Application of Synthetic Signal in High-Tech Factory Building

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Abstract: Due to electricity wirings setup and gas transmission pipelines allocation, high-tech factory buildings all equipped with elevated floors. However, the elevated floor usually amplifies the floor vibration into multiple times. This study applies these common background vibration factors, i.e. the movement of material handling equipments, the running motors inside mechanical facilities, the operation of air conditioning equipments and personnel walking around, etc. then based on in-field measurement results to apply Ensemble Empirical Mode Decomposition (EEMD) to proceed signal separation in order to build up the signal characteristic from each vibration source. Hereafter, apply MATLAB signal processing and white noise to simulate the synthetic signal formation then compare to its actual measured results. Lastly, this synthetic signal here is applied as the background vibration signal as the input data for SAP2000 Structural Analysis Software program, then proceed cross-analyzed with comparison to its actual measured results. The finding of this research indicates EEMD technology efficiently separate the major frequency from the signal and the wave theory effectively simulate its actual measured results. Besides, the synthetic signal generated from white noise can efficiently simulate the characteristic of on-site background signal and replace the in-field measured signal to proceed the time history analysis of the base. In the future, as long as built up sufficient signal characteristic database from versatile activities, the micro vibration specification value can be controlled to fit for every base in the preliminary planning stage.
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1. Introduction

Accompany with the trend of refined development in the feature and size of components, the requirements of chips manufacturing environment has become more challenging compare to the past, especially when it relates to ambient vibration issue(s). Due to electricity wirings setup and gas transmission pipelines allocation, high-tech factory buildings all equipped with elevated floors However, the elevated floor usually amplified the vibration into multiple times. The natural frequency inside high-tech factory buildings is around in 2~15Hz and the sensitivity frequency of most precision equipments base is around in 4~80Hz. As a matter of fact optoelectronic process and semiconductor equipments are extremely sensitive to micro vibration; therefore, when the natural frequency from the base and the building construction is close, the resonant vibration effect is easily generated between them within its sensitivity range where its affecting frequency range extends. This consequence has unfavorable impacts on the high-tech industry required critical vibration specification. These precision equipments must be allocated in the environment under standard vibration for greater functionalize its efficiency. Herewith, apply these vibration factors taken place frequently in the high-tech factory buildings. i.e. natural frequency from the building, machinery facilities, personnel walking, traffic, etc., to simulate the frequency and amplitude under every kinds of vibration circumstances to build up the database. Later the data is applied to simulate these possible generated vibrations. This helps to control the vibration characteristic of the base in the preliminary planning stage and discover the problem for seeking improvements as soon as possible (Zhong et al., 2003; Wang et al., 2003; Tu, 2006; Xie, 2007, Ding, 2004; Zeng, 2007; Huang et al., 1998).

2. Ensemble Empirical Mode Decomposition (EEMD) and White Noise

Empirical Mode Decomposition (EMD) method decomposed a complex signal of non-linear and non-stationary ones in the time domain. There is no need to apply any basis function as its distinguishing feature; simply it applies upper envelope method to separate the complicated signal data set into finite or smaller number of components called Intrinsic Mode Function (IMF) and left one residue. The characteristic of IMF signal is in symmetric, with the same number of extrema (its maximum and minimum), differ at most by one, and its mean value is close to zero. It’s easily occurred mode mixing problem to make the decomposed IMF affected by lots of uncertain factors. The results of this research indicates EMF theory have broadly applied into real practice among different fields. Its decomposition equation shown as follows (Huang et al., 1998):

$$x(t)=\sum_{i=1}^{n} IMF_i(t)+r_n(t)$$

In this equation: $x(t)$ indicates the signal waits for decomposition; $IMF_i(t)$ indicates the IMF value decomposed by EMD; $r_n(t)$ indicates the residue. The ideal setting of EMD component is the signal not polluted by noise; therefore, every IMF disclosure the meaningful amount from a signal. However, if signal being polluted by its contained noise, the calculated instantaneous frequency from IMF cannot be efficiently valid in its theoretic value. Herewith, represent the modified EMD analysis method (so-called EEMD) and its procedure has shown as follows.

