UNIVERSITY OF MALAYA

Journal of Zhejiang University-SCIENCE A

Assessment of the phase synchronization effect in modal testing during operation

Key words: Experimental modal analysis, Vibration, Impact-synchronous modal analysis, Impact-synchronous time averaging, Modal testing, Phase synchronization

- Cite this as: Zhi Chao Ong, Hong Cheet Lim, Shin Yee Khoo, Zubaidah Ismail, Keen Kuan Kong, Abdul Ghaffar Abdul Rahman, 2017. Assessment of the phase synchronization effect in modal testing during operation. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 18(2):92-105. http://dx.doi.org/10.1631/jzus.A1600003

Impact-Synchronous Modal Analysis (ISMA)

- Allows analysis to be performed during operation like Operational Modal Analysis (OMA)
- Information of input forces in the transfer functions is available
- Integrated with Impact-Synchronous Time Averaging technique prior to performing the Fast Fourier Transformation (FFT) operation
- Use the modal extraction techniques commonly used in Experimental Modal Analysis (EMA)
- Current device using manual impact hammer

Rahman AGA, Ong ZC and Ismail Z. (2011) Effectiveness of Impact-Synchronous Time Averaging in determination of dynamic characteristics of a rotor dynamic system. Measurement 44: 34-45.

Rahman AGA, Ong ZC and Ismail Z. (2011) Enhancement of coherence functions using time signals in Modal Analysis. Measurement 44: 2112-2123.

Rahman, A. G. A., et al. (2013). Impact-Synchronous Modal Analysis (ISMA)- An Attempt to Find an Alternative. Paper presented at the 5th International Operational Modal Analysis Conference, Guimarães - Portugal.

JZUSA

Problem Statement

- Conventional impact hammer in ISMA creates random impacts.

- At operating speeds that coincided with the natural modes, Impact-synchronous time averaging (ISTA) required a high number of averages.

- Lack of knowledge and control of impact with respect to phase angle of the disturbances using conventional impact hammer in ISMA has limited the effectiveness and practicality of ISMA.

Rahman, A.G.A., Ismail, Z., Noroozi, S., and Ong, Z.C., (2014). Enhancement of Impact-Synchronous Modal analysis (ISMA) with number of averages. Journal of Vibration and Control, 20(11): p. 1645-1655

(Journal of Zhejiang University-SCIENCE A)

JZUSA

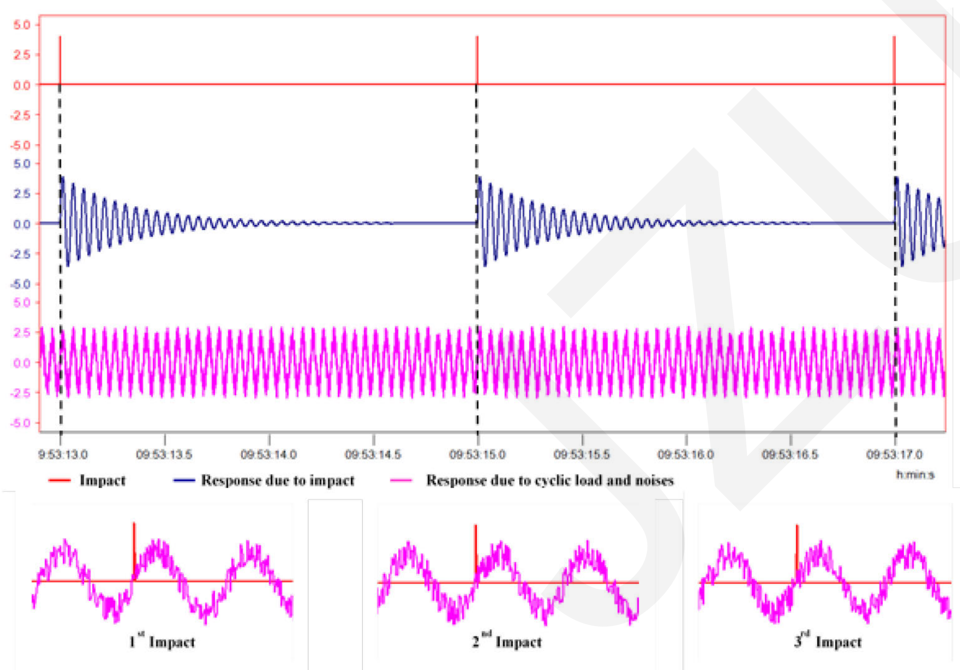
Methodology (Simulation)

