Structural Health Monitoring (SHM)
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Lecture - 35
Part - 1: Comparison of Damage Detection Methods

Friends, welcome to the 10th Lecture in Module 2 where we will continue to discuss about Comparison of Damage Detection Methods, which will be an extension of the last set of lectures.

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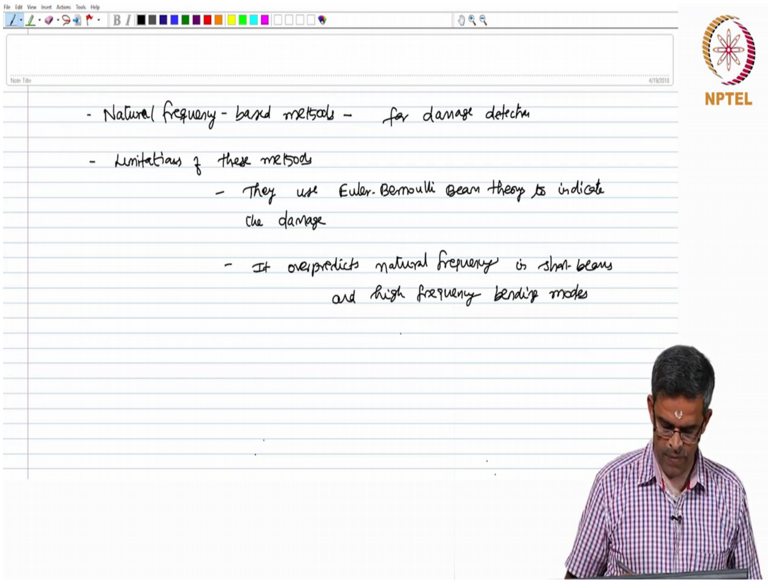

In the last lecture we saw, how natural frequency based methods can be useful for damage detection. We also saw about the limitations of these methods primarily due to the fact that, they use Euler Bernoulli Beam Theory to indicate the damage. And the common convention with this specific theory is that it over predicts the natural frequency in short beams and high frequency bending modes.

Alternatively there are other methods, which are useful, which are vibration based methods, which can also be useful for damage identification. We will discuss about them now.

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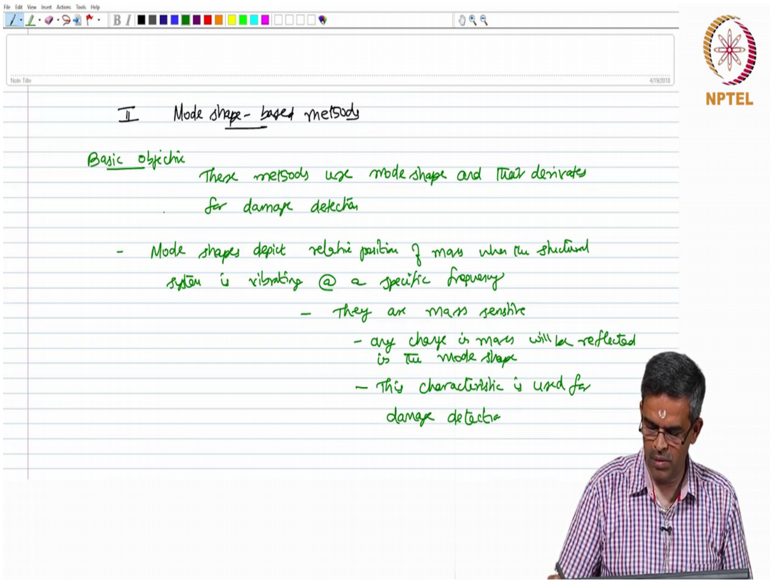

The second method which is popular is based upon the mode shape. So, we say mode shape based methods. The basic objective of these methods or the basic principle I should say is these methods use mode shape and their derivatives for damage detection.

Because, mode shapes actually depict relative position of mass when the structural system is undergoing or let us say is vibrating at a specific frequency. And therefore, they are mass sensitive, that is any change in mass can be I should say will be reflected in the mode shape. And this characteristic is used for damage detection. Mode shapes are very illustrative and interesting to use in case of multiple damage detection.

