Inspection and Quality Control In Manufacturing
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Lecture – 11
Acoustic Emission Inspection

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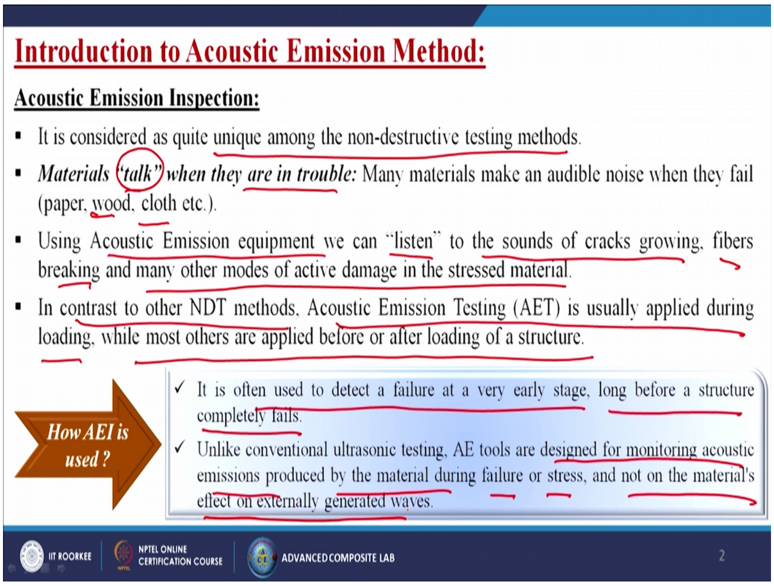

Hello my friends, now we are going to discuss, the new lecture on, Acoustic Emission Inspections. So first let us know that, what is Acoustic Emission Inspection is. Actually it is considered as quite unique among non-destructive testing methods. What are those? Materials talk. This is the important thing, when they are in trouble many materials makes an audible noise when they fail, say suppose we are having the paper, if we want to tear the paper, it will create some kind of sounds. If it is wood or maybe the cloth it is having the different sounds.

Now, using Acoustic Emission Equipment, we can listen to the sounds of cracks growing, fibers breaking, and many other modes of active damage in the stressed material. In contrast to other NDT methods, Acoustic Emission Testing is usually applied during loading, while most others are applied before or after loading of a structure.

How the acoustic emission inspection is used? It is often used to detect a failure at a very early stage long before a structure completely fails. Unlike conventional ultrasonic testing, AE tools are designed for monitoring acoustic emissions produced by the material during failure or stress and not on the materials effect on externally generated waves.

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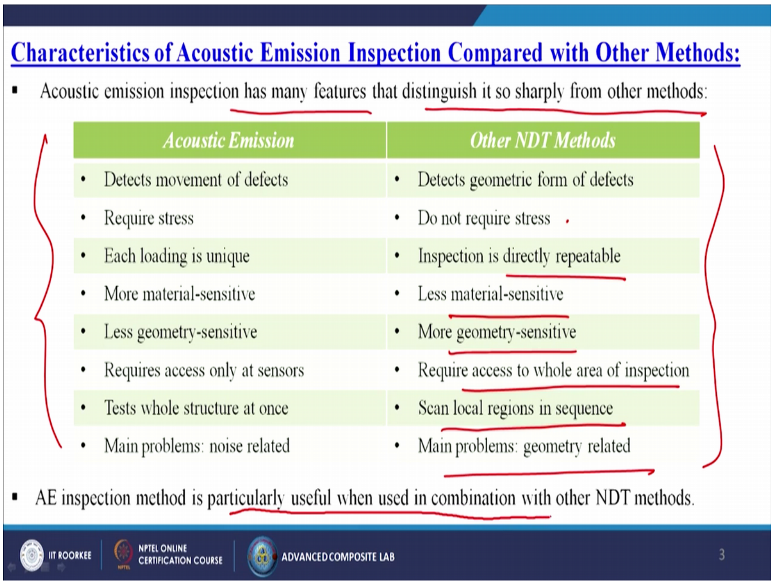

Characteristics of the Acoustic Emission Inspections Compared with the Other Methods: Acoustic Emission Inspections has many features that distinguish it so sharply from other methods. What are those? Say suppose, we are doing the acoustic emissions, what are the advantages? Detects, movement of defects required stress, each loading is unique more material sensitive less geometry sensitive. Requires access only at sensors tests whole structure at once main problems noise related. So these all are the advantages.

Now, if we see the other NDT methods, where it can detect geometric forms of defects, do not require the stress, inspection is directly repeatable, less material sensitive, more geometry sensitive, require access to the whole area of inspection, scan local regions in sequence, main problems the geometry related. So this is the thing. So AE inspection method is particularly useful, when used in combinations with other NDT methods. So you can see that, generally we are doing the double check at a time.

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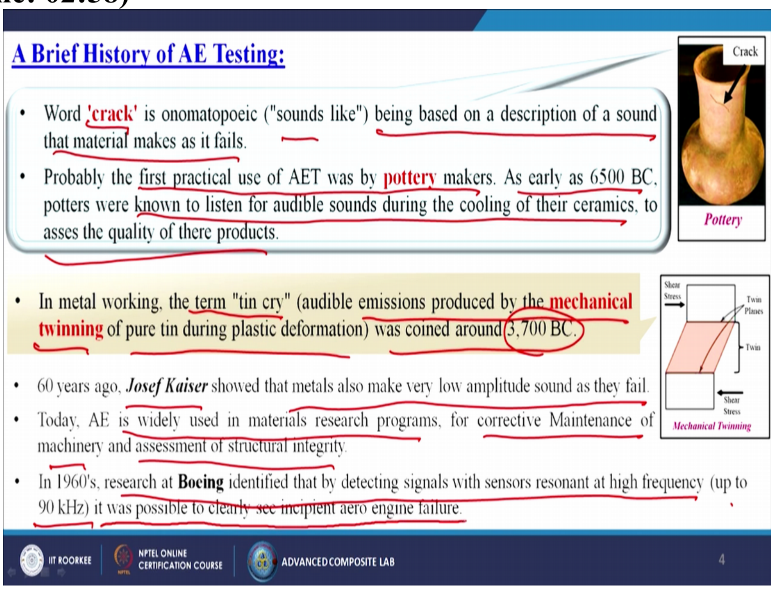

A brief history that what crack is an onomatopoeic sound like being based on a description of a sound that material makes as it fails. Probably the first practical use of AET was by pottery makers, as early as 6500 BC. Potters were known to listen for audible sounds during the cooling of their ceramics to assess the quality of their products.

Not only that, nowadays if we are going to purchase any kind of clay products say like some any bowls or maybe any kind of glass materials generally that shopkeepers they are making a sound on the surface and then after that, simple by getting that sounds they are telling that, whether any cracks are present inside the cups or plates or maybe any kind of glass products or not. So by these originally they are checking.

