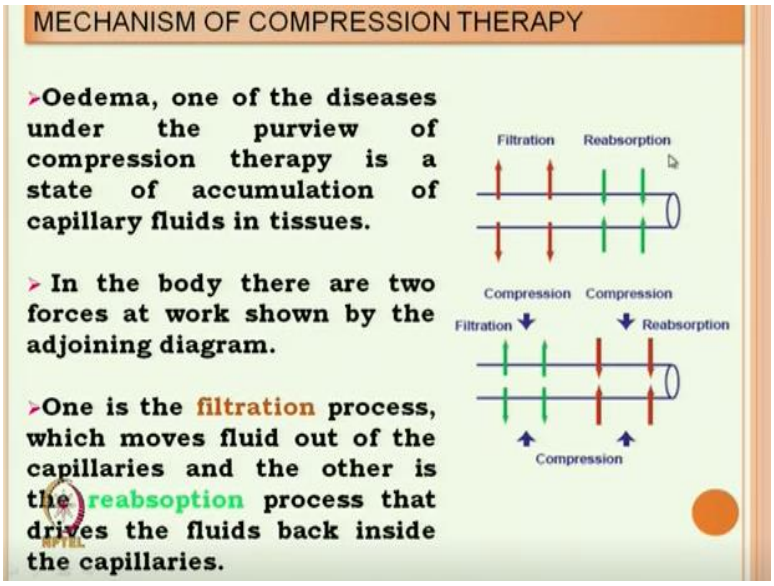

So from this diagram we can see that there are two processes - one is called filtration, another is reabsorption. The Oedema, one of the diseases under this purview of compression therapy is a state of accumulation of capillary fluid in the tissue. So these are the tissues, this one here this is capillary. Now during filtration whatever fluids are there in the capillary it comes to the tissues and due to lack of pressure the accumulation of fluid takes place in this zone that is in the tissues.

In the body there are two force work at the as it is shown in the diagram, as I have mentioned one force is called its filtration another is reabsorption. So in filtration the fluid moves out of the capillary and in other process the reabsorption in this process the fluids drive back to the capillary. So this reabsorption process is lacking due to the lack of pressure that is why the accumulation of fluids are there.

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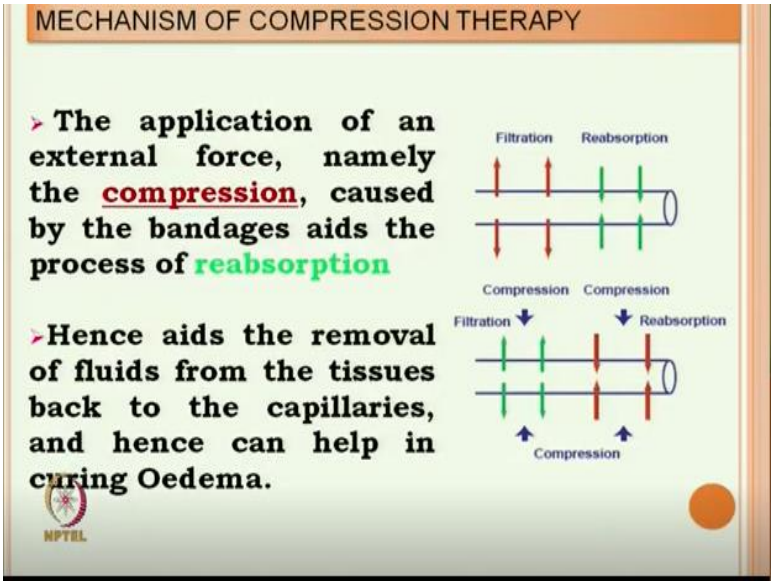

So in compression therapy, we apply extra compression pressure external force by the use of compression bandage and which helps in reabsorption. So by extra additional pressure from outside if we apply on the tissues that will help the reabsorption, so the fluid again comes back to the capillary. So hence aids the removal of fluid from the tissues back to the capillaries and hence can help in curing Oedema.

So accumulation of capillary fluid is eliminated. So by doing this we can treat the Oedema or different types of diseases related to the accumulation of fluid. Now from this discussion, it is very clear that this reabsorption is required in continuous fashion. When we apply compression bandage, at that time reabsorption will take place due to the higher pressure but if relaxation takes place then there will be drop and this reabsorption will be in effective.