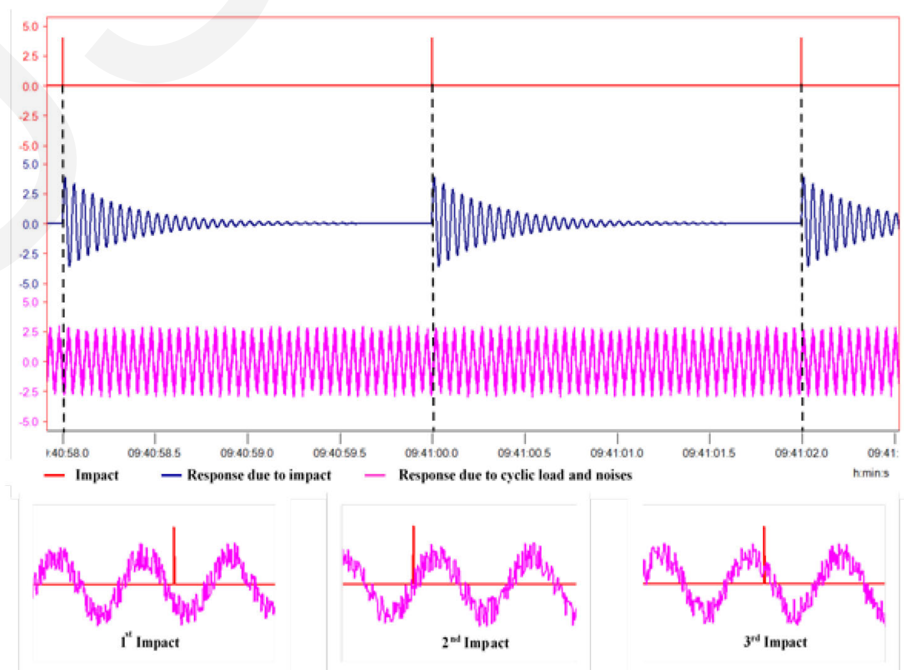
Consistent Phase Condition

The phase angles of response generated by each impact are **consistent** with the phase angles of response due to the cyclic load

Inconsistent Phase Condition

The phase angles of response generated by each impact are **not consistent** with the phase angles of response due to the cyclic load

