Structural Health Monitoring (SHM)
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Lecture – 79
Part – 1: Structural Health Monitoring (SHM) of lab model of TLP - III

Friends, welcome to the 8th lecture in module 4. Now, we are going to continue the discussion what we had in the previous lecture. We are going to talk about the design of structural health monitoring system which has been done on the lab scale to investigate the damage analysis of a tension leg platform which is been subjected to postulated failure.

As such the TLP has not failed in the lab, an intended failure has been caused on the TLP model and we are now designing a structural health monitoring system. And an alert monitoring system to see whether the proposed SHM is capable of diagnosing the defect which has happened on the failed model and is it able to communicate the failure to the user client server as required through SMS and email etc. So, we are talking about structural health monitoring of a tension leg platform which is lecture 3 we are investigating it on the lab scale.

As I said one is interested to investigate the postulated failure, so let us say the postulated failure is an intended failure cost on the platform.

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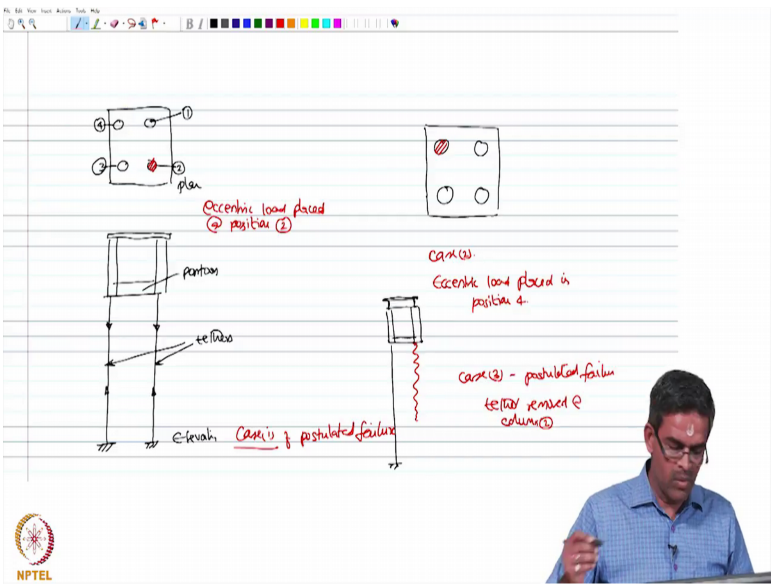

The platform is square in shape with 4 legs at each corner, let us say this is position 1, this is 2, and this is 3, and this is 4, this has got a deck on the top supported by columns and pontoon members at the bottom which are all anchored to the seabed using highly initial axial pretension tethers or let us say cables.

So, this is the pontoon as we have seen already in the last lecture, these are all tethers subjected to axial pretension and these are all the position of 1 2 3 and 4 this is of course, a plan and this is the elevation. In the postulated failure we create different cases let us say in case 1, in case 1 postulated failure there is an eccentric load kept on location 2. So, there is an eccentric load placed at position 2. Case 2 is an eccentric load placed in position 4. So, case 2 eccentric load placed in position 4.

We also have a case 3 if this is the elevation of the platform, these are the legs anchored to the seabed one of the legs is removed that is case 3 postulated failure where tether removed at column 2, ok.

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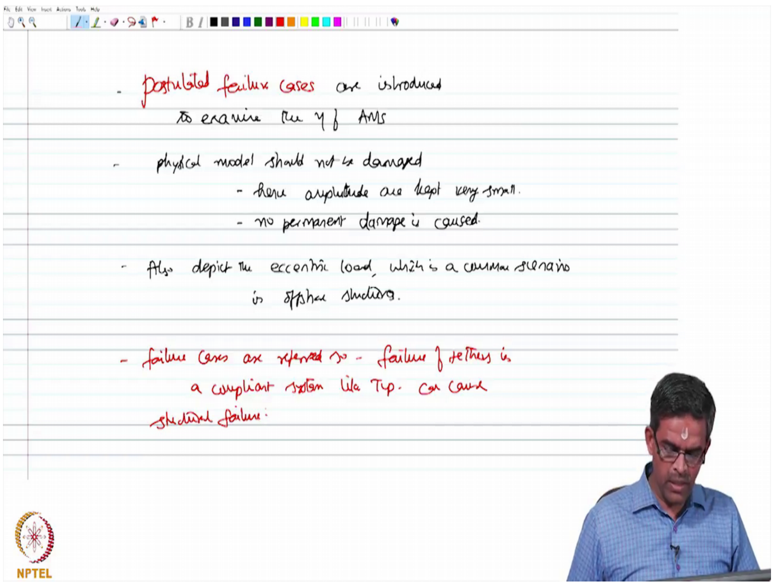

So, the postulated cases are introduced, I should say postulated failure cases are introduced to examine the efficiency of the alert monitoring system. However, the physical model should not be damaged ok, should not be damaged, hence the amplitude of waves are kept very small so that no permanent damage is caused, ok. So, the postulated failure cases also depict the eccentric loading which is a very, which is a common scenario in offshore structures.