In metalworking the term tin cry audible emissions produced by the mechanical twinning of pure tin during plastic deformations was coined around 3700 BC. 60 years ago Josef Kaiser showed that the metal also makes very low amplitude sounds as they fail. Today AE is widely used in materials research programs for corrective maintenance of machinery and assessment of structural integrity. In 1960s research at Boeing identified that by detecting signals with sensors resonant at high frequency up to 90 kilo hertz it was possible to clearly see incipient aero engine failure.

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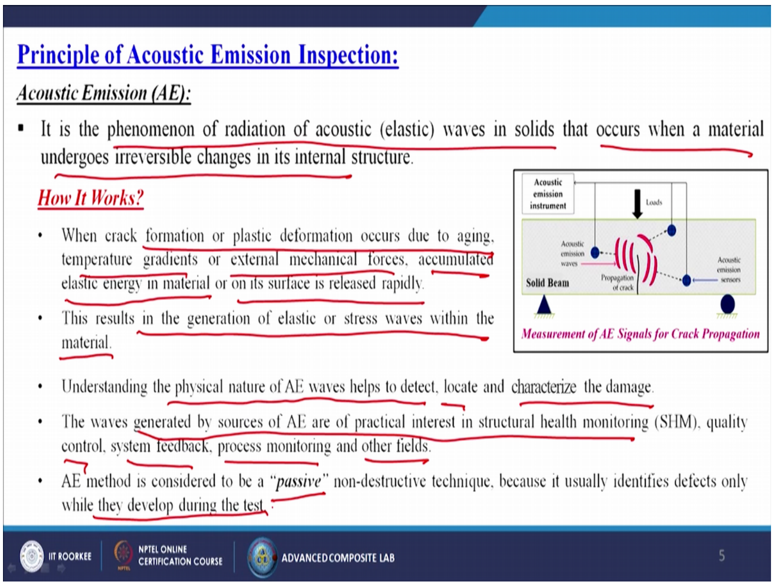

Now Principle of the Acoustic Emission Inspections: Acoustic Emissions, generally it is the phenomenon of radiation of acoustic waves in solids that occurs when a material undergoes irreversible changes in its internal structure. How it works? When crack formation or plastic deformation occurs due to aging, temperature gradients or external mechanical forces, accumulated elastic energy in material or on its surface is released rapidly. This results in the generation of elastic or stress waves within the material.

Understanding the physical nature of AE waves helps to detect, locate, and characterize the damage itself. The waves generated by source of AE are of practical interest in structural health monitoring, quality control, system feedback, process monitoring and other fields. AE method is considered to be passive non-destructive techniques because it usually identifies defects only while they develop during the test.

So simple, we are doing the different kinds of loading or maybe different kind of testing on the materials, and then at the time of testing, if the material is creating certain kind of noise, that noise we are detecting and by that way we are going to get the informations that whether any cracks, pores or maybe any kind of problems is occurring at the time of testing.

So simple we are having that acoustic instrument emissions instrument over here, so we are giving the waves over there, and then we are having that sensors on the different actions, we are giving the load and it is acting as a double cantilever beam type, so simple, if there will be any breaks or maybe the cracks or maybe the crack propagation will be taking place simply, that sensor will sense that sound, and it will give to us.

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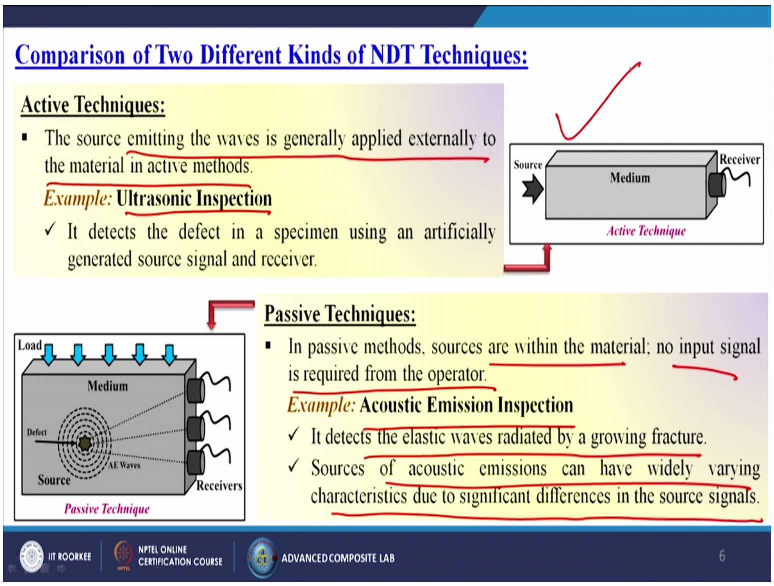

Comparison of two different kinds of NDT techniques: Active techniques the source emitting the waves is generally applied externally to the material in active methods. Example, Ultrasonic inspection, it detects the defect in a specimen using an artificially generated source signals and the receiver. Next one is called the passive techniques, in passive methods, sources are within the material no input signal is required from the operator itself.

Example: Acoustic emission inspections. It detects the elastic waves radiated by a growing fracture. Sources of acoustic emissions can have widely varying characteristics due to significant differences in the source signals. We have briefly discussed about these ultrasonic inspections in our last lecture, so in this lecture you can see that, we are having the source, the defect is creating over there, now we are having that receivers which will receive the signals from this particular defect and it will give to the us, when you are applying the constant load to that particular material.

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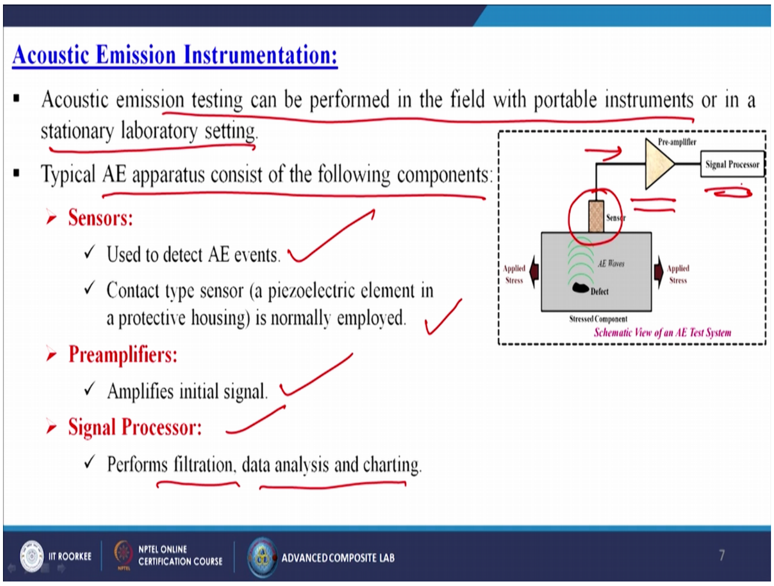

Acoustic emission instrumentations: Acoustic emission testing's can be performed in the field with portable instruments or in stationary laboratory settings. Typical AE apparatus consists of the following components, one is called the Sensors, used to detect the AE events, contact type sensors a piezoelectric element in a protective housing is normally employed. Preamplifiers, amplifies the initial signals, because that time as I told already, the signals frequency is very, very small, which we cannot detect.

