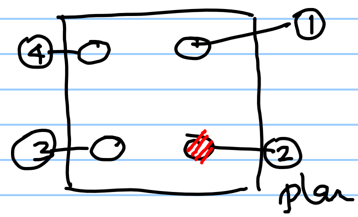
Note Title 5/9/2018

Module 4

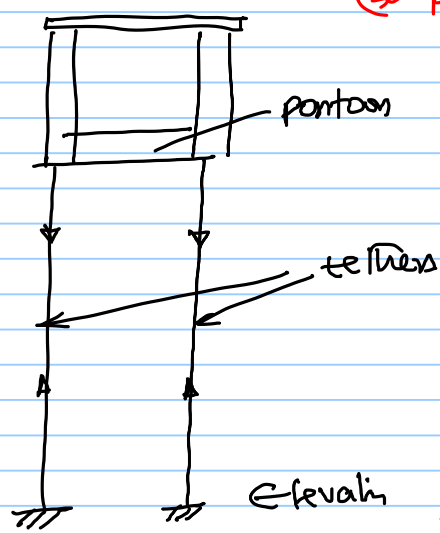
Lecture 8

✓ STHM an TLp - III

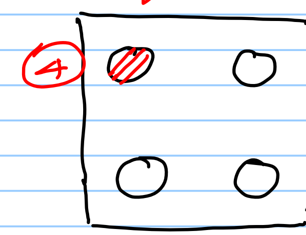
(lab scale)



Eccentric load placed @ position 2



Case (1) of postulated failure



case (2).

Eccentric load placed is position 4.

case (3) - postulated failure

tether removed @ column 2

Case 4. removal of tether @ 4.

- Postulated failure cases are introduced
  to examine the η of AMS

- physical model should not be damaged
    - here amplitude are kept very small.
    - no permanent damage is caused.

- Also depict the eccentric load, which is a common scenario
  in offshore structure.

- failure cases are referred to - failure of tethers in
  a compliant system like TLP. can cause
  structural failure.

mooring system

- taut moored
- high initial pretension
- under axial tension

<u>Sensors</u>

4 sensors are deployed

- position of the sensor is changed for each set of the experiment

<u>Assumptions.</u> In each postulated failure case, it is assumed that failure alone occurs in the platform.
(cumulative effect is ignored)

Sensor location

- chosen, the max response is measured
- located @ the mass center of the disk.

Data processing

- Signal-based data analysis
  - processing of the significant variations of the acquired time history data
  - alternatively, a frequency spectrum

Signal-based data analysis

processing can be classified as

(1) feature extraction
(2) pattern recognition

feature extraction process – processing of the time history data to extract sensitive damage features

- is the case of dealing with large data from multiple sensors
- this process condense the data into small set
- then processed using statistical tools

Frequency domain techniques

- to analyze the stationary event, which's localized in time domain

- Fast Fourier Transform (FFT)
- power spectral density (PSD)
- shorttime fourier transform (STFT)

are used to analyze the data in frequency domain

FFT is one of the best tools to identify the frequency components present in the signal.

Let $x(t)$ be time-varying function, which represents the acceleration time history ~~that~~ is measured (acquired) from the sensors during experiments

Fourier transform of $x(t)$ is given as

$$X(f) = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt \quad — \quad (1)$$

- FT decompose the signal into weighted combinations of sinusoids of diff frequency
- Transform finds the amplitude & phase difference these sinusoids.

For a specific value of (f), signal is correlated with the basis func $e^{-j2\pi ft}$

- value of f ranges from $-\infty$ to $+\infty$
- complex correlation coeff, obtained for this value of $(2\pi f)$ is called Fourier Transform coeff.

- PSD of the signal represents distribution of power across different frequencies present in the signal.

$$S_x(f) = \lim_{T \to \infty} E\left\{ \frac{1}{2T} |X(f)| \right\} = \lim_{T \to \infty} E\left[\frac{1}{2T} \left| \int_{-T}^{T} x(t)\, e^{-j2\pi ft}\, dt \right| \right] \quad (2)$$

Eq(2) can be interpreted as

expected value of FT of the signal, computed over an infinite period

- In FT, only global features of the signal are extracted in the frequency axis

- There is no localization of the features across the time axis
  - major defect of FFT

- Transform is the result of summarizing signal across the entire length
- a very frequency-resolution but a poor time-resolution

In case SHM,

FFT can identify the damage by presence of frequency spikes

but this damage, thus identified is only based on the information extracted from the freq value

- information on time content is lost.

Alternatively, STFT

- This actually slices the signal into different segments
- using a window func $w(t)$

Each of these segments are subjected to FT

$$= \quad x(\tau, t) = x(t)\,\omega(t-\tau) \quad \text{———} \quad (3)$$

where t is the window function.