Now, they are called failure cases because or referred so, because failure of tethers in a compliant system like TLP can cause failure really ok. I should say can cause your structural failure. So, now, we have seen there are 3 cases postulated case failure 1 with an eccentric load over column 2, you can see here column 2.

Postulated failure case 2 with eccentric load over column 4, then the case 3 is essentially the removal of legs at column 2 and case 4 is removal of leg at column 4 itself, that is removal of tether at position 4, ok. There are 4 cases we have examined the model is excited to a very high wave amplitude and then we want to see the damage condition, ok.

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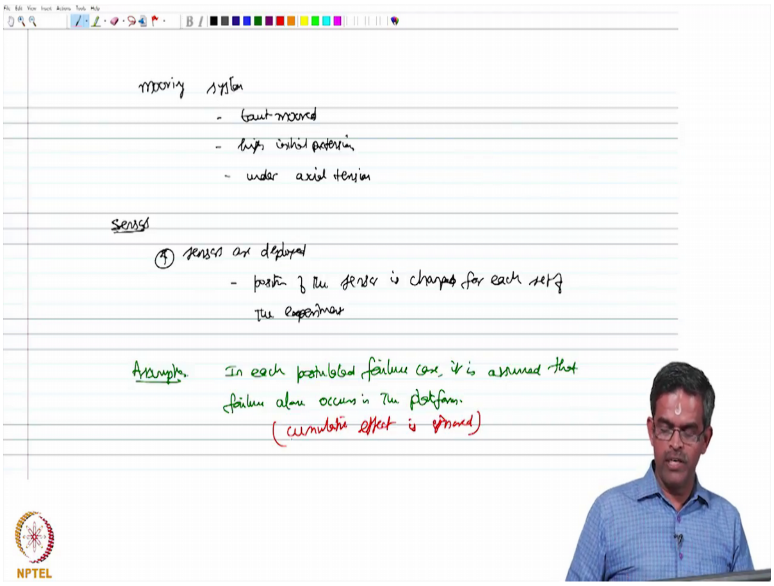

As far as mooring systems are concerned they are taut more with very high initial pretension they are only subjected to axial tension. As far as sensors are concerned 4 sensors are deployed, the position of the sensor is changed for each set of the experiment.

So, there is one assumption which has been made in this study which I will not highlight, in each postulated failure case it is assumed that failure alone occurs in the platform there is no cumulative effect of other failures on the platform. Cumulative effect is ignored only the failure occurs because of the postulated case that is an assumption made.

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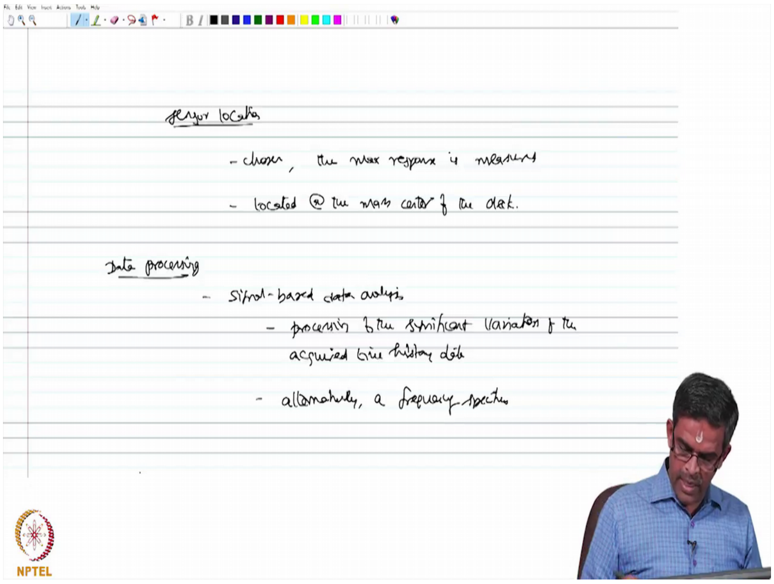

Now, sensor locations are chosen such that the maximum response is measured. They are all located at the mass centre of the deck. So, now, the data processing during the experiments is done with the signal based data analysis, which involves processing of the significant variations of the acquired time history. One can also do alternatively a frequency spectrum.