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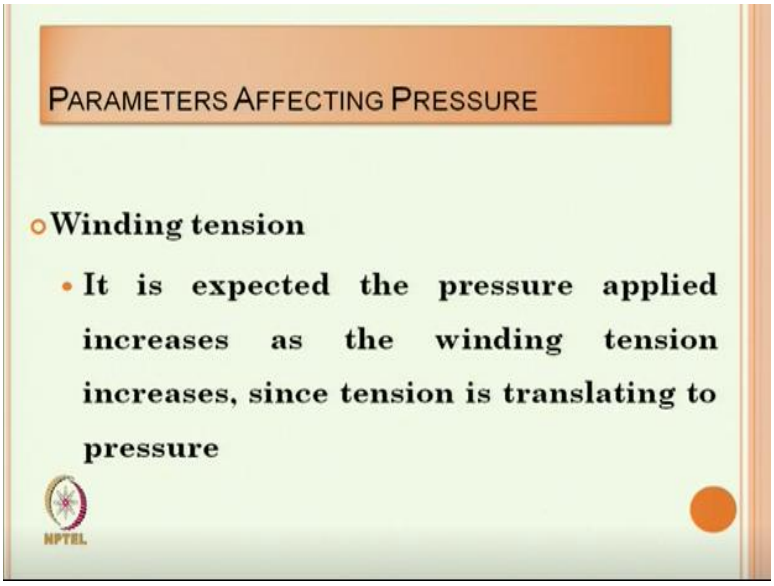

Now to increase the effectivity of the compression bandage, so we must know different parameters which affect the compression pressure as well as retention of the pressure which has been applied. So the parameters are the winding tension. So to increase or decrease the compression pressure we have to increase or decrease the tension during wrapping of compression bandage.

So it is expected that the pressure applied on our body increases as the winding tension increase because this tension is translating to the pressure. So whatever tension we apply on the compression bandage during winding that particular tension will get translated into the pressure applied on our limb. So winding tension is very important. So the doctor or nurses, they must know the level of tension we must apply during the wrapping of compression bandage.

And this tension also depends on the type of compression bandage, whether it is a short stretch compression bandage or long stretch compression bandage, so stiffness of compression bandage. So there are various parameters required. So we must know the level of compression, level of compression pressure during the winding, so accordingly we change the winding tension. So, next parameter which affect the pressure it is number of wraps.

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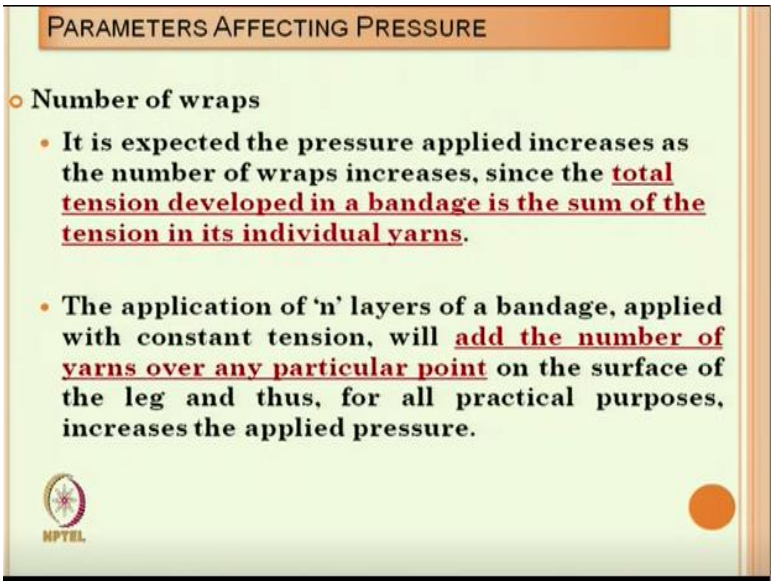

As we go on increasing the number of wraps the compression pressure increases. So it is expected at the pressure applied increases as the number of wraps increases, since the total tension developed in a bandage is the sum of tension in individual yarn. So it will keep on adding as we increase the number of wraps. The application of n layers of a bandage applied with constant layer, we are not changing the tension, will add the number of yarn over any particular point.

So that will keep on adding the number of yarn layer or number of fabric layer on that particular surface and that is why the pressure will increase consistently.

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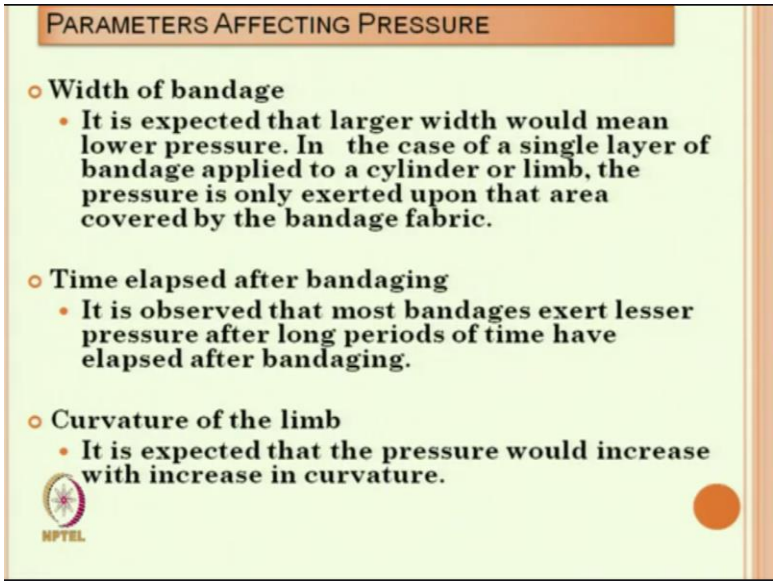

Third is the width of bandage. So as we know the area is inversely proportional to the applied pressure, keeping the load constant here the load is basically due to the tension during the wrapping of bandage, so if we use the narrow width and another is the wide width and for same winding tension the wide width means the effective area will be more so accordingly the pressure will reduce.