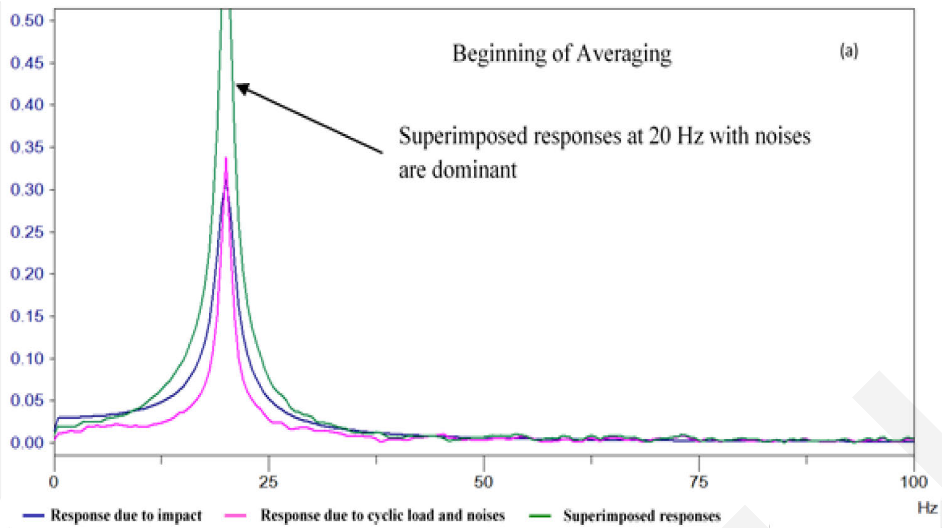


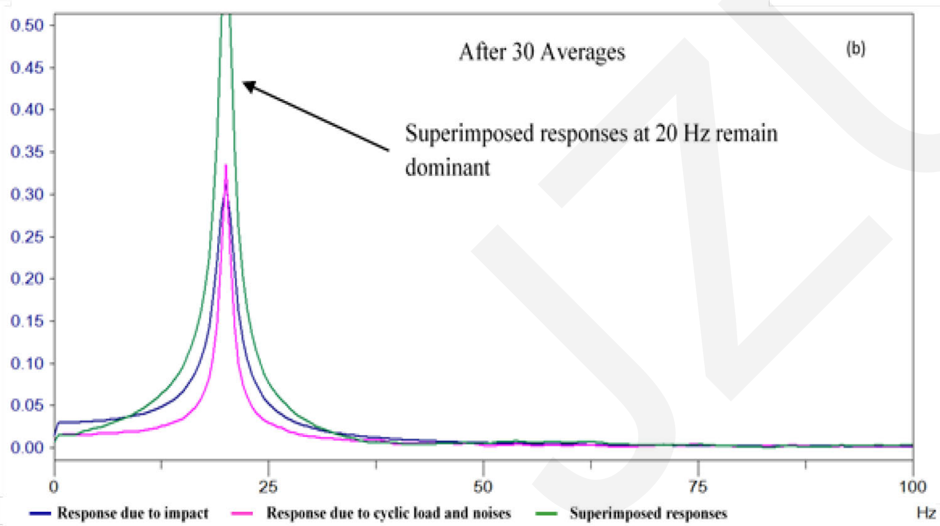


(*Journal of Zhejiang University-SCIENCE A*)