So we are using the amplifier to amplify that particular signal. Then, Signal Processor performs the filtration, data analysis and the charting. So here we are having the defect, we are having the sensors, and it is directly into the contact mode, and then after that whatever the signals are coming we are pre amplifying it and then we are having the signal processor over there. So now we are doing it at the time of giving the constant load to that particular material.

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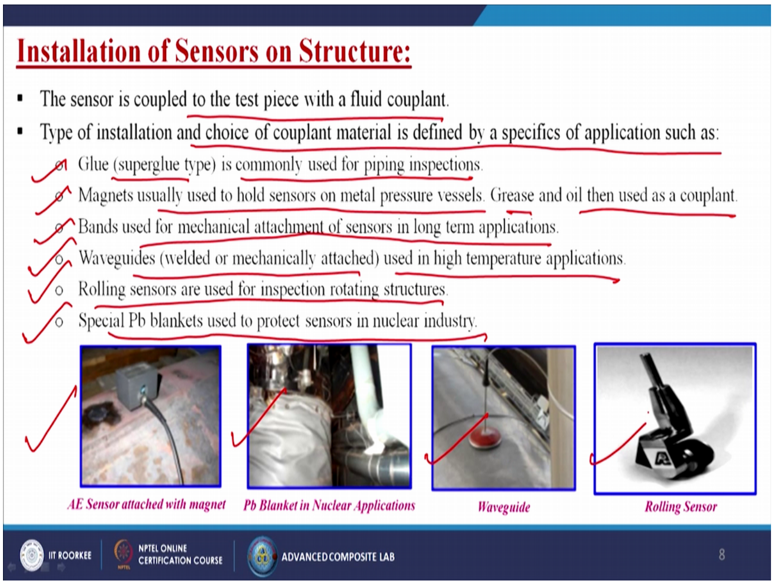

Installation of sensors on structure: The sensor is coupled to the test piece with a fluid couplant. Type of installations and choice of couplant materials is defined by a specific of applications such as, Glue, super glue type is commonly used for piping inspections. Magnets usually used to hold sensors on metal pressure vessels. Grease and oil then used as a couplant, bands used for mechanical attachment of sensors in long term applications.

Waveguides welded or mechanically attached used in high temperature applications. Rolling sensors are used for inspection rotating structures. Special Pb blankets used to protect sensors in nuclear industry. So AE sensors attached with the magnet, Pb blanket in nuclear applications, waveguide and the rolling sensors, these all are the examples.

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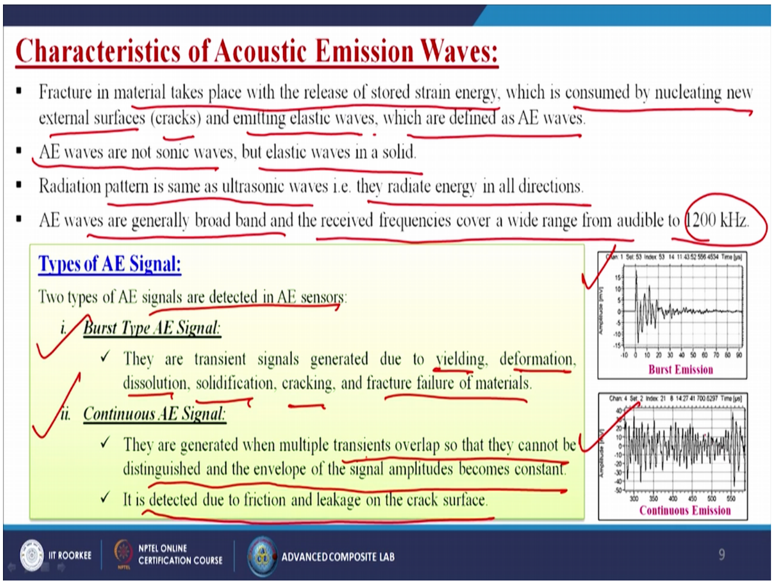

Now characteristics of the Acoustic Emission Waves: Fracture in material takes place with the release of stored strain energy which is consumed by nucleating new external surfaces cracks and emitting elastic waves, which are defined as AE waves. AE waves are not sonic waves, but elastic waves in a solids. Radiation pattern is same as ultrasonic waves; they radiate energy in all directions. AE waves are generally broadband and the received frequencies cover a wide range from audible to 1200 kilo hertz.

Types of the AE signal. Two types of AE signals are detected in AE sensors. First one is called the, Burst type AE signal. They are transient signals generated due to yielding, deformations, dissolutions, solidification, cracking and fracture failure of materials. So, this is the example of the burst emissions that how we are getting the results. Now we are having the second one, Continuous AE signal.

So they are generated when multiple transient overlaps so that they cannot be distinguished and the envelope of the signals amplitudes becomes constant. It is detected due to the friction and leakage of the crack surface. So by seeing that plot, simple, we can detect that what kind of problems is going to takes place inside the material.

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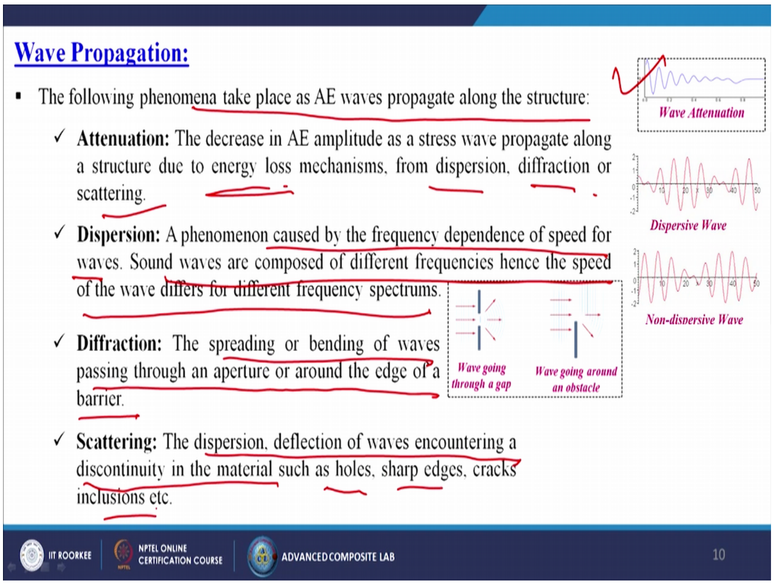

Now come to the Wave Propagation. The following phenomena takes place as AE waves propagate along the structure. First one is called the Attenuation, the decrease in AE amplitude as a stress wave propagates along a structure due to energy loss mechanism, from dispersion, diffraction or the scattering. It looks like this, wave attenuation. Second one is called the Dispersion, a phenomenon caused by the frequency dependence of speed for waves.