— window function is placed such that

Centre of window coincides with start of the signal and it traverses along the length of the signal.

$$X(\tau, \epsilon) = \int x(\tau, t)\, e^{-j\epsilon t}\, dt \qquad \| \qquad (4)$$

$$X(\tau, \epsilon) = \int x(t)\, \omega(t-\tau)\, e^{-j\epsilon t}\, dt \qquad \| \qquad (5)$$

τ is the centre of window's time, ϵ is the mean freq of the window

$w(t-\tau)e^{-j\epsilon t}$ is the SFFT – analyzing function

Window should have compact support

- It should exist only over a finite time
- vanish outside the interval

- If the window is too long $\equiv$ length of the signal, this process will converge to FFT

Inverse of STFT is given by

$$X(t) = \frac{1}{2\pi}\iint X(\tau,\epsilon)\, e^{j\epsilon t}\, d\epsilon \quad \text{———} \quad (6)$$

$$= \frac{1}{2\pi}\iint \left\{ x(t)\, w(t-\tau)\, e^{-j\epsilon t} \right\} w(t-\tau)\, e^{-j\epsilon t}\, d\epsilon\, d\tau \quad \text{———} \quad (7)$$

Spectrogram - squared magnitude of STFT

- spectrogram is the energy density in the time-frequency plane

Energy decomposition of the signal is given by:

$$\int |x(t)|^2 \, dt = \frac{1}{2\pi} \int |X(\omega)|^2 d\omega$$

$$= \frac{1}{2\pi} \int\int |X(\tau, \epsilon)|^2 \, d\epsilon \, d\tau \quad \text{— (8)}$$

Spectrogram, $S(\tau, \epsilon)$ is given by

$$S(\tau, \epsilon) = |X(\tau, \epsilon)|^2 = \left| \int x(t) w(t-\tau) e^{-j\epsilon t} dt \right|^2 \quad \text{— (9)}$$

validate the developed SHM system

In order to validate the readings, wireless SHM, response of scaled TLP, is acquired in both wired / wireless sensors

- Results are compared, both in time & frequency domains to estimate error of displacement

- Wired sensors - connected to DAQ through wires
  - data is processed @ central server, which is connected to DAQ

- Wireless sensors
  - low-cost computing modules & sensor units
  - Acquired data will be transmitted thr wi-fi transmitter (SHM system)

Specificatn f accelerometr

	Wired	Wireless
Acc	393B04	Mpu 6050
Type	Integrated circuit piezo electric	MEMS
# f axis	one	3
Range	$\pm 5g$	$\pm 16g$ (opted for $\pm 2g$)
sensitivi	$1V/g$	16384 LSB/g
Noise performance	$0.3\ \mu g/\sqrt{Hz}$	$400\ \mu g/\sqrt{Hz}$

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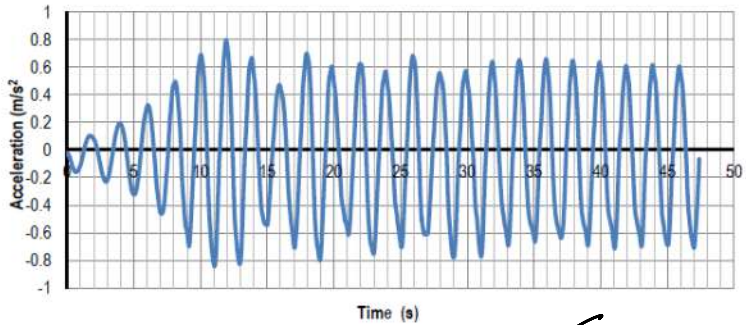
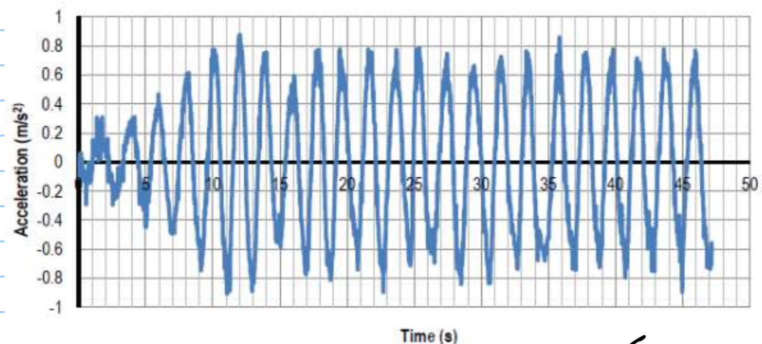
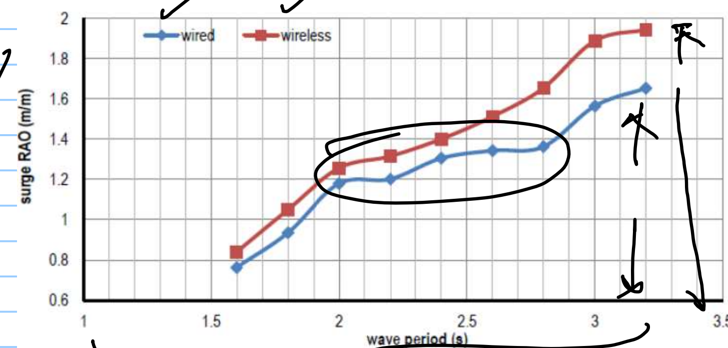