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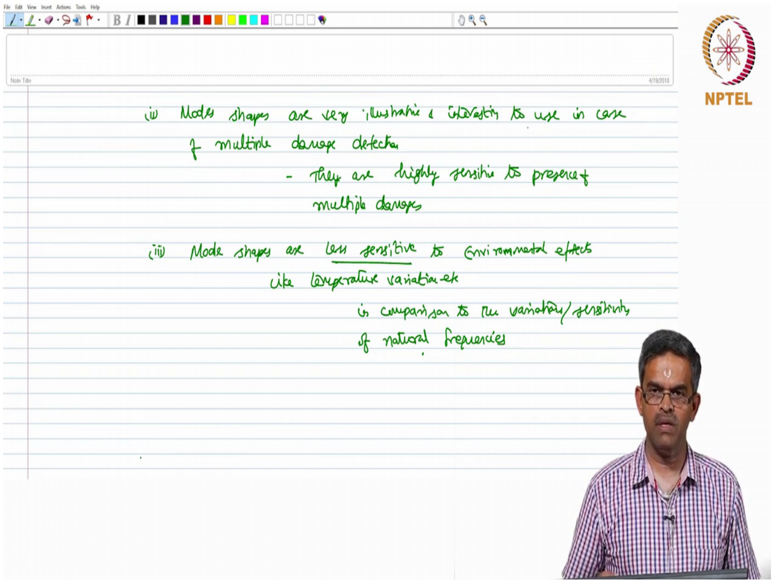

It is due to the fact that they are highly sensitive to the presence of multiple damages.

There is another advantage and basic objective why mode shapes are being used for damage detection; mode shapes are less sensitive, to environmental effects like temperature variation etcetera in, comparison to the variations or sensitivity of the corresponding natural frequencies.

So, it is because of this reasons mode shapes are preferred to identify not even single, but multiple damage locations.

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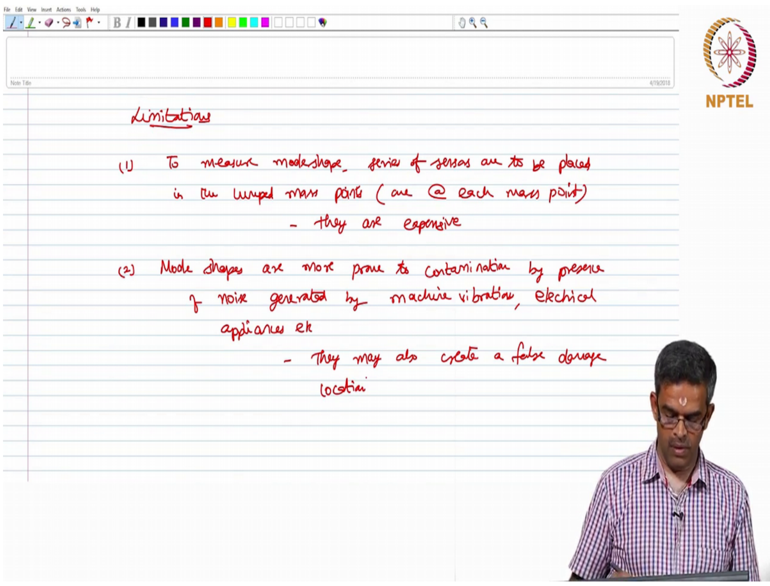

However, these methods have some limitations. In fact, to measure a mode shape series of sensors are required. In fact, 1 at each mass point; so by that logic they are expensive. Second mode shapes are more prone to contamination by presence of noise generated by machine vibrations, electrical appliances, etcetera. So, there is a possibility that they may also create a false damage location.

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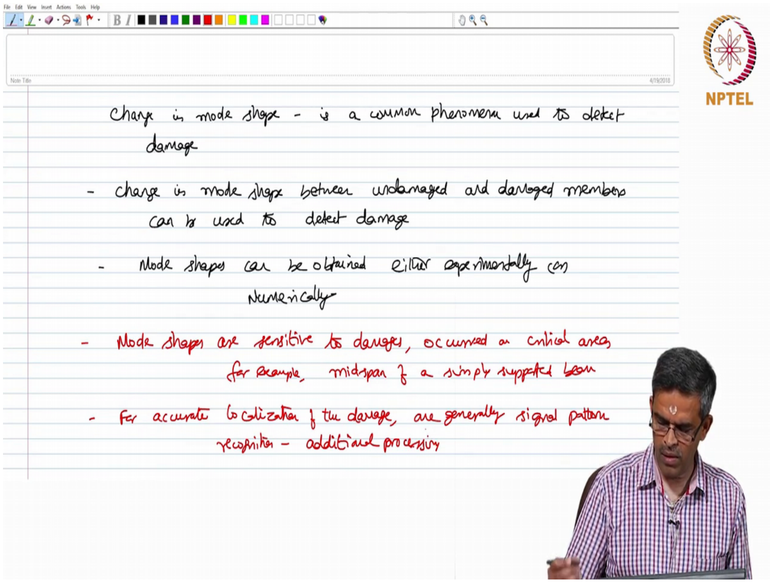

