MODIFIED EMD WITH DOUBLE DENSITY WAVELET BASED MACHINERY ABNORMALITY DETECTION

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ABSTRACT

Machinery Vibration signal and analysis of the fault signal of rotating machine is one of the important for fault diagnosis and a method based on enforced de-noising and EMD with double density wavelet. In order to remove the hidden noise in the high frequency fault signal, the enforced threshold butterworth band pass filter is used. The proposed system decompose the signals into finite samples, using Modified EMD for number of stationary intrinsic mode function (IMFs), and the double density wavelet transform is used to convert the IMF's of time domain to frequency domain. The proposed method could extract the fault condition effectively with less response time.

Keywords: vibration signal, denoising, modified emd, double density wavelet.

1. INTRODUCTION

Now-a-days the foremost common ordinary mechanical instrumentation plays an important role in industrial production and national economy, if the machines work in abnormal conditions; it will bring an incredible distress in industrial safeguard and nation's production in previous incidence of years. Many researchers are focuse to increase the accuracy and reliability with against possible fault signals for machinery rotating motor [1]. Analysis of the vibration signal of rotating machine is divided into three classes mainly; time-domain based method, such as dimensionless and collective dimensionless [2], frequency-domain based method [7], and time-frequency analysis such as wavelet and modified EMD [5, 6]. These methods based on frequency have obtained greater contribution both non linear and non-stationary signal analysis, for producing false signals and false frequency occurrence, while processing the vibration signal, the time and frequency domain has been widely using in the rotating machinery for fault diagnosis [5], hence, drawbacks are essentially adjustable for windowed Fourier transform which are not having ability of self-adaptive in nature. The resent self-adaptive signal analysis method, name modified empirical model is developed by Huang et. al., based on local characteristics of the time scaling signal and can be decomposed into a number of intrinsic mode functions. These IMFS are applied to be non-linear and non-stationary signals that are vibration signal [11-12].

Modified EMD shows the best performance for non-linear and non-stationary signal, itself having some draw backs such as endpoint effect, shifting stop criterion, extreme interpolation, model fixing etc. To overcome these drawbacks of Modified EMD, some achievements have reported recently, such as to reform the end effect an extension method based on grey prediction model and the contamination of waveform data obtained by waveform matching method [13]. The actual vibration signal, is a non-stable and non-linear, and it has the properties of both modulation and weak, and the information of fault signals are get submerged in the strong background noise which is not really white noise. The de-nosing methods based on band pass filters to remove the high frequency noise, and in the each IMFs, there were exited the linear relation measurements which can be used to discriminate the authenticity of each IMF. Combining of all the higher than, a vibration signal analysis methodology supported enforced de-noising and Modified EMD is utilized, in this proposed method to remove the high-frequency noise during which the fault info were flooded, and therefore a comparatively pure signal with fault info is obtained. Double density wavelet transform is also a adaptive in nature and multi resolution of waveform are obtained. These double density wavelet method is employed to intrinsic mode function, which divides a time scale into two different components to frequency domain through the Fast Fourier transform which are capable of obtaining the two frequency wavelengths and also the pitch frequency is obtained by the latent period that is additional accuracy compared to the prevailing system, hence above all methods are used to get a good information fault signal without any fault occurring [3].

2. MODIFIED EMD ALGORITHM

Modified EMD methodology is projected by Huang, through the EMD methodology, the original signal is decomposed into many narrow bands components, each of components to be called as an intrinsic mode functions. And they must satisfy the following conditions [10]. All the contained data, the number of extremes and the number of zero-crossings must be either differ or equal mostly nearby one. At any point of sbline, the mean value of the envelop defined by local maximum and the local minimum is zero. A given time-scale signal as x(t),then obtained all the extreme point of the local signal x(t), and its upper and lower signal value are defined as u(t) and v(t) through employed the cubic spline connected all the local extreme maximum value , respectively. The m(t) function is mean of both upper and lower envelopes of the local signal is given as following:

$$m_1(t)=u_1(t)-v_1(t)/2 \quad (1)$$

The first component h1(t) is defined as

$$h_1(t)=x(t)-m_1(t) \quad (2)$$

if the first component h(t) meets these conditions mentioned, and h(t) is named as the first component intrinsic mode function of the given signal. However, if h(t) is not meet the condition, then h(t),is treated as the new original signal, and repeat the above two equations, after k times the function h(t) becomes an IMF which is given as

$$h_k(t)=h_{k-1}(t)-m_{k-1}(t) \quad (3)$$

In the reiteration or rehearsal process of solving the IMF, the mean of upper and low envelop can be upgraded by following

$$m_{k-1}(t)=u_{k-1}(t)-v_{k-1}(t) \quad (4)$$

First c(t) of original signal should contain the shortest period component of signal or finite scale period, and the rest of the signal r(t) are obtained until h(t) meet the conditions mentioned above which can be given as following regarded r(t) as the new original signal, and then carried out the above iteration steps, the second IMF c2(t) of x(t) is obtained, repeated the iteration n times, until the monotonic function, which cannot extract the component that meet the IMF conditions, finished the iteration processing. And then the given signal x(t) can be rewritten as

$$x(t)=\sum_{i=1}^{n} c_i(t)+r_{n(t)} \quad (5)$$

the Hilbert and marginal spectrum obtained by carrying out Hilbert transform for each IMFs, which had given as the follows:

$$c_{ii}(t)=\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{ci_{.(t)}}{t-\tau} \quad (6)$$