Sound waves are composed of different frequencies; hence the speed of the wave differs for different frequency spectrums. Next one is called the Diffraction. The spreading or bending of waves passing through an aperture or around the edge of a barrier, and the last one is called the Scattering. The dispersion, deflection of waves encountering a discontinuity in the material such as holes, sharp edges, cracks or maybe the inclusions.

So here you can see that our graphs are totally different. So when we are getting these kind of graphs, so simple, from that particular graphs, we can get the informations that, whether it is due to the sharp edges, or maybe that crack inclusions or maybe the holes formations or maybe what kind of defects are taking place.

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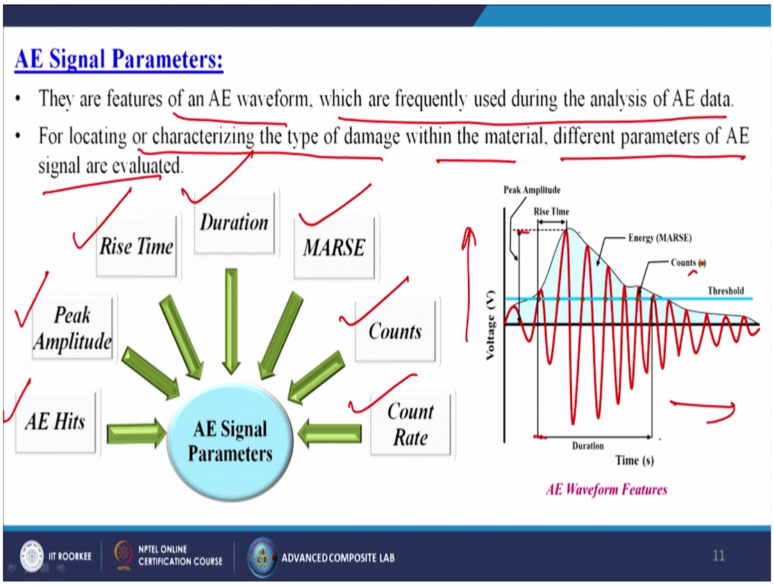

Now AE signal parameters. They are features of an AE waveform which are frequently used during the analysis of AE data. For locating or characterizing the types of damage within the material, different parameters of AE signals are evaluated. So like AE hits, Peak amplitude, Rise time, Duration, MARSE, Counts and the Count Rate. So here this is the AE way from feature over there, this side is the voltage and this side is the time into the x-axis and now you are getting this kind of amplitude or maybe that peak over there. So now this is known as the Peak Amplitude, that is the maximum and then Rise time, then Energy then Counts and the Threshold value and this is the Durations. So these all are the things.

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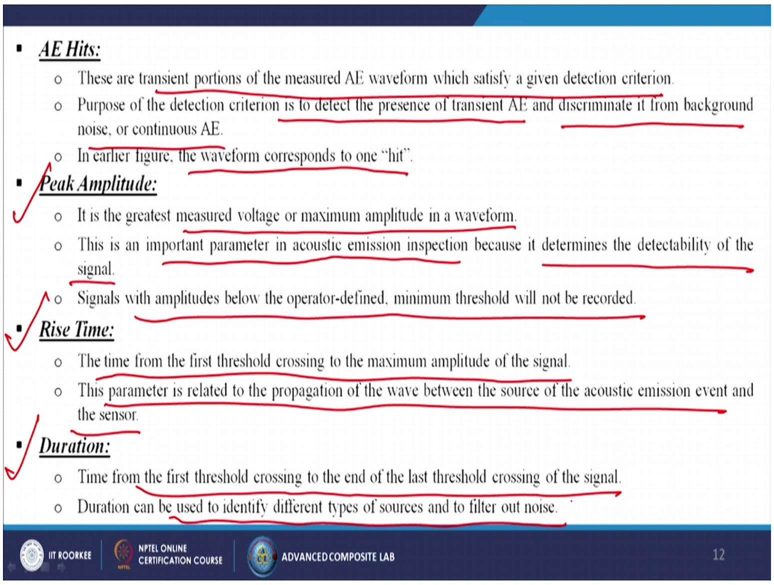

So first come to the AE Hits. These are transient portions of the measured AE waveform which satisfy a given detection criteria. Purpose of the detection criteria is to detect the presence of an transient AE and the discriminate it from the background noise or maybe the continuous AE. In earlier figure, the waveform corresponds to one hit. Next come to the Peak Amplitude. It is the greatest measured voltage or maximum amplitude in a waveform.

This is an important parameter in acoustic emission inspection, because it determines the detectability of the signals itself. Signals with amplitudes below the operator defined, minimum threshold will not be recorded. Rise time, the time from the first threshold crossing to the maximum amplitude of the original signal.

This parameter is related to the propagation of the wave between the source of the acoustic emission event and the sensor. Next come to the Duration, time from the first threshold crossing the end of the last threshold crossing of the signal. Duration can be used to identify different types of sources and to filter out the noise.

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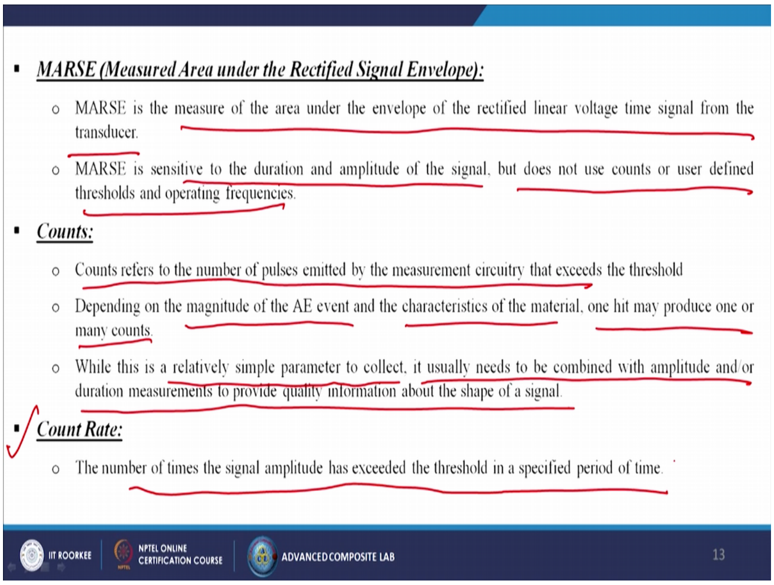

Next come to the MARSE, Measured Area under the Rectified Signal Envelope. MARSE is the measure of the area under the envelope of the rectified linear voltage time signal from the transducer itself. MARSE is sensitive to the duration and amplitude of the signal, but does not use counts or user defined thresholds and operating frequencies. Counts, Counts refer to the number of pulses emitted by the measurement circuitry that exceeds the threshold value.

Depending on the magnitude of the AE event and the characteristics of the material, one hit may produce one or many counts. While this is a relatively simpler simple parameter to collect it, it usually needs to be combined with amplitude and or duration measurements to provide the quality information about the shape of a particular signal. Then come to the Count Rate, the number of times the signal amplitude had exceeded the say threshold in a specified period of time.