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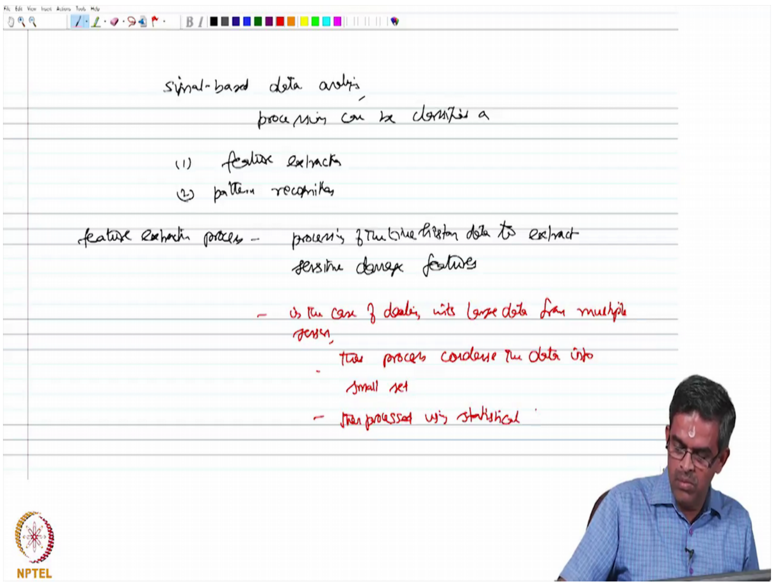

Now, in the moment you say signal based data analysis, then the processing can be classified as one feature extraction, two pattern recognition. The feature extraction process involves processing of the time history data, to extract sensitive damaged features.

Now, in the case of dealing with large data, from multiple sensors this process condense in the data into small set which can be then you processed using statistical tools.

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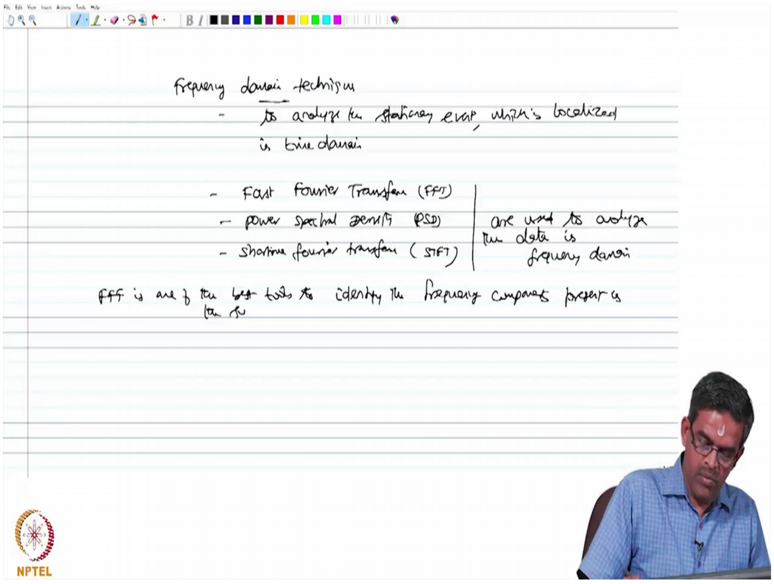

The frequency domain technique to analyze the stationary event which is localized in timeline; So, the tools like fast Fourier transform FFT, power spectral density PSD, and short time Fourier transform which is STFT are used to analyze the data in frequency domain. We all do agree that FFT is one of the best tools to identify the frequency components present in the signal.

Little bit theory about the Fourier transform.