(1) Add sufficient white noise into the original signal contained with noise, then proceed EMD to get one set IMF;
(2) Repeat abovementioned (1) procedure for several times, but every time apply the newly generated white noise and add it into the original signal;
(3) Apply these IMF value derived from EMD results and get its Ensemble Average value. The ultimate IMF is the goal result here.

The ultimate IMF value must be corresponding to the original signal with 0.2 as standard deviation. But it still depends on the signal frequency itself. If the major signal is in low frequency then its noise amplitude value can be bigger; otherwise, it lowers down its noise signal amplitude. The equation definition shown as follows (Wang et al., 2003):

$$IMF_1^{'}=\sum_{i=1}^{N}\left(IMF_1\right)_i$$

In random vibration analysis, it always assumed the signal source is the random white noise in stability and its characteristic is same as the time domain Fig.1 indicates that its curve is really stable. From its frequency domain same as Fig.2 indicates that its energy and power spectral density is very even. Its autocorrelation coefficients same as Fig.3 indicates that it has powerful energy at the original time point but accompany with faster decreasing condition. This signal can be applied here to analyze these structural responses, the energy from the micro vibration signal is relatively small and all locates in the linear range so its structural responses shall be referred as linear behavior. This value only relates to the mass ratio μ. However, its external vibration frequency usually has certain variation range to make the main system frequency falls within these two resonant vibration points. In general, it required μ.>0.1, if the main system has influenced by other different vibration frequency, shall pay more attention to these vibrations see if generates new resonance(s) at the resonant point.

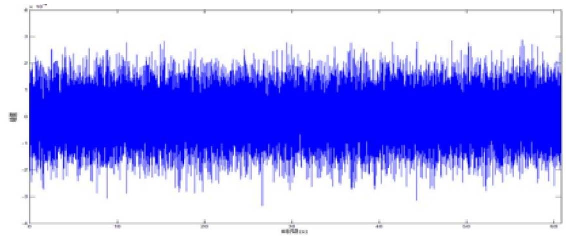

Figure 1. White Noise

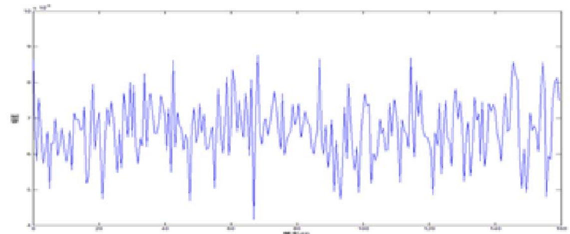

Figure 2. White Noise Power Spectral Density Diagram

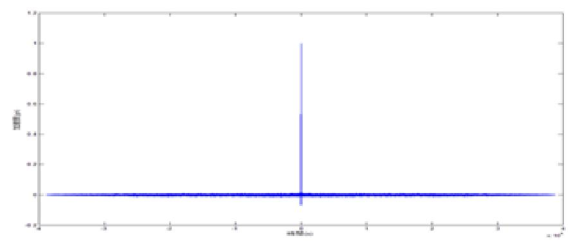

Figure 3. White Noise Autocorrelation Coefficients Diagram

Based on abovementioned definition of white noise, surd from the given power spectrum to acquire the Fourier Amplitude Spectrum. Execute the Fourier Transform on the Fourier Amplitude Spectrum and any given random phase to get its real part and imaginary part. Later, proceed the Fourier Inverse Transform to get the time span of its random white noise. The random white noise equation shown as follows:

$$y(t)=FFT^{-1}\left[\sqrt{S(\omega)e^{i\phi(\omega)}}\right]$$

$$S(\omega)=\begin{cases}1 & (\omega_0\le\omega\le\omega_1)\\ 0 & (Other)\end{cases}$$

In this equation: $y(t)$ indicates the white noise time span; $S(w)$ indicates the power spectrum of a given frequency range [w_0, w_1]; $\phi(w)$ indicates the random value within 0~2 π in the random phase spectrum.

3. Analysis Cases

The case object is applied the self-assembled base same as Fig.4 indicates located at the second floor laboratory in the sixth floor SRC building from the ground. The base specification indicates on Table 1 and its viaduct size can be found on Table 2.