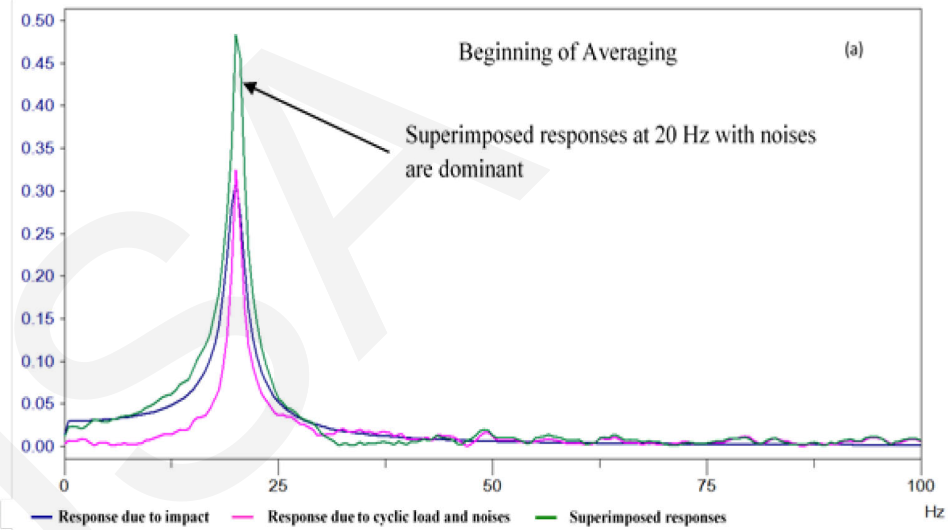
Simulation Results

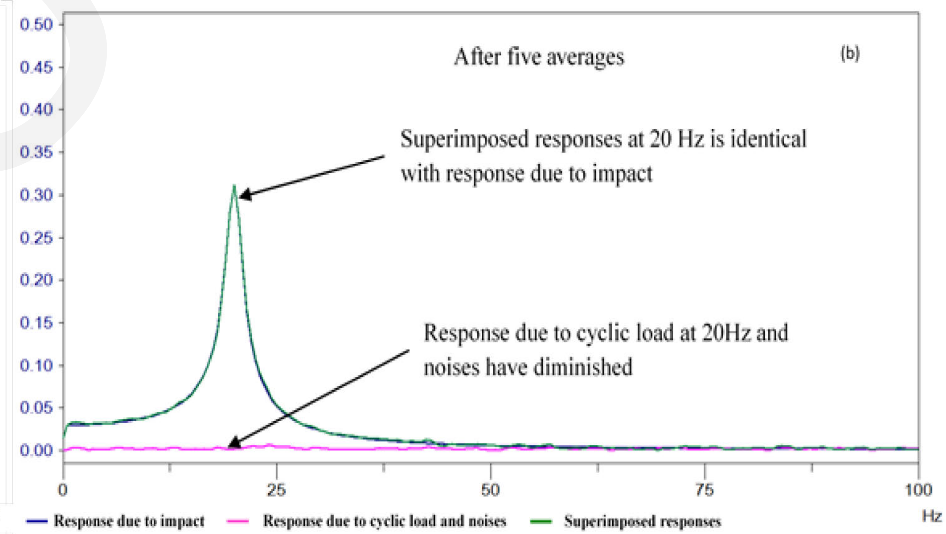
Consistent Phase Condition





Inconsistent Phase Condition



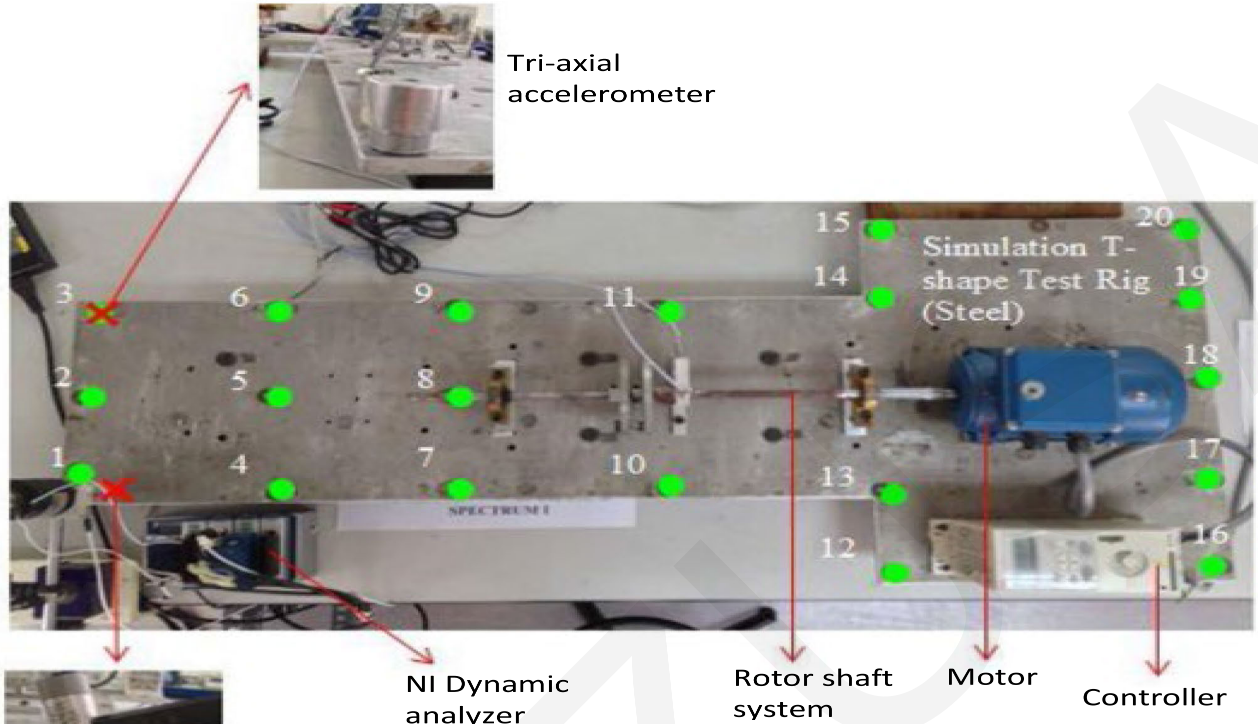


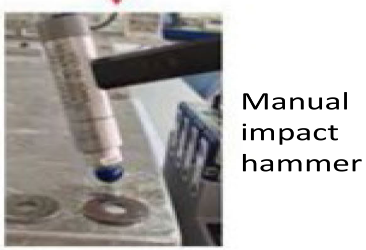
<u>Percentage of improvement at 20Hz after 5 averages</u>

0.3% (consistent phase condition) < 98.48% (inconsistent phase condition)