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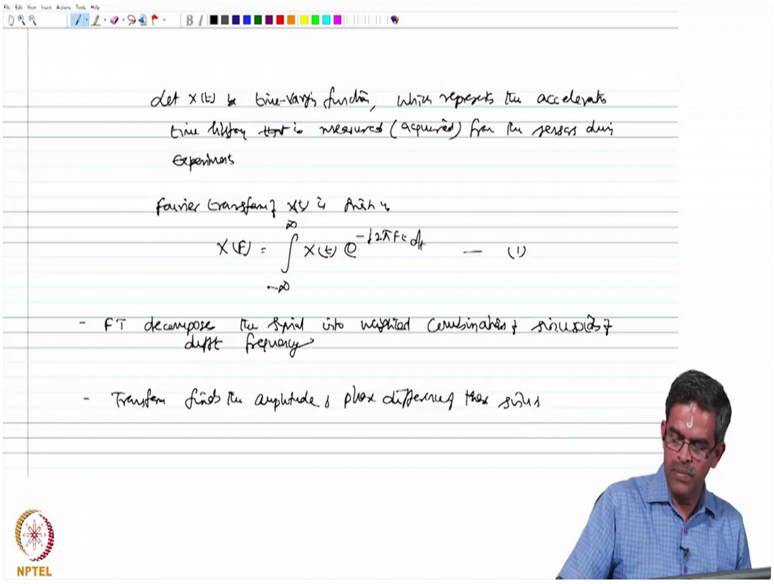

Let X of t be time varying function which represents the acceleration time history that is measured or you should say that is acquired from the census, during experiment.

Now, the Fourier transform X of t is given by X of F which is minus infinity to plus infinity, X of t e minus j 2 pi of t d t. The Fourier transform decomposes the signal into weighted combinations of sinusoids of different frequency. The transform finds the amplitude and phase difference of these sinusoids.

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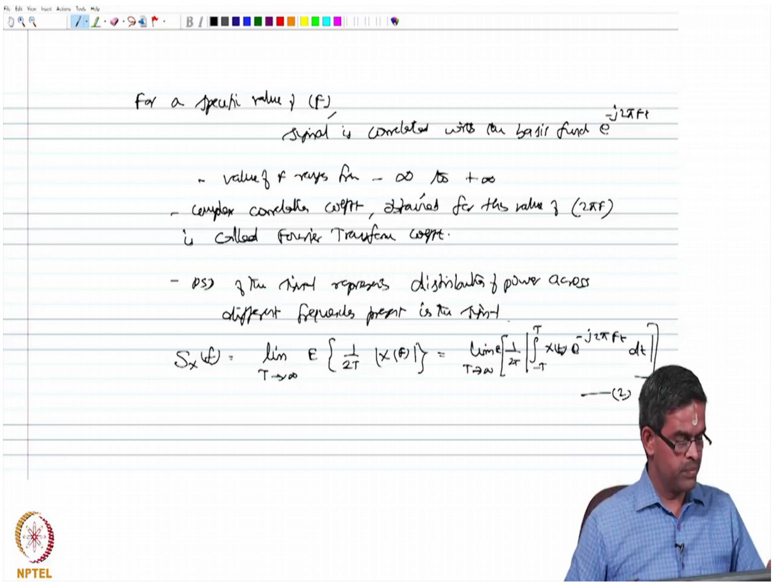

For a specific value of F the signal is correlated with the basic function e to the power minus j 2 pi f t. Now, the value of f ranges from minus infinity to plus infinity, complex correlation coefficient obtained for this value which is 2 pi f is called the Fourier transform coefficient. The power spectral density function of the signal represents distribution of power across different frequencies present in the signal.

And is given by S X f is equal to limit, T tends to infinity to T, X of F mod value is equal to limit T tends to infinity 1 by 2 T expected value of minus T to plus T, X of t e minus j 2 pi f t d t.

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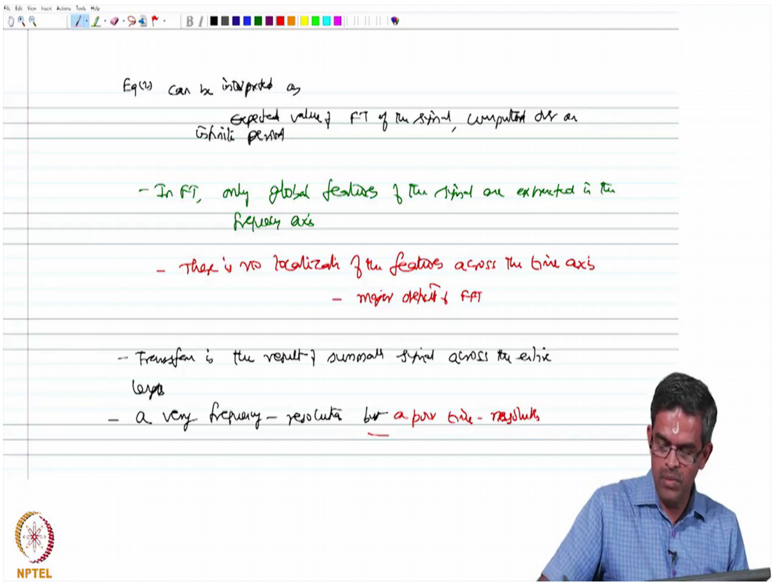

Equation 2, can be interpreted as expected value of the Fourier transform of the signal computed over an infinite period. There is an issue here, in Fourier transforms only global features of the signal are extracted in the frequency axis. Importantly there is no localization of the features across the time axis. This is seen as one of the major deficit of FFT.