Figure 4. Self-Assembled Base

Table 1 Base Specification

Length	60cm
Width	60cm
Height	122cm

Table 2 Viaduct Size

	SIZE
Beam	L75×75×6
Pillar	L75×75×6
Bracing	L75×75×6

First apply the motion as the vibration source where has obvious index frequency to examine each vibration condition of frequency signal. Use frequency 4Hz, 8Hz, 15Hz, 30Hz and 60Hz for run this experiment then observe each vibration. The cross comparison result from each actual measured value and limited element simulated value indicates same as Fig.5 to Fig.7 shows. The results reveal the lower frequency is covered by its surrounding disturbing frequency; therefore, its frequency presentation is not so obvious. In this case, the limited element software cannot project some certain frequency to complete the simulation; so its frequency value has been underestimated and this might be result from the base has direct contact with the air vibration so partial base value has been amplified.

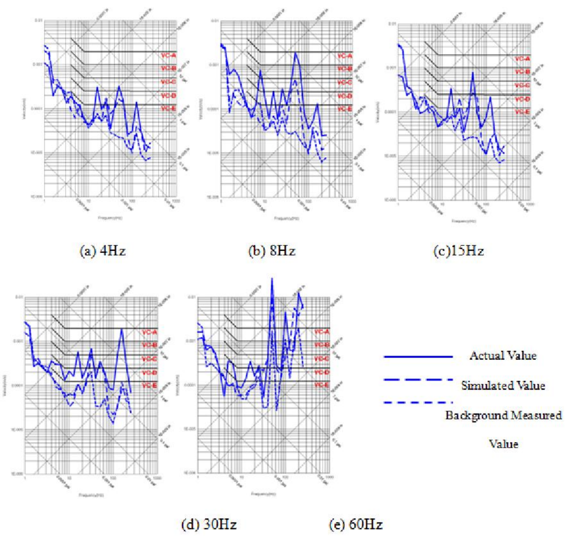

Figure 5. The Triaxial Comparison Diagram of Actual Measured Value and Limited Element Simulation Value from X Axial Direction

The vibration generated from walking personnel might also be the factor to influence the accuracy degree of the running equipment(s); therefore, based on this specific base vibration then continue further simulations. Appoint one person to walk away from the base as the start to simulate walking and running personnel inside the high-tech factory buildings. This experiment is taken at speed 60 steps/min for normal walking and speed at 180 steps/min for running as standards, hereafter proceed to simulate the vibration condition at different speed. The comparison result from the actual measured value and limited element simulated value at different waking speed has been shown as Fig.8 to Fig.9 indicates. It can be found the vibration frequency and its tendency of normal walking and running is similar. From both cases can be seen that the frequency value of running has elevated in comparing to normal walking. It represents the influences from running is stronger than walking. However, some certain frequency cannot be simulated from limited element software analysis and it has lower frequency value.

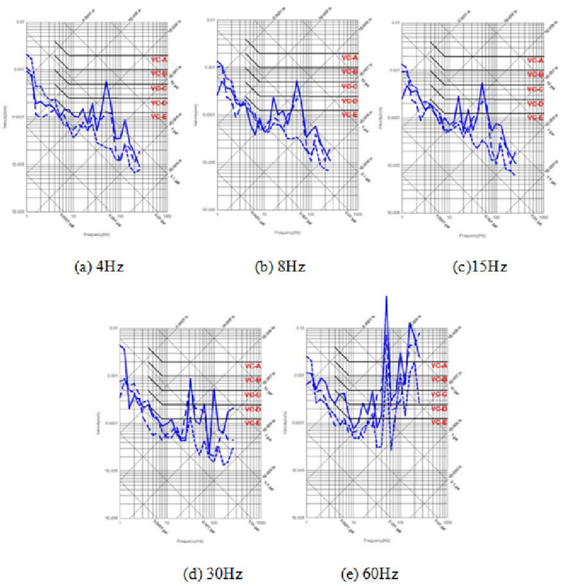

Figure 6. The Triaxial Comparison Diagram of Actual Measured Value and Limited Element Simulation Value from Y Axial Direction