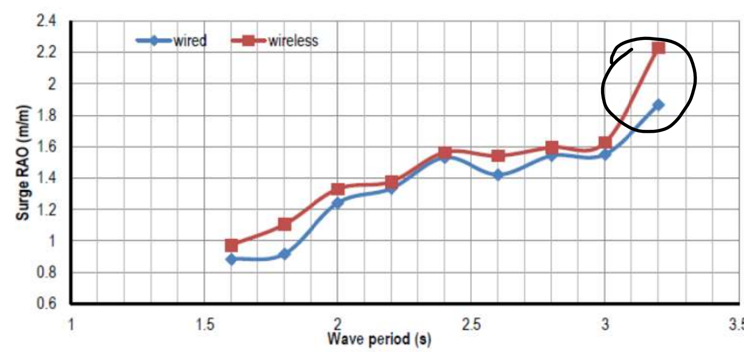
a) Wired acquisition



b) Wireless acquisition

a) surge response.

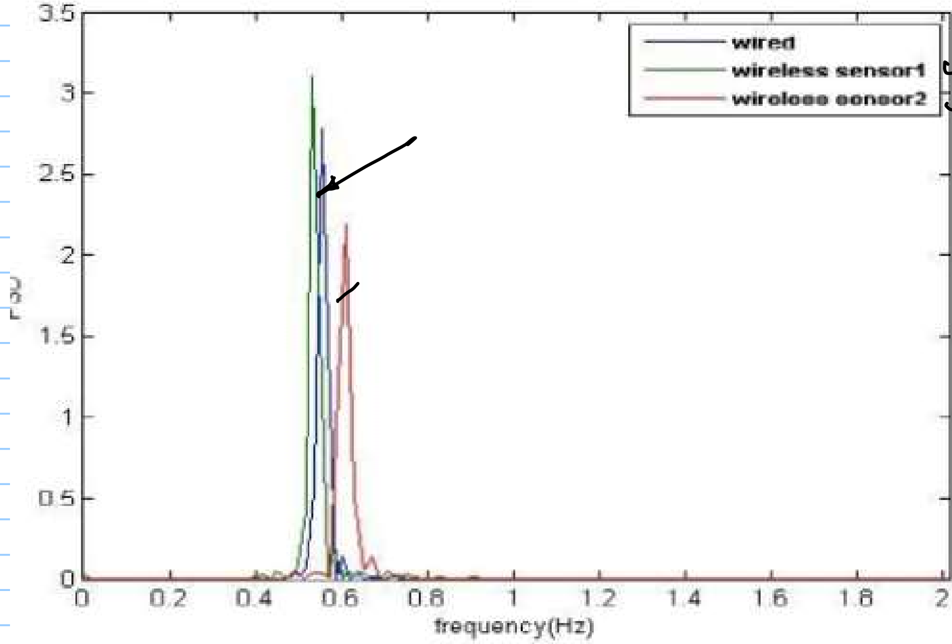




Wave Period (S)	WH = 8cms			WH = 10cms			WH = 12cms		
	Wired	Wireless	Diff in %	Wired	Wireless	Diff in %	Wired	Wireless	Diff in %
1.6	0.76	0.84	10.00	0.89	0.98	10.18	0.89	0.97	9.71
1.8	0.94	1.05	12.28	0.92	1.01	9.58	0.99	1.13	13.67
2	1.12	1.26	6.53	1.25	1.33	7.15	1.18	1.28	8.59
2.2	1.20	1.32	9.43	1.34	1.38	3.26	1.31	1.44	9.36
2.4	1.31	1.40	7.33	1.54	1.57	2.17	1.34	1.53	14.59
2.6	1.34	1.51	12.62	1.42	1.55	8.47	1.42	1.55	9.73
2.8	1.36	1.66	21.41	1.54	1.59	3.44	1.34	1.73	29.77
3	1.57	1.89	20.70	1.55	1.63	4.87	1.53	1.98	29.82
3.2	1.66	1.94	17.57	1.87	2.22	19.50	1.58	1.96	23.46

- On comparison b/w wired & wireless % error is higher for higher periods.

- wired/wireless, variation is less.



Psd of surge response.

- PSD - after post-processing the data

- there is a marginal variation in terms of global features / without time localization.

- peak frequency acquired in both wired & wireless (STM-I)

  - marginal difference

- STM-II, WSN,

  variation with wired - 10%,

- shift in frequency -

  due to time lag

  in the response of the platform.

Reliability of the results

- Reliability problem is formulated
  - assumptions
    1) peak amplitude of the acquired response under normal conditions (no postulated faults)
       - as threshold value
    (2) If response amplitude, acquired during the postulated failure cases exceeds this value, we need to activate the alert monit. sys (AMS)

system failure is defined as user-induced postulated failure. (progressive failure is not considered)

post - process the data.
statistics

Summary

- experimental investig of TYP (lab scale)

Wired

wireless

error %

STM - I

STM - II