So it is expected that larger width would mean lower pressure. In the case of a single layer of bandaging we are keeping the layer constant, applied to a cylindrical limb, the pressure only exerted upon the limb will be depending on the tension applied and the area. So if we increase the area then the compression force will reduce. So that is why it has been observed that, if we in belt, if we apply the wider belt so that will exert less compression pressure than in case of narrow width belt.

Time elapsed after bandaging, it is very important for retention of compression bandage. So as we know the textile materials are visco-elastic in nature and this bandages will try to relax there will be stress relaxation in the structure. So gradually the pressure will reduce with the time. So it is observed that most bandages exert lesser pressure after long period of time. So we must know the level of pressure drop for different types of bandages and accordingly we have to replace the bandage for easy or quick recovery from the disease.

Otherwise the bandage will be ineffective. So either we replace the bandage or we again rewrap the bandage after certain time. Curvature of the limb is also very important and it is expected that the pressure would increase with the increase in curvature. From our daily experience we know if we wrap when we wrap any band along over the waist so what we observe that the side portion the pressure exerted by the band is higher.

So we actually experience higher pressure here at the side then at the front or back, the reason is that at the side the curvature is very high, higher than the front and back which are flatter in shape. So due to the change in curvature, although the tension along the around our waist remain same but the pressure applied by this band is different and it depends on the curvature of a particular zone.

So the same principle is applied here keeping all other parameters constant. When we wrap the bandage in an area where the curvature is high, the pressure will also be high.

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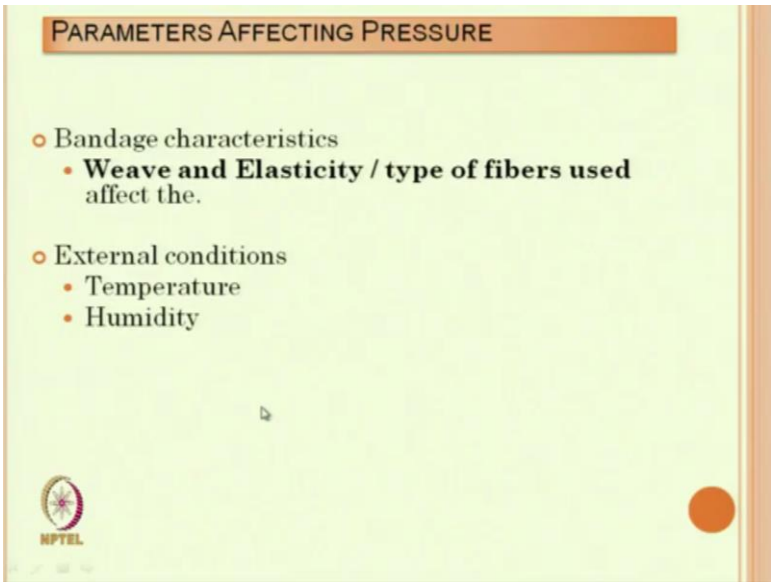

Bandage characteristics is also important. We must select the bandage carefully. Their weave elasticity type of fibers, okay stretchability, so these are very important, their structure and last parameter which are external condition. This external condition we must know before selecting the bandage like with the increase in temperature there will be relaxation in compression pressure due to the extension that is thermal expansion of the structure.

There may be thermal compression thermal shrinkage also there. So this external condition temperature ultimately changes the total pressure profiling. So during selection of during bandaging we must know what will be the type of temperature in the environment and accordingly this selection should be there. Also with the change in humidity sometime what happened that the shrinkage of structure takes place or expansion may take place.

So that parameter affects the bandage pressure directly. So, these external conditions we must take into account during selection of bandage.