Therefore, one can say transform is simply the result of summation of signal across the entire length of the signal; a very good frequency-resolution but a poor time-resolution.

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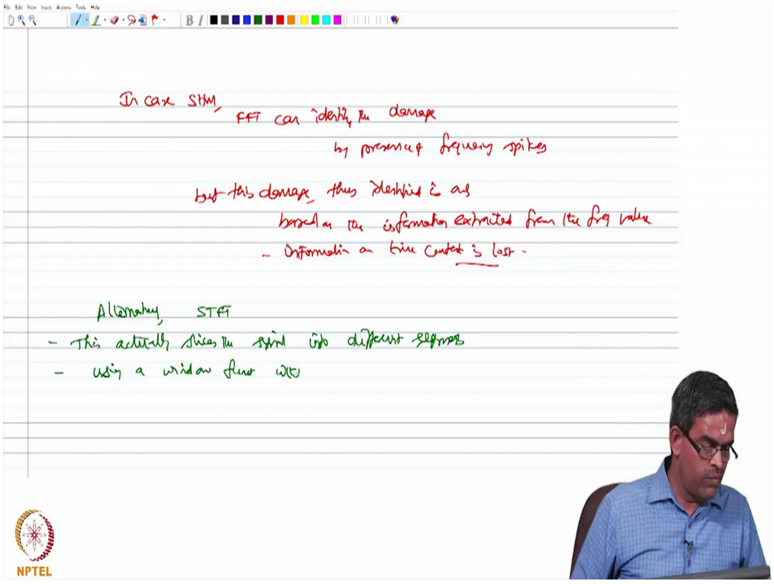

However, in case of structural health monitoring fast Fourier transform can identify the damage by presence of frequency spikes, but this damage thus identified is only based on the information extracted from the frequency value information on time content is lost.

So, what is the alternative? Alternatively one can use STFT, ok. What does it do? This actually slices the signal into different segments. How this is done? This is done using a window function omega of t.

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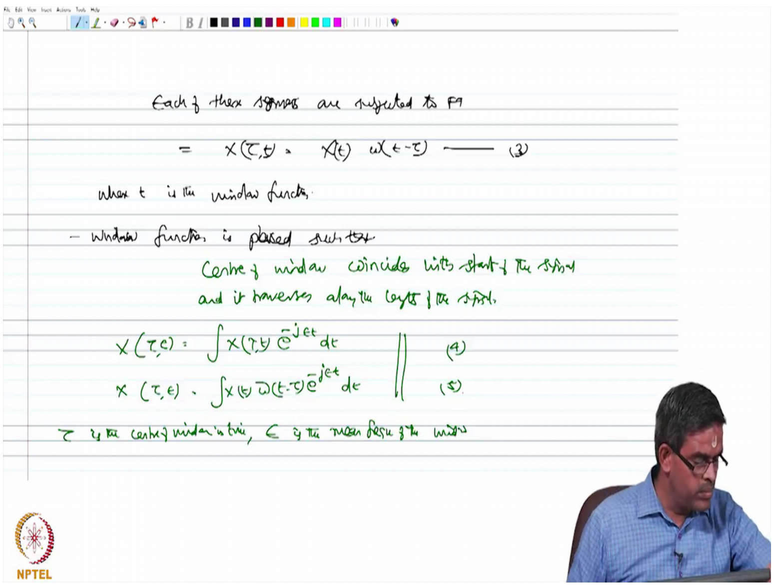

Now, each of these segments are subjected to Fourier transform which is equal to X tau t will be X t omega t minus tau, where t is the window function.

The window function is placed in such a manner, such that centre of the window coincides with start of the signal and it traverses along the length of the signal. Therefore, X of tau epsilon is equal to integral X of tau comma t e minus j epsilon t dt and X of tau epsilon is also equal to X of t omega t minus tau e minus j epsilon t dt, equation let us say 4, 5. In this case tau is the centre of the window in time, and epsilon is the main frequency of the window.