(***Journal of Zhejiang University-SCIENCE A***)

Methodology (Experimental)



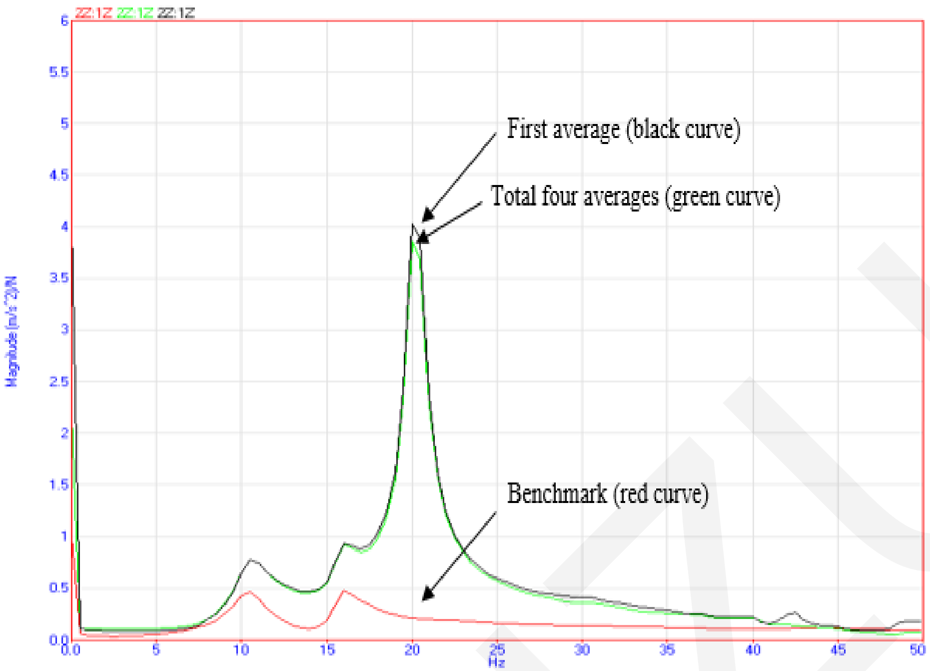


- Sampling rate = 2048 samples/sec, block size = 4096 --- **the vibration signal was collected for 2 seconds**
- The motor was set at **20 Hz** during operation
- Four averages were taken at point 2 during static and operation