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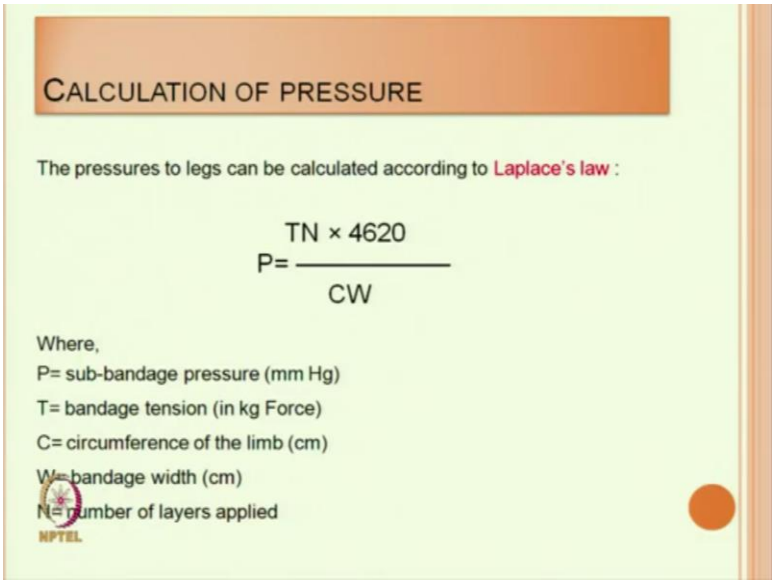

Now coming to the factors which we have already discussed, so these factors are incorporated into the measuring the sub-bandage pressure by Laplace law. So what Laplace law is telling that sub-bandage pressure P is equal to T multiplied by N multiplied by 4620 divided by C and multiplied by W. So what is T? So P is directly proportional to the tension applied during the bandaging. So as the tension increases pressure will also increase compression pressure.

As the number of wrap increases the pressure will increase proportionately as we have discussed and 4620 is the constant parameter this is nothing but the conversion this is the constant during the unit conversion. As we increase the circumference of the limb the pressure will reduce. That is circumference of limb is inversely proportional to the curvature. So that means circumference of limb if we increase the pressure will decrease keeping all other parameters constant and bandage width as I have already mentioned.

So with the increase in bandage width the pressure applied will reduce. So this Laplace law it is it will give us one broad idea about the factors affecting the compression pressure but actual pressure applied on our body which is soft in nature, it is this does not follow exactly the Laplace law although the trends are same, which means if we know the tension on the bandage, circumference of bandage, width of bandage, and number of wrap we cannot exactly predict the pressure applied.

Because this formula is applied it is based on the hard surface, hard circular surface, but our body is soft in nature. So this pressure normally, actual pressure, is different from this theoretical pressure. But if we understand if we can get some correction factor, then we can predict the actual pressure using the Laplace law.

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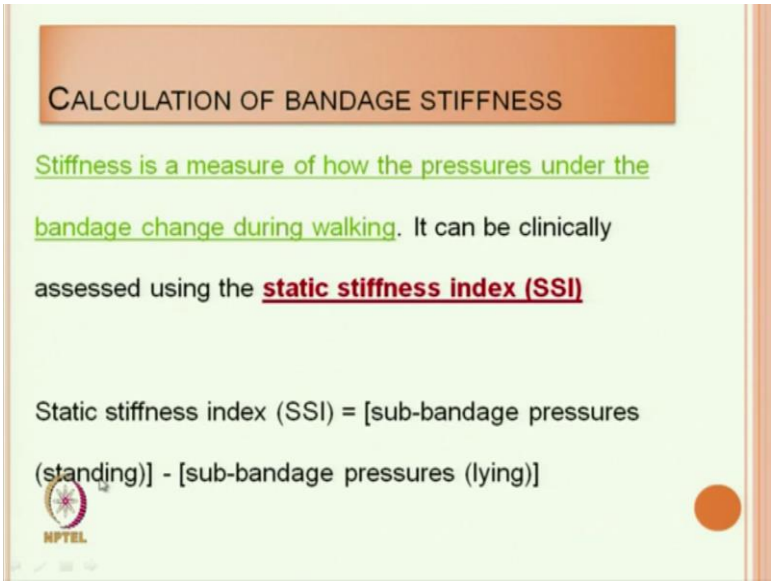

The stiffness is measured is a measure of how the pressure under the bandage changes during walking. So another parameter which we can measure that is called stiffness index. So static stiffness index this will give us idea about the change in pressure during activity. So, static stiffness index; is the difference between sub-bandage pressure in standing condition and sub-bandage pressure in lying condition.

Suppose someone is lying that the sub-bandage pressure is lower than when he is standing because during standing the muscle get expanded and that will exert more sub-bandage pressure and this difference is known as the static stiffness index of bandage. If the index is more that means sub bandage pressure after standing will be more because it will resist the expansion of the limb so that is why the static stiffness index will increase.

So indirectly it shows that the bandage with higher modulus will have higher static stiffness index.