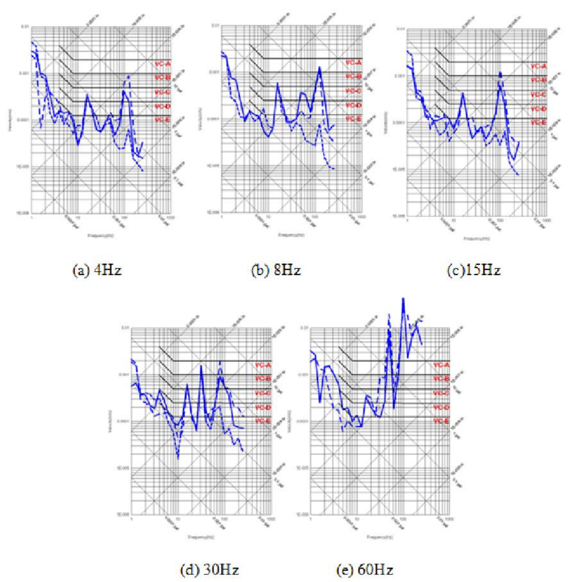

Figure 7. The Triaxial Comparison Diagram of Actual Measured Value and Limited Element Simulation Value from Z Axial Direction

To simulate the vibration frequency of a falling object, herewith take the basketball sold on current market as the falling object, set the dribbling height around in 150 cm with speed at 80 cycles per minute to get its frequency in 1.33Hz. From Fig.10 can be found that under limited elements simulation analysis it occur lower amplitude situation, but in general the tendency remains in accordance.

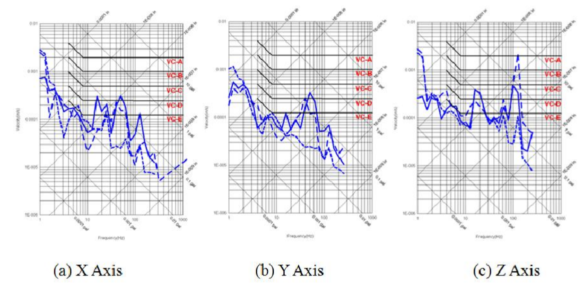

Figure 8. The Triaxial Comparison Diagram of the Actual Measured Value from Normal Walking and Limited Element Simulation Value

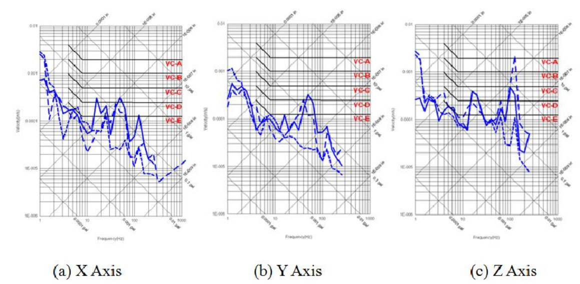

Figure 9. The Triaxial Comparison Diagram of the Actual Measured Value from Running and Limited Element Simulation Value

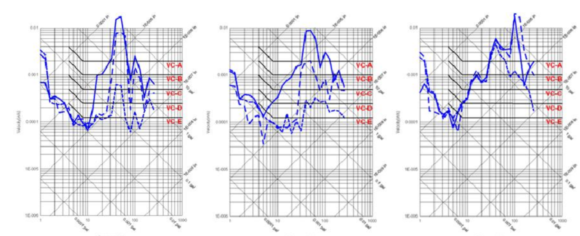

Figure 10. The Triaxial Comparison Diagram of the Actual Measured Value from Dribbling Basketball and Limited Element Simulation Value

4. Simulation

First, acquire the actual measured value from undisturbed background, then apply the middle number of the background as the maximum value to generate white noise as the major signal; afterwards, apply EEMD to decompose the background value with disturbed signal, then apply its middle number as the maximum value to generate the prominent frequency and synthesize it with white noise, later take this synthesized background signal as the in-field measured vibration signal from the floor background vibration as the time span curve data for limited element analysis software to simulate the base vibration. From Fig.11 to Fig.14 can be found as the comparison of micro vibration frequency decomposition from EEMD, the actual measured value and white noise simulation value.