Change in mode shape is a common phenomena used to detect damage, that is change in mode shape between undamaged and damaged members, can be used to detect damage.

Now, mode shapes can be obtained either experimentally or numerically very interestingly one should understand that mode shapes are sensitive to damages, occurred on critical areas. That is say for example, mid span of a simply supported beam. So, damages occurred at other locations in a given member may not influence the change in mode shape between the damage and undamaged conditions.

Further for accurate localization of the damage, one generally uses signal pattern recognition, which requires an additional processing.

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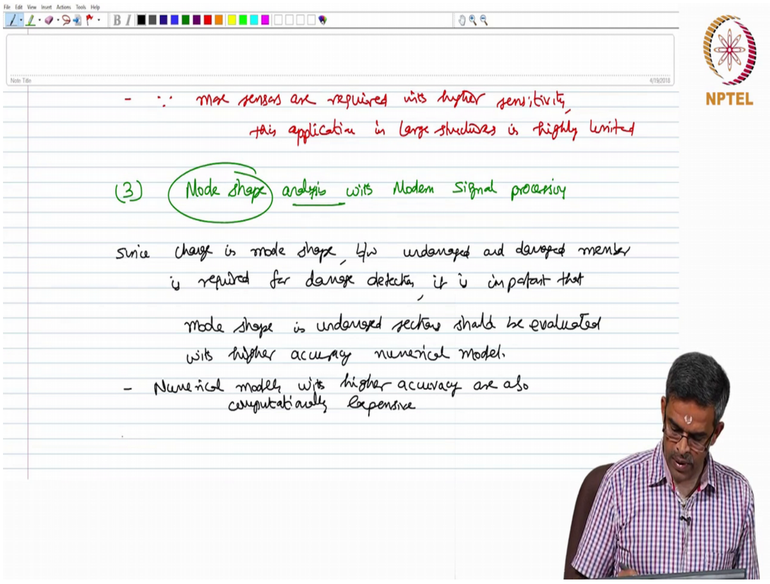

Since more sensors are required with higher sensitivity, this method or this application in large structures is highly limited. Alternatively people use mode shape analysis with modem signal processing.

Let us discuss about this specific method for damage detection, which also principally use mode shape. Now, interestingly friends since change in mode shape between undamaged and damaged member is required for damage detection. It is important that mode shape in undamaged sections should be evaluated with higher accuracy numerical model. We all do agree that numerical models with higher accuracy are also computationally expensive. Therefore, is any possibility that we can avoid the numerical model?

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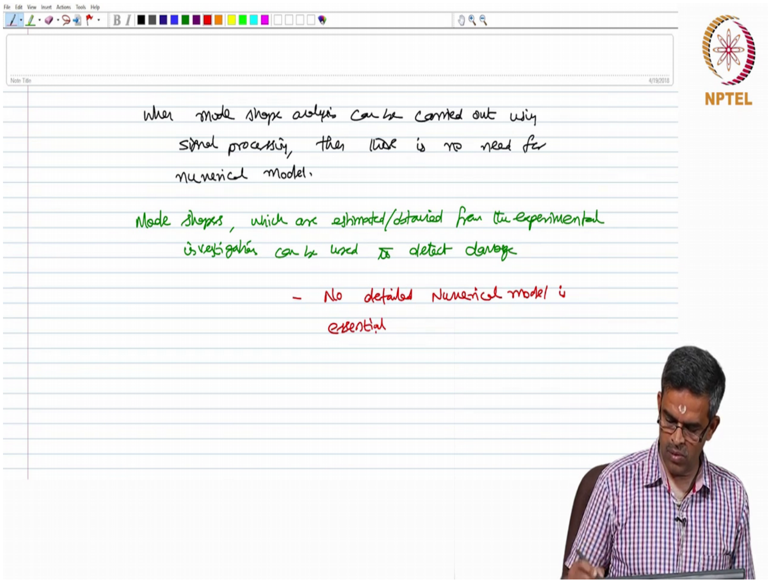

Now, the method which are currently discussing, when the mode shape analysis can be carried out using signal processing, then there is no need for the numerical model. Mode shapes, which are estimated from the experimental studies or which are obtained from the experimental investigations can be used to detect damage.