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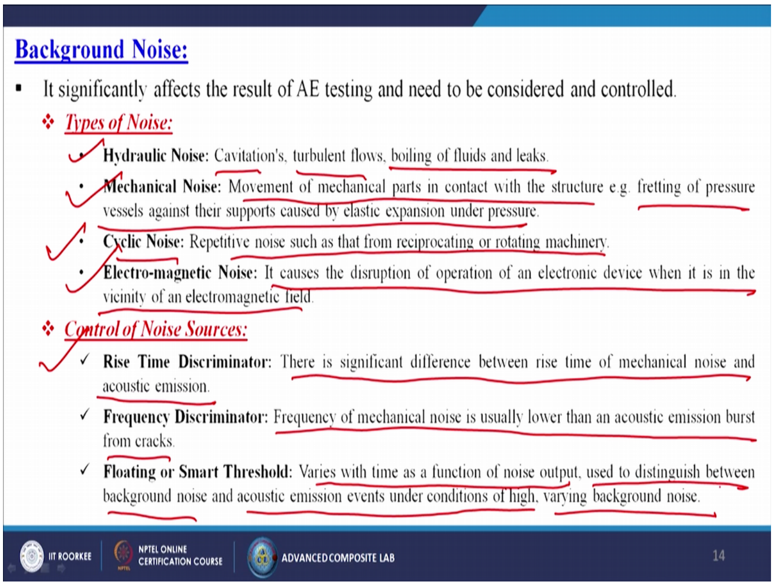

Now come to the Background Noise. It significantly affects the result of AE testing and need to be considered and controlled. Yes. Types of Noise like Hydraulic noise, cavitations turbulent flows, boiling of fluids and the leaks, mechanical noise, movement of mechanical parts in contact with the structure for example fretting of pressure vessels against their supports caused by elastic expansion under pressure. Cyclic noise, Repetitive noise such as that from the reciprocating or the rotating machinery, electromagnetic noise, it causes the disruption of operation of an electronic device when it is in the vicinity of an electromagnetic field.

Control of Noise Sources: Rise Time Discriminator, there is significant difference between the rise time of mechanical noise and acoustic emissions. Frequency Discriminator, frequency of mechanical noise is usually lower than an acoustic emissions burst from cracks. Floating or Smart Thresholds, varies with time as function of noise output, used to distinguish between background noise and acoustic emissions event under conditions of high, varying background noise.

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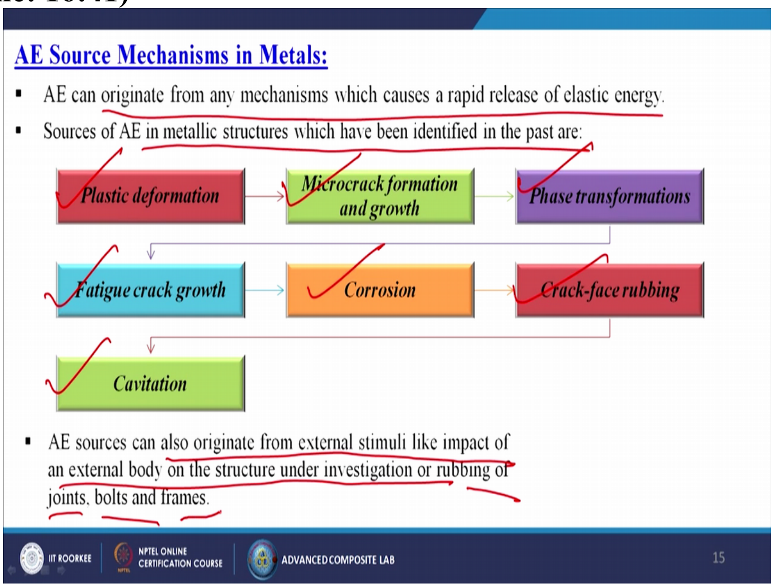

AE Source mechanisms in metals: AE can originate from any mechanisms which causes a rapid release of the elastic energy. Sources of AE in metallic structures which have been identified in the past are, like Plastic deformation, Microcrack formation and growth, Phase transformations, Crack face rubbing, Corrosion, Fatigue crack growth and Cavitation. AE source can also originate from external stimuli like impact of an external body on the structure under investigation or rubbing of joints, bolts and the frames etc.

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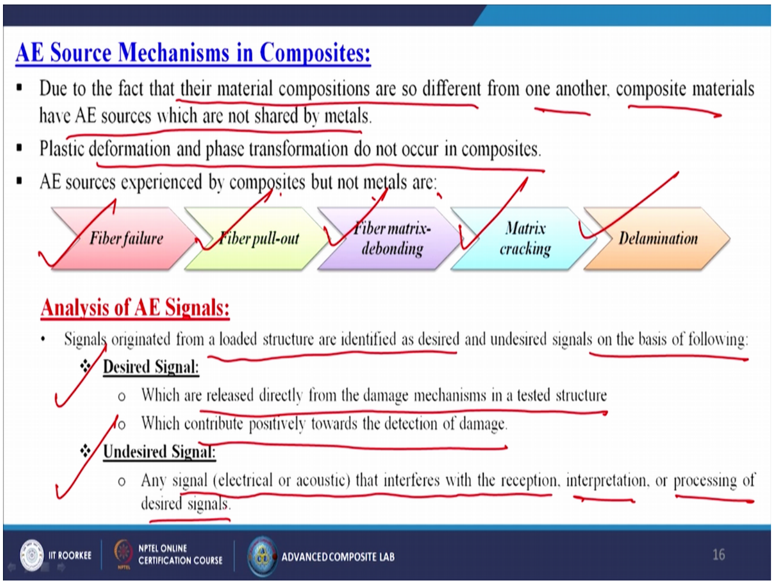

AE Source Mechanisms in Composites: Due to the fact that their material compositions are so different from one another, composite materials have AE sources which are not shared by the metals itself. Because when you are talking about the composite materials, they are having so many materials, we are mixing together. So, plastic deformation and phase transformation do not occur in composites. AE resources experienced by composites but not metals are, fiber failure, fiber pull out, fiber matrix debonding, matrix cracking, and last one is called the delamination.

Analysis of the AE signals: Signals are originated from a loaded structure are identified at desired and undesired signals on the basis of the following, yes, because some signals are originally created by the formations of the cracks or maybe some kind of defects and some are the background noise, some are the machine noise, some are the environmental noise. So these all are the things.

Now which one is your desired signal which are released directly from the damaged mechanisms in a tested structure. Which contribute positively towards the detection of damage. Undesired signal, any signal electrical or acoustic that interferes with the reception, interpretation, and processing of the desired signals.