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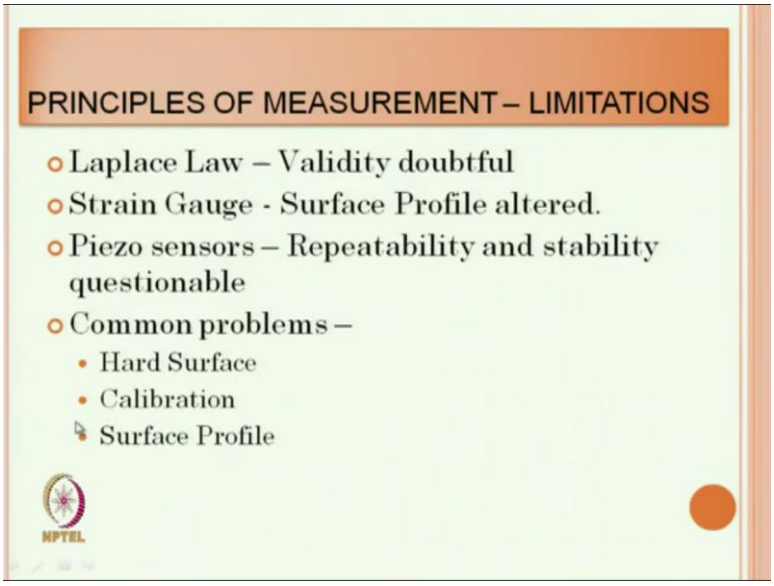

There are different measurement principles as I have already mentioned Laplace law is one of the basic equation from which we can get idea about the applied pressure by the compression bandage, but the problem here is that it is validity is doubtful because actual pressure when we measure by using different sensors the actual pressure applied by the bandage on our body they are different from the calculated pressure which is which we get from the Laplace law.

Then next principle is that strain gauge principle. The problem here is that here surface profile alters.

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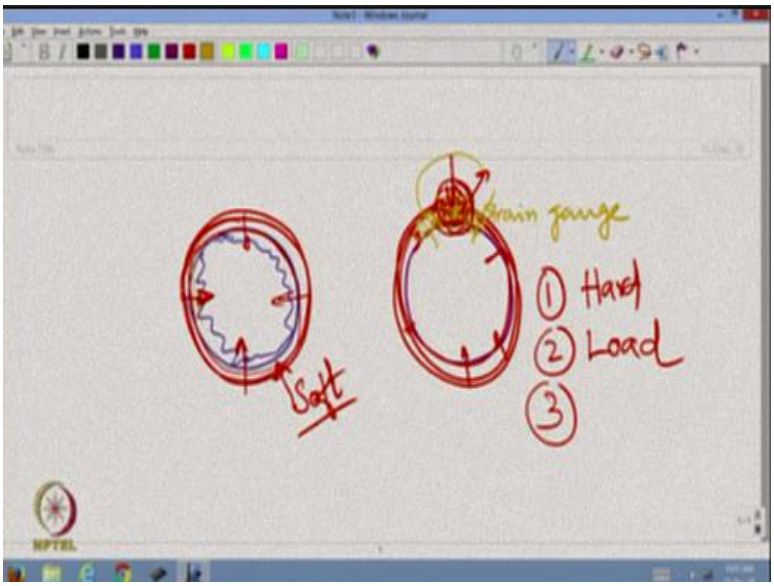

Now, let us see suppose this is the cross section of the limb our leg and we are trying to apply compression bandage, wrap the compression bandage. Ideally we must know the level of pressure this is exerting. But and the main problem here is that our leg is it is a soft, they will get contracted and these are wrapped around the leg there is no gap. This is the ideal condition but the strain gauge principle works on that there will be hard surface there must be some hard surface here and the strain gauge is kept, this is strain gauge.

Now the tension due to the tension this is in compression mode, here this works on compression mode. When we wrap the bandage along this due to this compression load, this is due to the wrapping, this is applying compression load, but here the recording is due to the strain in this gauge due to compression. So it is like either tensile or compression and indirectly we get the value of compressive pressure.

Actually it is we are getting the compressive load here we are getting load and that too in single point. So main drawbacks are, first is that these are on hard surface but actual compression is on soft surface. So that how what we get we are not getting the actual measure of the compression force. Second drawback is that it measures the compressive load, not the pressure here, in a particular point.

And third and most important part is that this deviation from actual condition there is protrusion this bandage is this strain gauge is projecting outside the surface but in actual condition it should be perfectly wrapped. So there is at this zone these zones adjacent to this strain gauge due to the projection they are not exerting pressure. So the strain gauge principle will give some value but which is actually not the value which we want for as compression, so internal pressure applied.