So, I should say here no detailed numerical model is essential how do we do this?

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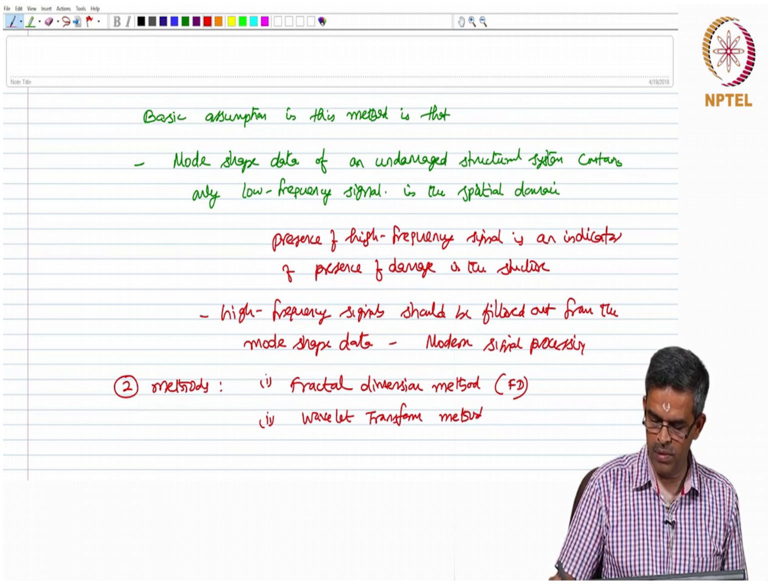

Let us look at the basic ideology or assumption in this method. The basic assumption in this method is that mode shape data of an undamaged structural system contain only low frequency signal in the spatial domain. So, therefore, presence of high frequency signal is an indicator of presence of damage in the structure.

So, therefore, high frequency signals should be filtered out from the mode shape data, which is generally done using modern signal processing. There are 2 methods by which this can be processed one fractal dimension method F D method, the second could be by Wavelet transform method.

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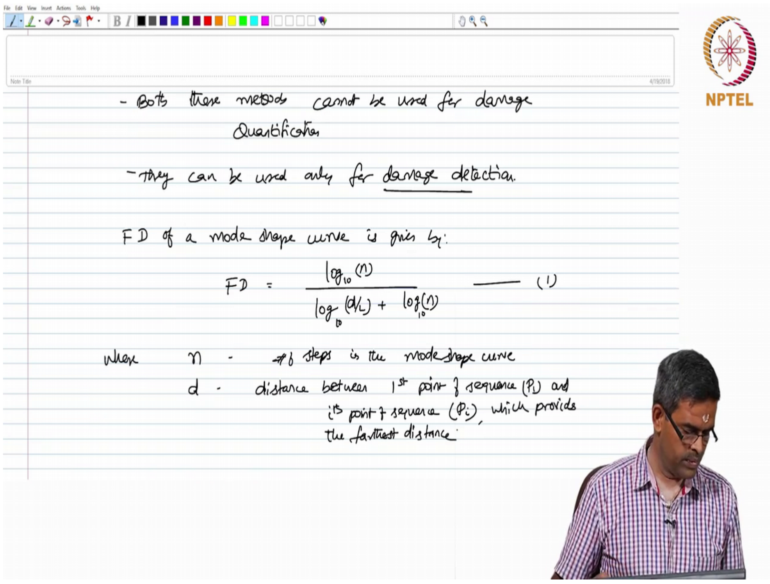

There is a common (Refer Time: 18:03) between both these methods both these methods cannot be used for damage quantification, they can be used only for damage detection, that is very important.