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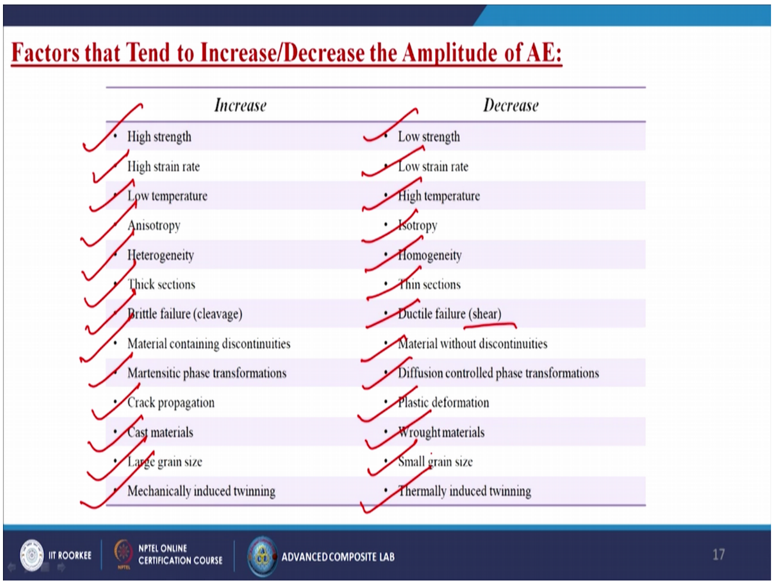

Factors that Tend to Increase or Decrease the Amplitude of the AE: Increase High strength, High strain rate, Low temperature, Anisotropy, Heterogeneity, Thick sections, Brittle failure or maybe the Cleavage, Material containing discontinuities, Martensitic phase transformations, Crack propagation, Cast materials, Large grain size, Mechanically induced twinning.

Which will decrease? Low strength, Low strain rate, High temperature, Isotropy, Homogeneity, Thin sections, Ductile failure or maybe the shear, Material without discontinuities, Diffusion control phase transformations, Plastic deformations, Wrought materials, Small grain size and the Thermally induced twinning.

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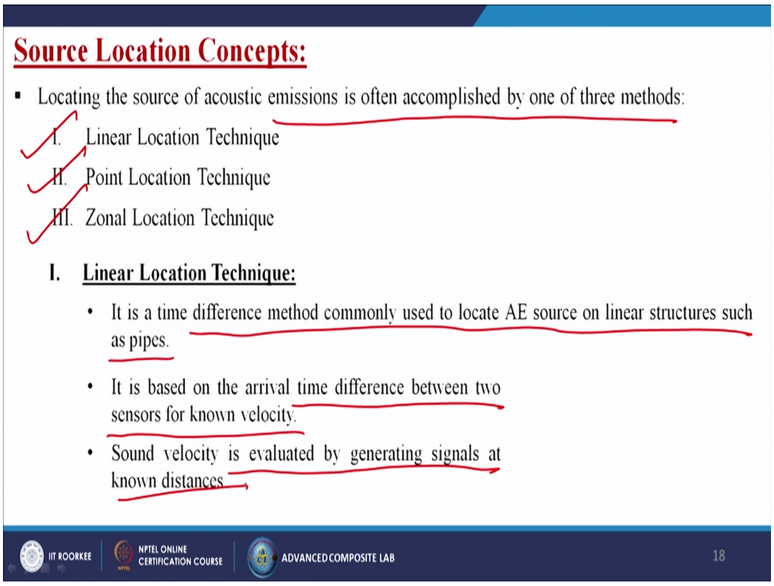

Source Location Concepts: Locating the source of acoustic emissions is often accomplished by one of three methods. One is called the Linear Location Technique, Point Location

Techniques and third one is called the Journal Location Technique. So, What is linear location techniques? It is a time difference method commonly used to locate the AE source on linear structures such as pipes, simple. It is based on the arrival time difference between two sensors for known velocity. Sound velocity is evaluated by generating signals at known distances.

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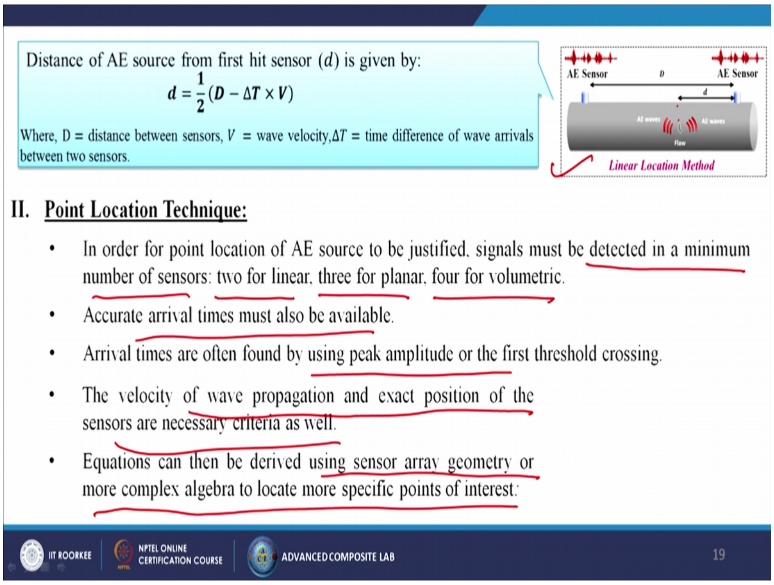

Distance of AE source from first hit sensor is given by small d is equal to half into capital D minus del capital T into capital V, where capital D is the distance between sensors, capital V is the wave velocity, del T is the time difference of wave arrivals between the two sensors. So here you can see we are using two sensors over there, both are giving the peaks over there, and AUFC is generating and flaws are present over there. So small d is this distance and capital D is a distance in between the two sensors. This is called the Linear location method.

Then second one is called the Point location technique. In order for point location of AE source to be justified, signals must be detected in a minimum number of sensors, two for linear, three for planar, four for the volumetric. Accurate arrival times must also be available. Arrival times are often found by using peak amplitude or the first threshold crossing.

The velocity of wave propagation and exact position of the sensors are necessary criteria as well. Equations can then be derived using sensors array geometry or more complex algebra to locate more specific points of interest.

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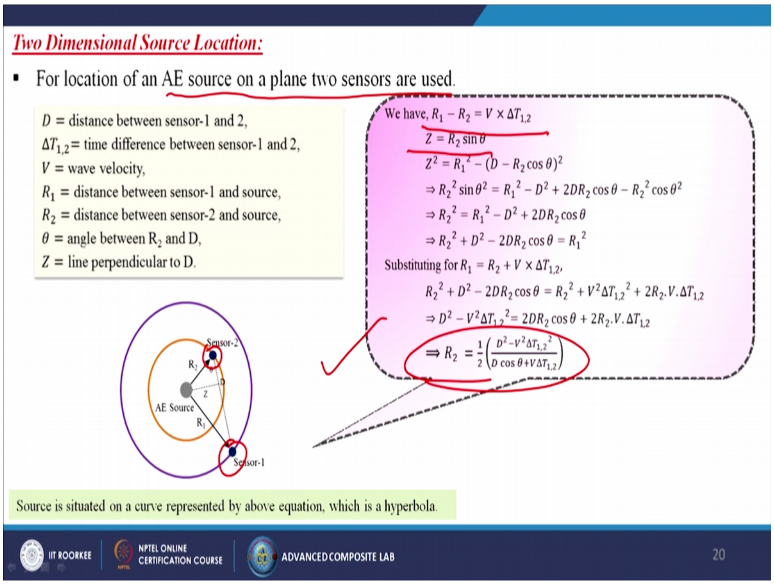

Two-Dimensional Source Locations: So for locations of an AE source on a plane, two sensors are used. So in this case we are putting sensor one over here and the sensor two over here. So now D distance between sensor 1 and 2, del T 1,2 - time difference between sensor 1 and 2, V wave velocity, R1 distance between sensor 1 and the source R2 distance between sensor 2 and source, theta is the angle between R2 R2 and D, and Z line perpendicular to D.