Same problem is with piezo sensor. Here also we have to place the piezo sensor which alters the surface characteristic that is it will be projected and here again they are placed on hard surface. So in soft surface if we try to place the piezo electric sensor or strain gauge will not be able to get the actual pressure, like let us see suppose somehow we have created soft surface;

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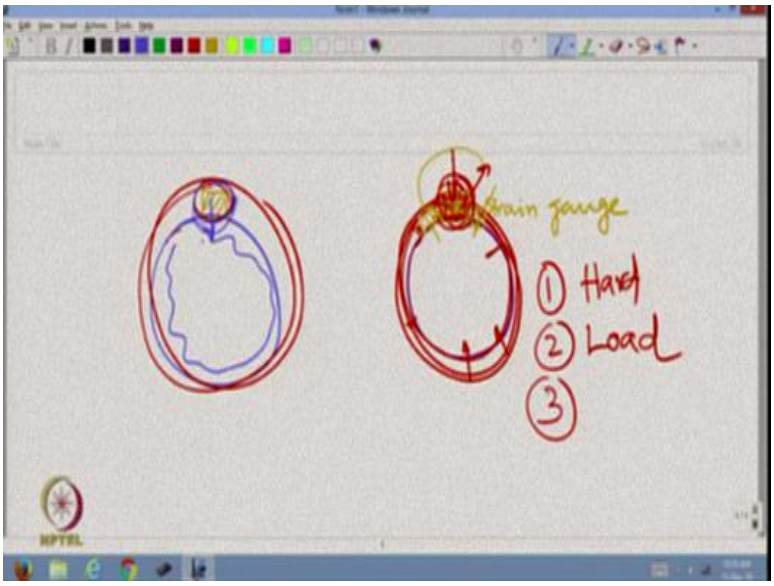

Somehow we have created soft surface, this surface is soft. Now if we place the strain gauge or Piezo sensor here that means during application of compression bandage as these are soft instead of giving the exact value of compression pressure there will be deformation, as it is soft. So this total whole system will actually push down, that will not give the actual, even the compression load value.

This will be absorbed by the deformation of the surface. So the common problems here it is a hard surface, calibration problem is always there we have to always recalibrate and surface profile change.

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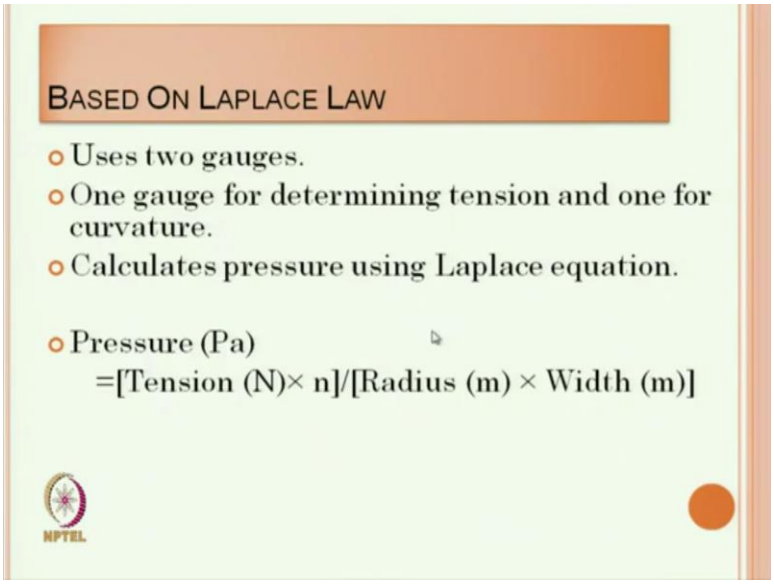

So based on Laplace law as I mentioned there are instruments available, where we use two gauges. So one gauge because in Laplace law, we need to determine the tension and curvature, so keeping all other things constant and all other parameters are known because number of wraps are known, width of bandage is known, the unknown parameter is that it is a amount of tension applied and the curvature of the particular limb.

So in the instrument the which works on based on Laplace principle they use two gauges - one gauge is for determining the tension and other is for determining the curvature. So these are this is the formula by which we can get the compression pressure. So tension N is obtained from one gauge and another is the radius of curvature we get from another gauge.

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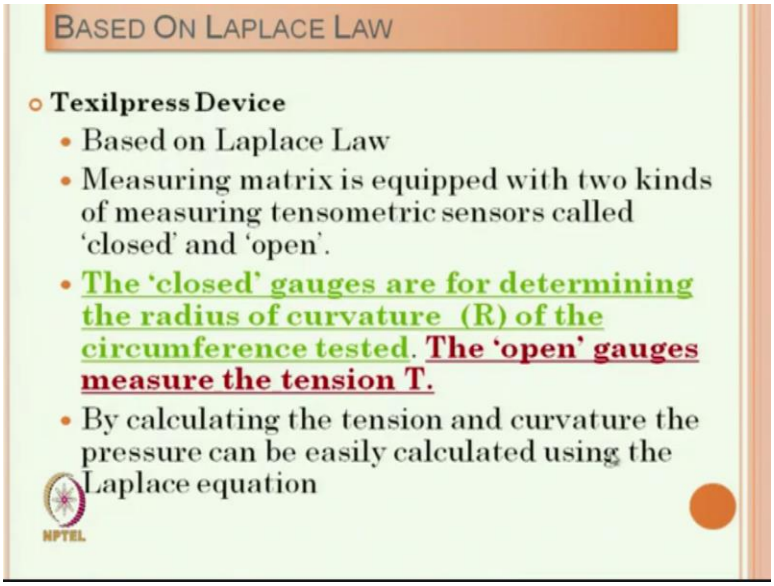

So, one commercial equipment based on this Laplace law is Texilpress device. This works on the Laplace principle. Here as has already been mentioned we need two gauges. So these are basically closed and open. The two gauges are closed gauge and open gauge. The closed gauges are for determining the radius of curvature R of the circumference tested and open gauge is to measure the tension.