Now, the fractal damage or fractal dimension, the fractal dimension of mode shape curve is given by FD is equal to log 10 to the base I mean log n to the base 10 by log d by l to the base 10 plus log n to the base 10, where n represents the number of steps, in the mode shape curve considered for the analysis d actually represents the distance between first point of sequence, that is P 1 and ith points of sequence that is P i, which actually provides the farthest distance.

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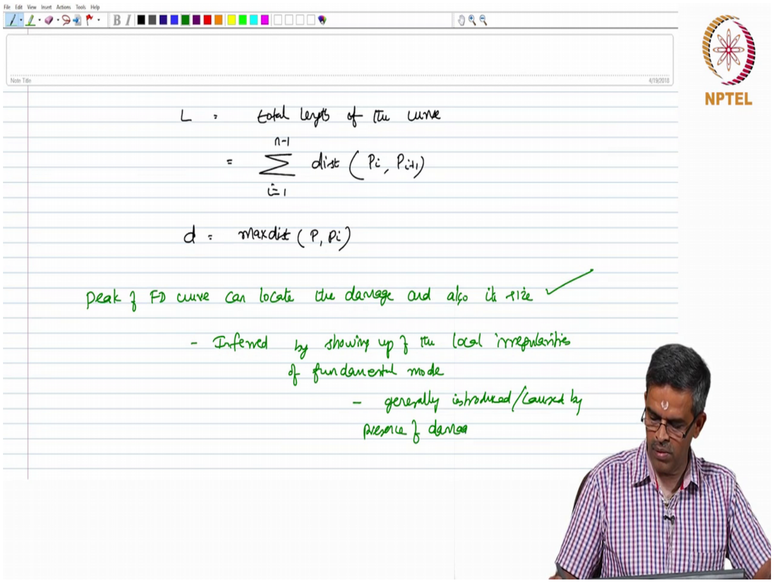

L represents total length of the curve, which is actually given by summation of i equals 1 n minus 1 distance between P i and P i plus 1 whereas, d is a simple function of maximum distance between P and P i.

Now, friends there is another information about the fractal dimension method Peak of the FD curve can locate the damage. And also the size of the damage, that is one main advantage by this method. This can be inferred by showing up of the local irregularities of fundamental mode shape, which is generally introduced or generally caused by the presence of damage.

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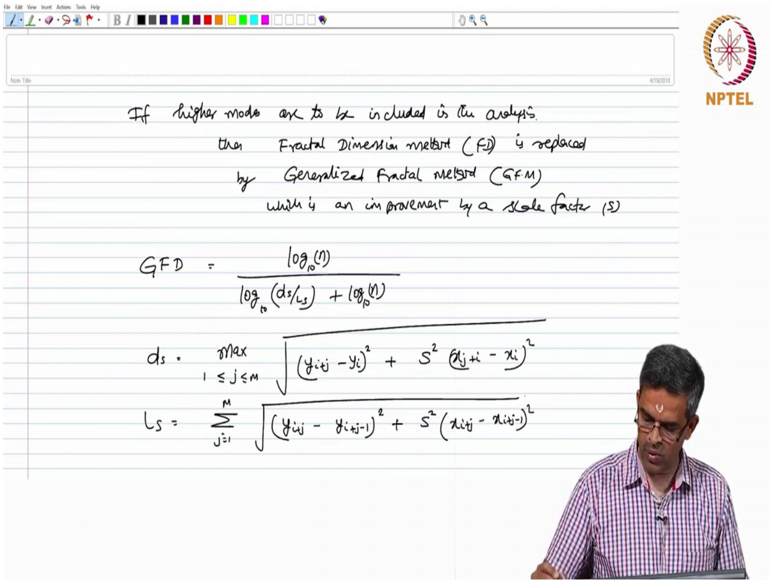

If one nit include higher modes in the analysis, then the fractal dimension method, that is FD is replaced by a method called generalized fractal method, which is an improvement by a scale factor S.

So, generalized fractal method for damage detection is given by log n to the base 10 divided by log d s by L s to the base 10 plus log n to the base 10, where the subscript s indicates, that these values are improved by a scale factor. So, d as in this case given by maximum 1 less than, j less than M square root of y i plus j minus y i the whole square plus the correction factor or the scale factor S square x i plus j minus x i the whole square. And whereas, L S is given by j equals 1 2 M square root of y i plus j minus y i plus j minus 1 that is the previous value square plus S square of x i plus j minus x i plus j minus 1 square.