So now in this case, you can get more accurate results. Source is situated on a curve represented by above equations which is a hyperbola. So just we are getting the R2 value by calculating this particular formula, substituting it, because we have R1 - R2 is equal to capital V into del T1,2 - so now we are getting Z = R2 sine theta. So in this particular hyperbola case, now we can calculate and you can calculate the value of the R2.

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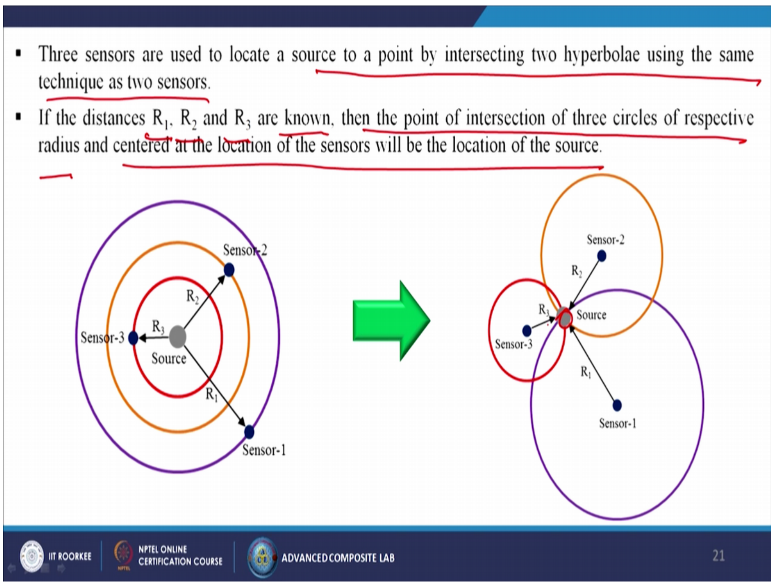

Three sensors are used to locate a source to a point by intersecting two hyperbola using the same techniques as two sensors. If the distance R1 R2 and R3 are known, then the point of intersection of three circles of respective radius and centered at the locations of the sensors will be the location of the source itself. So simple, you can calculate the source positions applying the three sensors.

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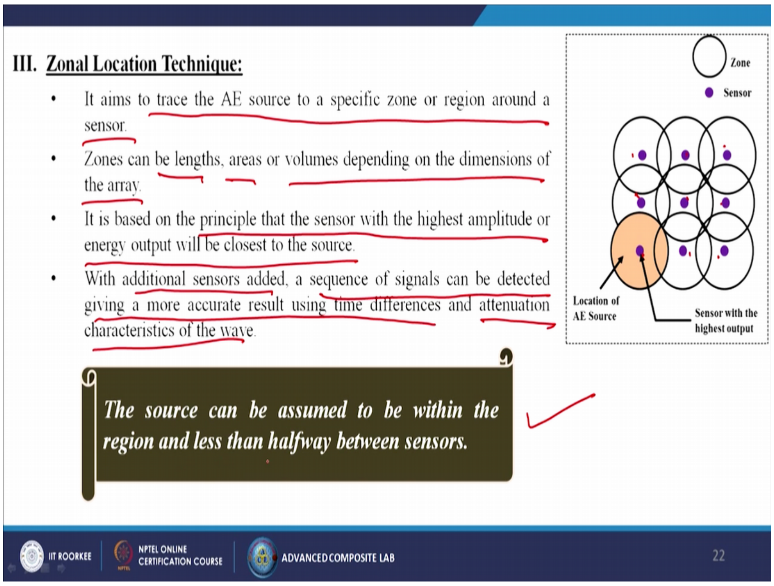

Zonal location technique: Third one, it seems to trace the AE source to a specific zone or region around a sensor. Zones can be lengths, areas, or volumes depending on the dimensions of the array. It is based on the principle that the sensor with the highest amplitude or energy output will be closest to the source itself. With additional sensors added, a sequence of signals can be detected giving a more accurate result using time differences and attenuation characteristics of the wave.

So now here you can see, the location of the AE source, sensors with the highest output is over here. So now we are putting so many sensors over there and now these all are the Zones as created. Zones can be assumed to be within the region and less than halfway between the sensors.

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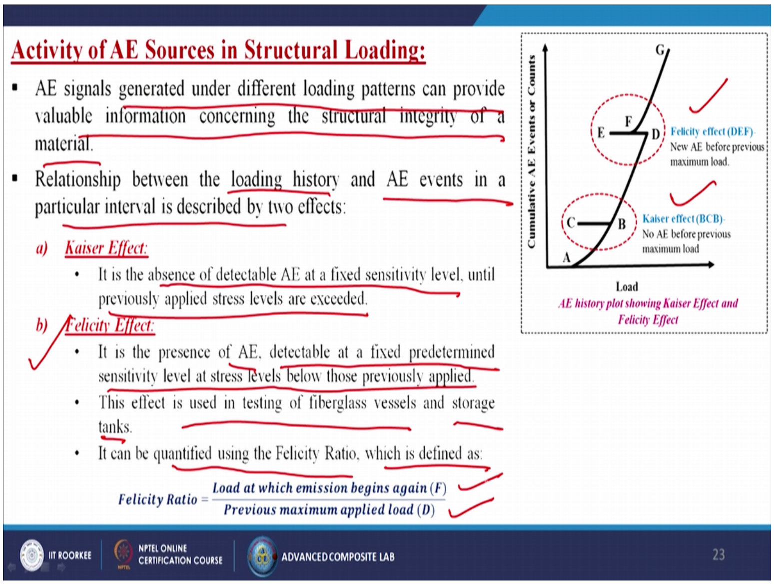

Activity of AE source in the Structural Loading: AE signals generated under different loading patterns can provide valuable information concerning the structural integrity of a material itself. So relationship between the loading history and the AE events in a particular interval is described by two effects. One is called the Kaiser effect or maybe the BCB another one is called the Felicity effect that is the DEF point.

So, in this particular case that BCB this is the Kaiser, no AE before previous maximum load and Felicity effect DEF new AE before previous maximum load, here in the y axis we are having that cumulative AE events or maybe the counts, and x axis it is the load. What is Kaiser effect? It is the absence of detectable AE at a fixed sensitivity level until previously applied stress levels are exceeded.