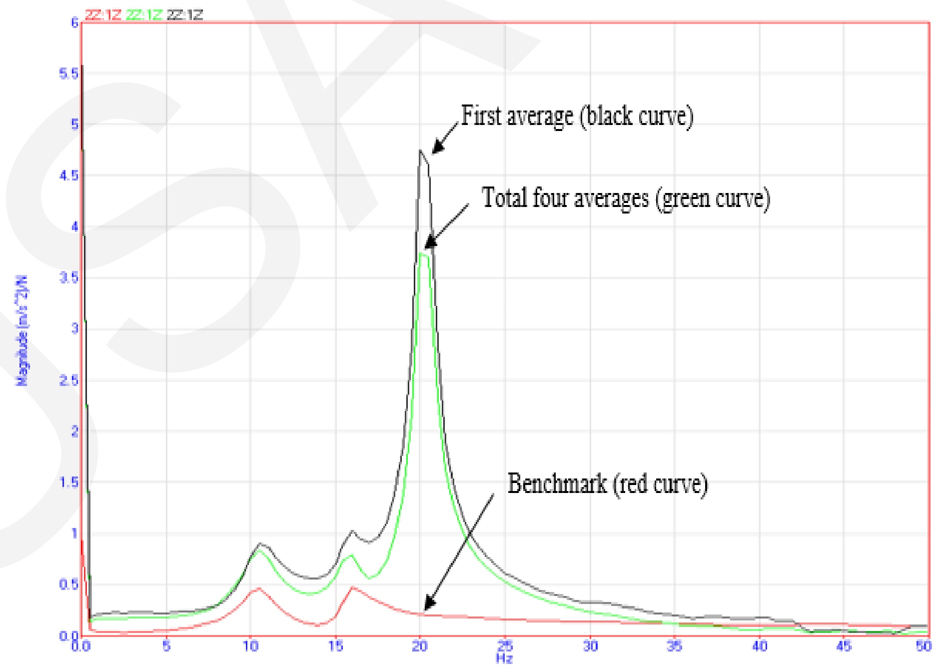
(*Journal of Zhejiang University-SCIENCE A*)

Experimental Results

Scenario 1: Consistent Phase Condition for All Impacts



Scenario 2: Consistent Phase Condition for Certain Impacts



<u>Percentage of improvement at 20Hz</u>

4.96% (scenario 1) < 33.5% (scenario 2)

<u>Percentage of difference for 1st and 2nd natural mode with benchmark data</u>

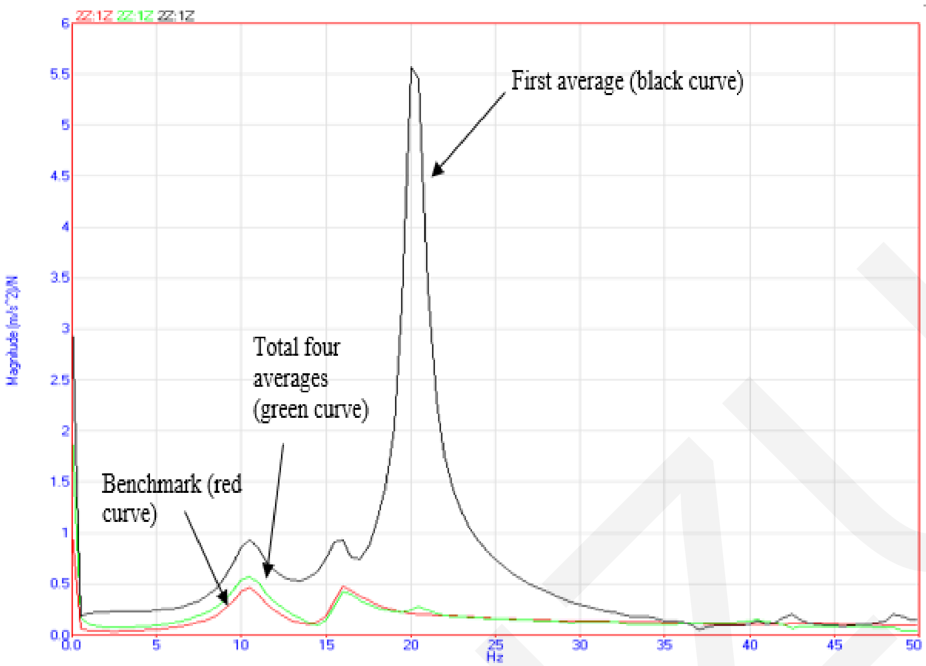
66.37% & 95.29% (scenario 1) > 65.72% & 61.88%(scenario 2)