So, if we know these two parameters through this closed and open gauge, so we can immediately get the value of the pressure applied knowing the width of the bandage and the number of wrap. By calculating the tension and curvature the pressure can easily be calculated using Laplace law.

But due to all the problems which have been discussed the actual result obtained by the other gauges is different from the pressure applied by the obtained through the Laplace equation.

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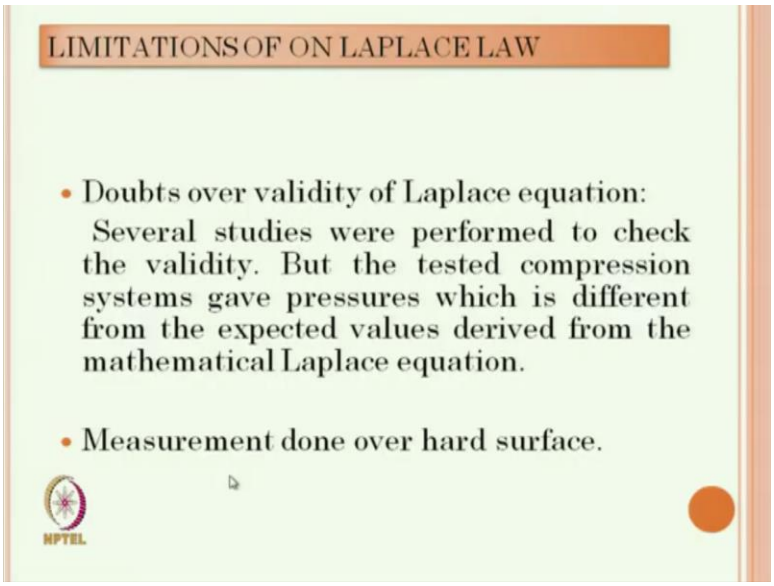

So main limitations are the doubts over validity of the Laplace equation, several studies were performed to check the validity but the tested compression system gives pressure which are different from the expected value by Laplace equation, so that is why the validity is doubtful and the reasons I have already mentioned because the measurement done over the hard surface.

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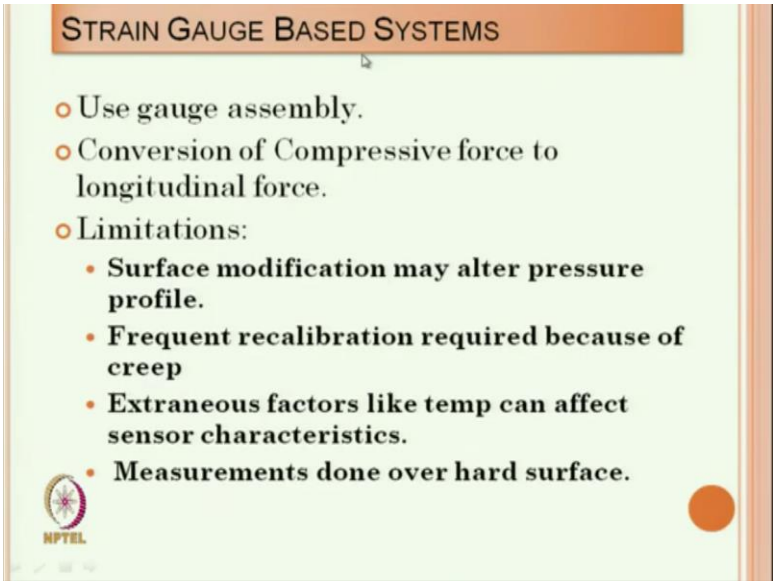

And the problem with strain gauge based system as I have already mentioned we have discussed this use gauge assembly strain gauge assembly is required. Conversion of compressive force to

longitudinal force that is basic problem here, in bandage pressure calculation, we need longitudinal force but here we measure the compressive force and this conversion during this conversion the errors are inserted actually, the errors come in the calculation.

The limitations of strain gauge type system is that surface modification may alter the pressure profile, frequent calibration is required, extraneous forces like temperature can affect the sensors characteristics because if sensor changes or humidity changes the sensitivity of the sensor get changed and measurement is done on hard surface. This is the problem with the strain gauge principle as well as the piezoelectric sensor.

