BETM 3583

Vibration Analysis and Monitoring

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Contents

1. Deterministic/Random Signal Separation
2. Time-frequency analysis

Learning Outcome

1. Understand the concept of signal separation and its use in vibration analysis
2. Understand the use of time-frequency analysis in vibration diagnostic

Deterministic/Random Signal Separation

Condition monitoring → Large of separating mixed signals into some components from individual sources.

Separating deterministic signals (i.e. from gears) from random signals

→ Understandable and analyzable

Deterministic/Random Signal Separation

In this lecture, introduction of several methodologies of signal separation are presented in short.

However, it is not presented in detail since most of separation process requires many mathematical calculations which are not suitable for engineering technology scope.

Instead, basic understanding is given as a fundamental knowledge in field measurement → technologist

Deterministic/Random Signal Separation

Common methods :

1. Order tracking
2. Time sychronous averaging (TSA)
3. Adaptive noise cancellation (ANC)

Deterministic/Random Signal Separation

1. Order Tracking

A so-called strategy to remove small random speed variation in a rotating shaft.

Frequency x-axis basis → 'orders' of shaft speed

i.e. 1x 2x

Deterministic/Random Signal Separation

1. Order Tracking

It is important to generate sampling signals from tachometer or shaft encoder.

Yet, it has a finite response time and cannot keep up with random fluctuations i.e. in ICE.

Best way : Angular resampling – resample each record digitally based on the corresponding period of the tachometer signals.

Deterministic/Random Signal Separation

1. Order Tracking

To do Angular resampling :

1. Increase the sample rate by large factor (i.e. 10)
2. Select the nearest example to each theoretical interpolated position

Deterministic/Random Signal Separation

2. Time Synchronous Averaging (TSA)

→The classic way to separate periodic signals from background noise

In practice : it is done by averaging together a series of signals segments

Deterministic/Random Signal Separation

2. Time Synchronous Averaging (TSA)

→The classic way to separate periodic signals from background noise

$$y_a(t) = \frac{1}{N}\sum_{n=0}^{N-1} y(t+nT)$$

Deterministic/Random Signal Separation

3. Linear Prediction

→ Obtaining a model of predictable part of a signal (or deterministic), based on a certain number of samples in the immediate past, and then using this model to the next value in the series.

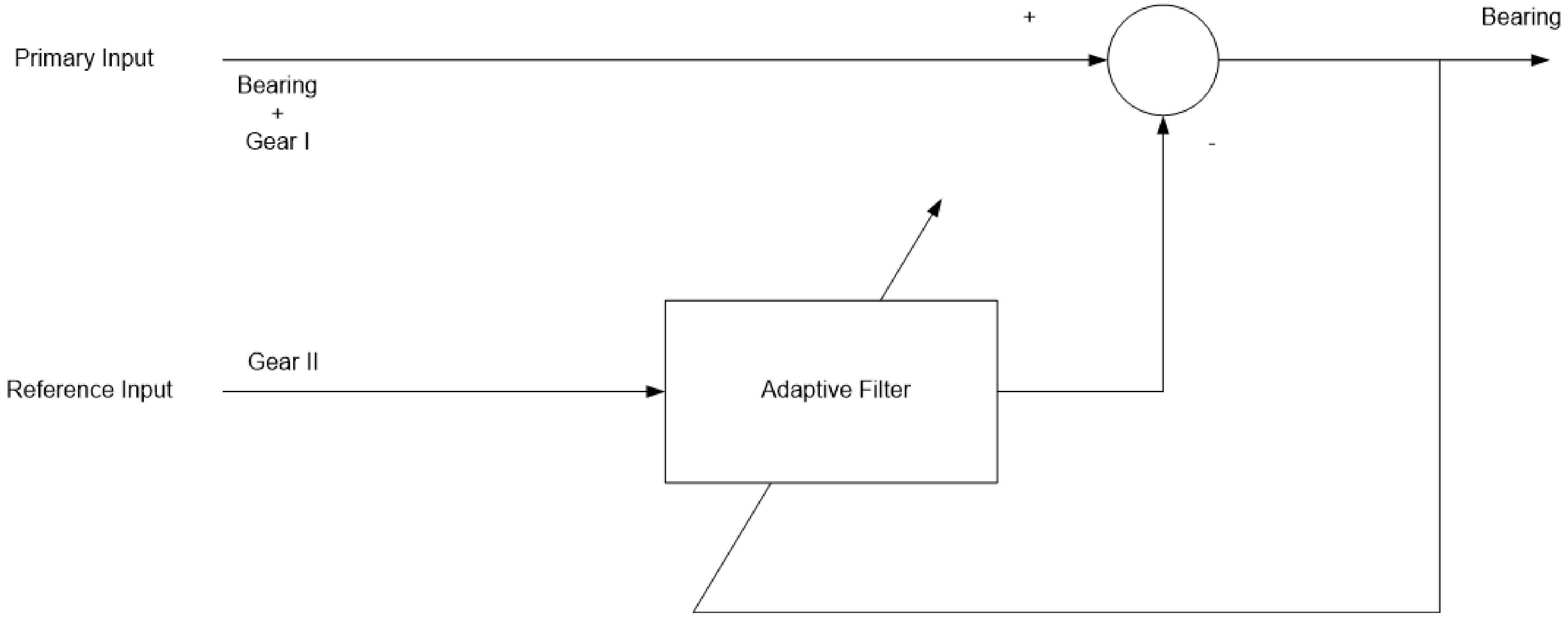
Deterministic/Random Signal Separation

3. Adaptive Noise Cancellation (ANC)

→ A method to separate uncorrelated components by relating the reference signals to the primary signals by a linear transfer function

Deterministic/Random Signal Separation

3. Adaptive Noise Cancellation (ANC)



Time & Frequency Analysis

Time & Frequency Analysis

Time & Frequency Analysis

Time & Frequency Analysis has become parts of signal processing.

It is also important to note that time & frequency data should also be presented in good ‘resolution’

In some cases, human ear can detect the differences of signal ‘resolution’. For example : Music.

Time & Frequency Analysis

Common methods :

1. The Short Time Fourier Transform
2. The Wigner-Wille Distribution
3. The Wavelet Analysis

Time & Frequency Analysis

1. The Short Time Fourier Transform (STFT)

→ Moving a short time window along the record and obtain the Fourier Spectrum as a function of time shift.

$$S(f,\tau) = \int_{-\infty}^{\infty} x(t)\varpi(t-\tau)\exp(-j2\pi ft)dt$$

Time & Frequency Analysis

2. The Wigner-Wille Distribution

→ Avoid the uncertainty in appearing to provide better resolution than STFT.

$$C_x(t, f, \phi) = \wp\{R(t;\tau)\}$$

$$R(t;\tau) = \int_{-\infty}^{\infty} x\left(u + \frac{\tau}{2}\right) x^*\left(u - \frac{\tau}{2}\right) \phi((t-u), \tau) du$$

Time & Frequency Analysis

3. The Wavelet Analysis

→ Decompose the signal into a family of wavelets which have a fixed shape, but still can be shifted and dilated.

$$W(a;b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\psi^{*}\left(\frac{(t-b)}{a}\right) dt$$

Time & Frequency Analysis

3. The Wavelet Analysis

→Another wavelet applications :

- →Wavelet denoising
- →Morlet wavelets
- →Choice of wavelets

Thank you

Q n A