So constantly we are giving the load so without load and with load. Next is called the Felicity effect, it is the presence of AE detectable at a fixed predetermined sensitivity level at stress levels below those previously applied. This effect is used in testing of fiber glass vessels and the storage tanks. It can be quantified using the Felicity ratio which is defined as load at which emission begins again, previous maximum applied load, that means, one is without any load, another will give you that if there is any residual load is present from the earlier testing.

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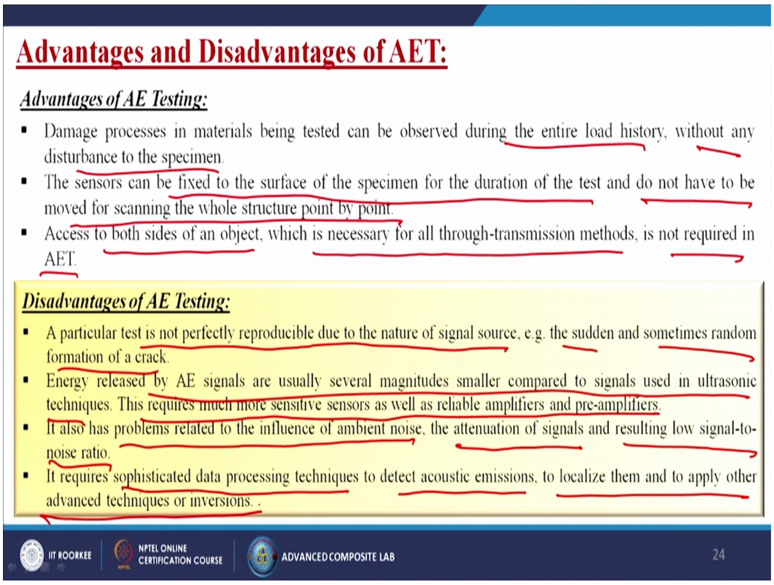

Advantage and Disadvantages of the AET: Advantages of the AE testing: Damage processing materials being tested can be observed during the entire load history without any disturbance of the specimen. The sensors can be fixed to the surface of the specimen for the duration of the test and do not have to be moved for scanning the whole structure point-by-point. Access to both sides of an object which is necessary for all through transmission methods is not required in AET.

Of course we are having certain disadvantages also. What are those? A particular test is not perfectly reproducible due to the nature of signal source the sudden and the sometimes random formation of crack, because we do not know what will happen inside the materials. So pre plan testing is not possible. Energy released by AE signals are usually several magnitude smaller as compared to signals used in ultrasonic techniques.

This requires much more sensitive sensors as well as reliable amplifiers and preamplifiers. It also has problems related to the influence of ambient noise, the attenuation of signals and resulting low signal-to-noise ratio. It requires sophisticated data processing techniques to detect acoustic emissions to localize them and to apply other advanced techniques or inversions.

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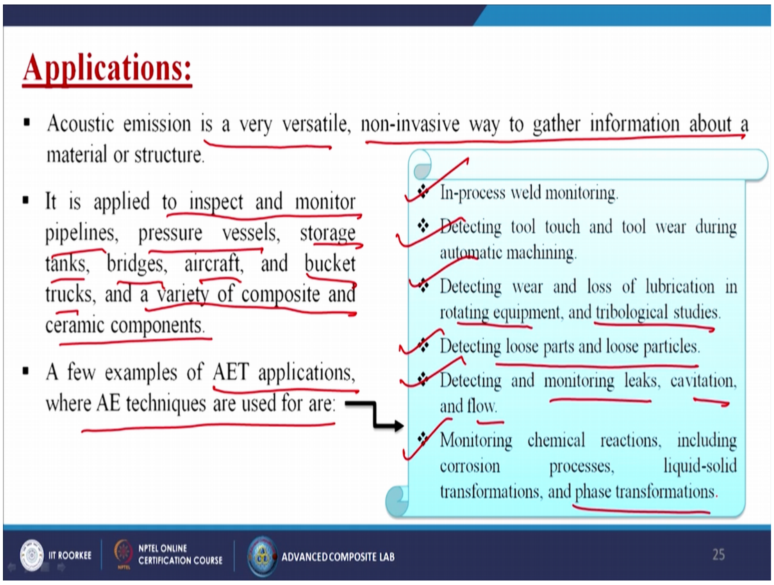

What are the applications? Acoustic emissions are a very versatile non-invasive way to gather their informations about a material or structure. It is applied to inspect and monitor pipelines, pressure vessels, storage tanks, bridges, aircraft, and bucket trucks, and a variety composite and ceramic component. A few examples of AET applications, where AE techniques are used for our, In process well monitoring detecting, Detecting tool touch and tool wear during automatic machining.

Detecting, wear and loss of lubrication in rotating equipment and the tribological studies, detecting loose parts and loose particles, detecting and monitoring leaks, cavitations and flow, monitoring chemical reactions, including corrosion processes, liquid solid transformations and the phase transformations.

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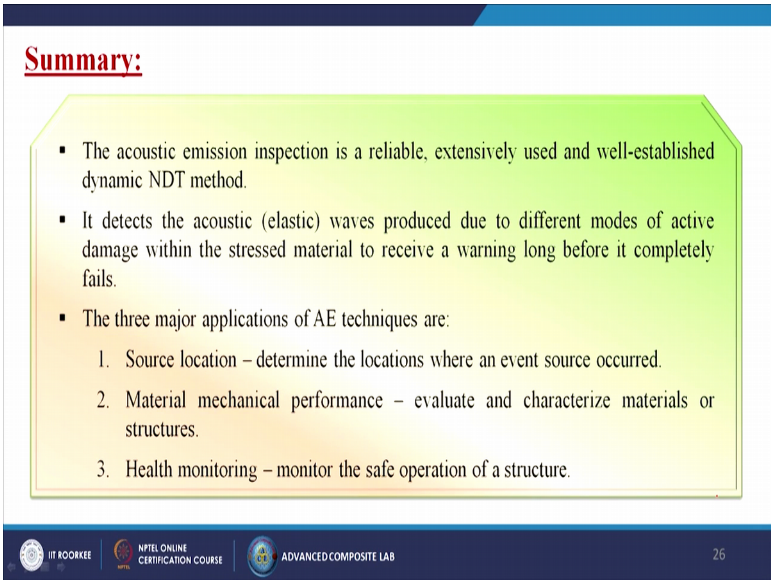

So now we have come to the last light of this particular lecture. So in summary we can conclude that acoustic emission inspections is very very reliable one, extensively used and well established dynamic non-destructive testing. It detects the acoustic waves produced due to different modes of active damage within the stressed material to receive a warning, long before it completely fails.

So when I am installing certain machine or maybe that certain parts, that time only, I am putting the sensors with it and continuously it will monitor, give insights, any crack formation will be taking place, at the initial stage it will give us the signal, and then we can rectify that problem, before it fully film. The three major applications of the AE techniques are, first one is called the Source locations.

Determine the locations where an event source occurred. Material mechanical performance, evaluate and characterize the materials or structures and that third one is the Health monitoring, monitor the safe operation of a structure itself. Thank you.