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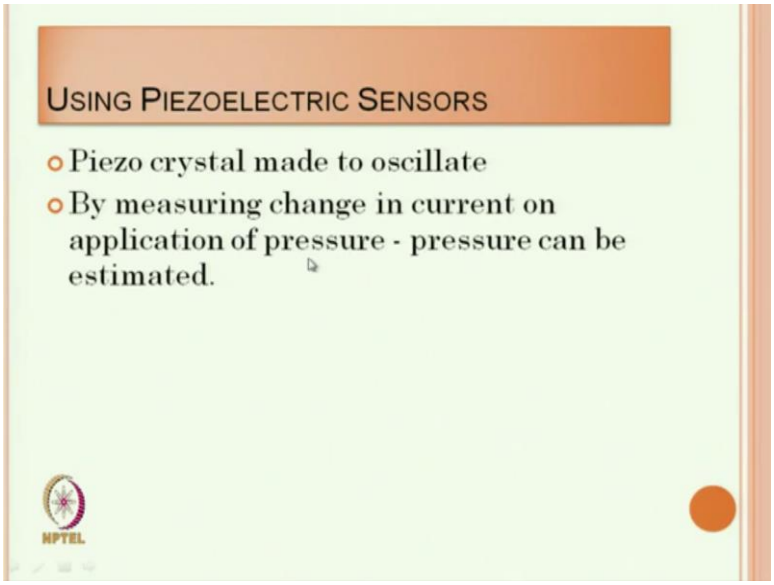

The Peizo crystal made oscillate by measuring changes in current during the application of load we can get the pressure. Main problem with piezoelectric sensor the continuous measurement for long time it is difficult. So for compression bandage we need to monitor the pressure in continuous fashion.

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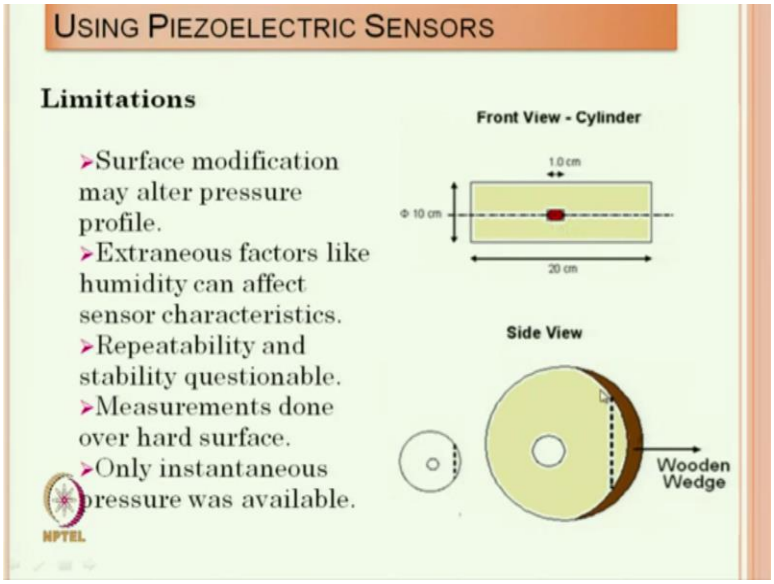

This is the piezoelectric sensor. The surface modification may alter the pressure profile here surface modification is required. So external factors like humidity and temperature they affect the piezoelectric sensor, repeatability is questionable here. Again it is a hard surface and only instantaneous pressure was available that is the problem here. We do not get the continuous pressure profile here. So these are the existing principles available.

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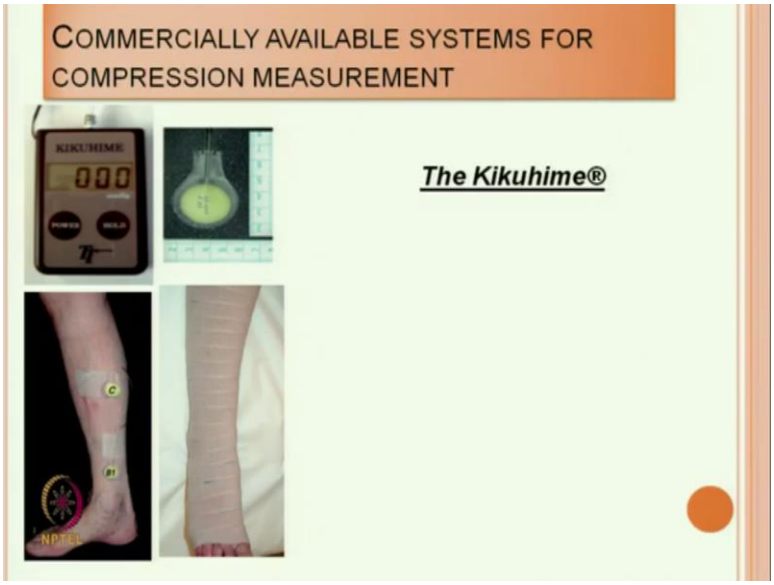

There are different commercially available compression measurement systems for compression bandage, so this will discuss in next class, till then thank you.