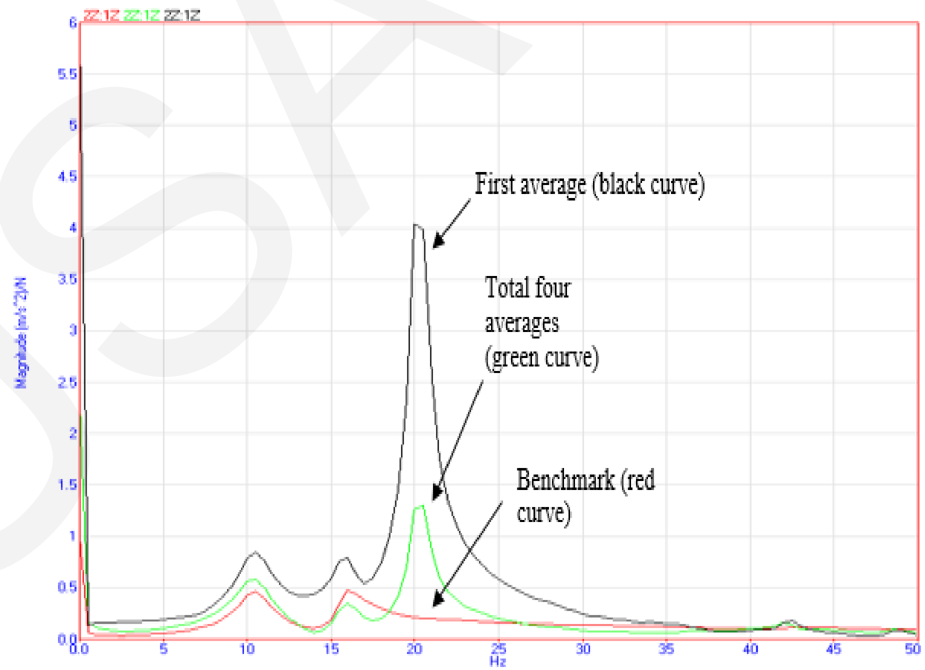
(*Journal of Zhejiang University-SCIENCE A*)

IJUSA

Scenario 3: Inconsistent Phase Condition for All Impacts (Ideal Case: Cyclic Load Components Cancel Each Other Out)

Scenario 4: Consistent Phase Condition for Certain Impacts





<u>Percentage of improvement at 20Hz</u>

95.22% (scenario 3) > 74.75% (scenario 4)

<u>Percentage of difference for 1st and 2nd natural mode with benchmark data</u>

23.8% & 10.49% (scenario 3) < 26.2% & 28.05% (scenario 4)

(***Journal of Zhejiang University-SCIENCE A***)

Conclusions

In this paper, the effect of phase synchronization in ISMA during operation was investigated in simulation and experimental testing in the effort to enhance the effectiveness of the technique. The study looked into two conditions, i.e., consistent and inconsistent phase conditions, between response due to impacts and response from the cyclic load component.

- Small amount of average is sufficient to eliminate the non-synchronous components with 98.48% (simulation), 74.75% (scenario 3) and 95.22% (scenario 4) of improvement when every impact applied is not consistent with the phase angles of periodic response due to cyclic load.

- An improvement of 95.22% in the scenario 3 which is much higher than the scenario 4 indicated that there is probably a relationship tailored between phase angle of cyclic load component with respect to impact applied.