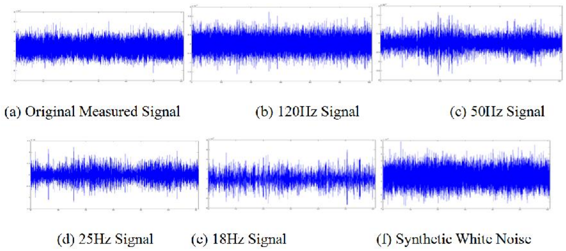

Figure 11. The Decomposed X Axial Direction Signal from EEMD

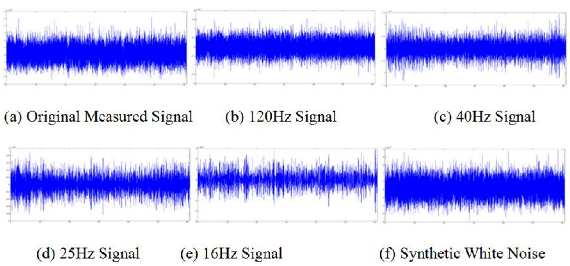

Figure 12. The Decomposed Y Axial Direction Signal from EEMD

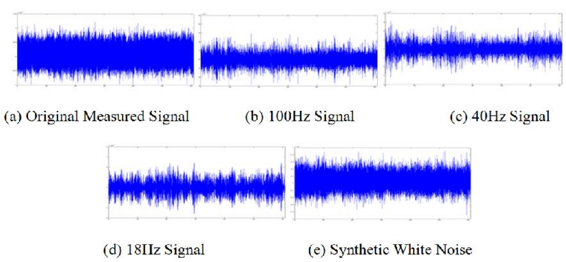

Figure 13. The Decomposed Z Axial Direction Signal from EEMD

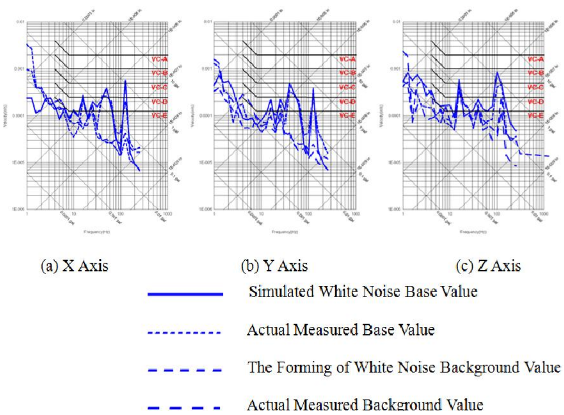

Figure 14. Actual Measured Value and Simulated White Noise Value

From above experiments, it clarifies the vibration source frequency and its amplitude from high-tech factory buildings. Then compare the actual measured value with its base simulation in triaxial diagram, the limited element model can generally control the frequency response from the base; however, there are some slight variations for some certain part has amplified and for this it's necessary to conclude air vibration factor within. In the white noise part, it can be applied to simulate the actual measured value and the vibration tendency can also be controlled where the high frequency part generally has amplified response with dramatic curves and the low frequency part is more flat than its actual measured value.

5. Conclusion

A. The synthetic white noise is close to the original background signal tendency. Therefore, apply white noise as the floor signal can achieve greater results.

B. EEMD can efficiently decompose each major frequency within the signal and it's appropriate for the application into signal analysis.

C. Apply periodical wave theory to simulate the decomposed main frequency from EEMD and its result is close to the actual frequency.

D. In actual measuring environment, the noise transfer through the air has direct influences on the base and vibration probe. Therefore, it caused the limited element software cannot proceed the simulation and such influence factor must be concluded.

6. Recommendations

A. The low frequency signal generated from SAP2000 is in corresponding with the tendency of actual measured signal. However, for the frequency above 100Hz has dramatic curve; therefore, there are many boundary conditions needed to be adjust its detail.

B. The base shall be cleared without other construction or object nearby it, especially for those giant racks, electronic equipments or those might generate disturbances at the vibration probe. This act to eliminate these surrounding objects might generate resonance or trigger other unnecessary frequency.

C. In later research may conclude noise factor within to seek influential analysis of the base vibration.

D. Highly recommend to have more than 2 people to simulate the real walking, running or doing both at the same time in order to close the real environment variation.

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