Constructing analytic signal is represented as:

$$z_i(t)=c_i(t)+j_{cii}(t)=a_i(t)e^{j\theta(t)} \quad (7)$$

3. DOUBLE DENSITY WAVELET TRANSFORM

Wavelet transform is an adaptive, multi-resolution capability method, has it made to be a important tool for rotating machinery vibration signal fault diagnosis. In the proposed system, single scaling function with two distinct wavelets and it have more wavelets than required gives the small scale with a closer spacing in between the adjacent wavelets. Double density wavelet transform is redundant with a factor two, which independent of number of levels, Hence the double density wavelet transform is used for converting the intrinsic modes of signal of time scale into frequency domain through the Fast Fourier transform of Finite impulse response that obtaining the correct good perform signal is having the wavelength and frequency response. Double density wavelet is less sensitive than critically.

4. MODIFIED EMD WITH DOUBLE DENSITY WAVELET

The classical EMD algorithm has been used significantly in the information to decompose signals that contain both nonlinear and non- stationary waves. But once an indication contains 2 or additional frequencies that area unit near each other the decomposition would possibly fail in classical EMD formula. To overcome this failure Modified EMD is proposed a new formulation of this algorithmic program that is predicated on the zero crossings of the signal and show well even once the classical algorithmic rule fail. We address also the filtering properties and convergence rate of the modified EMD algorithm versus the classical EMD algorithm. These properties are compared then to those of the fundamental component algorithm. Finally we apply this algorithm rule for the detection of gravity waves in the atmosphere. When the filtered signal undergoes Modified EMD here decomposition of filtered signal will occurs even though the signals having frequencies close to each other. The decompositions are intrinsic mode functions (IMF's). These IMFs will undergo with double density wavelet method where the parameters like wavelength, peak frequency IMFs. Using this double density wavelet in modified EMD will generate two different frequencies so the signal will have two wavelengths at two different frequencies. This process is done for both training and test signals. And parameters are found.Finally the amplitude and phase function obtained as below respectively

$$a_i(t)=\sqrt{c_i^2-c_{ii}^2}(t) \quad (8)$$
$$z_i(t)=c_i(t)+j_{cii}(t)=a_i(t)e^{j\theta(t)}$$

The instantaneous frequency obtained

$$f_1(t)=\frac{w_i(t)}{2\pi}=\frac{1}{2\pi}+\frac{d\theta(t)}{d(t)} \quad (9)$$

Then Hilbert transform and marginal spectrum defined as below respectively

$$h(w)=\int_0^L H(w,t)dt \quad (10)$$

Endpoint effect is one of key issues influencing the functioning of EMD, in the process of modified EMD, decomposition, it cannot be say that the endpoint is the extreme point, which resulting of modified the uniformly spaced fitting error, with the deepening of the decomposition of signal, the fitting error accumulated continuously, and spreading inward into step by step process, Leading to the decomposition of signal becomes no meaning. In order to restrain the endpoint effect, many researchers put their attention to solve the problem of endpoint effect of EMD and obtained certainly progress.

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Waveform extension is a self-adaptive method for restraining the endpoint effect, which extension the wave at the endpoint by the most similar sub-wave for the trend of the internal signal to endpoint. The computational cost of this kinds of endpoint effects restrained method is very high because of they need to analysis the signal wave for forecasting the trend of the wave entirely. In this paper, cosine window function used to restrain the endpoint effects, which is given as

$$W(t) = \begin{cases} \sin\left(\frac{\pi}{2} * \frac{t}{A}\right) & 0 \le t \le A \\ \cos\left(\frac{\pi B}{2} * \frac{t-B}{B}\right) & B \le t \le L \\ 1 & A < t < B \end{cases} \quad (11)$$

5. VIBRATION SIGNAL ANALYSIS SYSTEM

A machinery system having rotating components such as bearings and gears provides a good example of condition monitoring. Especially, mechanical components of bearing systems produces, experience overload, misalignment, fatigue, looseness, and contamination, that leads to causes cracked or break into smaller pieces on the surface of the inner or outer-race. Then, the fault signals that are induced from the rotating machinery are masked by environmental noise that involves due to the periodically impulses, along with the high frequency domain of structural components of rotating machinery components. The demanding of monitoring the condition of rotating machines is how to identify the rotating component with a defect in the area where an increased vibrations level has been noticed or measured, but it's suitable means of detecting the damage and identifying nature for the easy measurement of the machinery vibration signal.

The vibration signal of roller is bearing a typically non-stationary process signal, which is the direct information source for rotating mechanical equipment running status and fault diagnosis in electro mechanical equipment. But the vibration signal acquired from the practical engineering field inevitably contains noisy signals, which will seriously interfere with the extraction of fault characteristic information. Recently, as one of the most widely used de-noising methods, wavelet threshold technique has obtained novel results in many fields. However it has certain limitations in dealing with the white noise, non-stationary and nonlinear signals. Specifically the selection of wavelet base, decomposed layers, threshold and the threshold function is flexible. For a signal, how to select the above parameters to make the de-noising effect better has not been solved well yet.

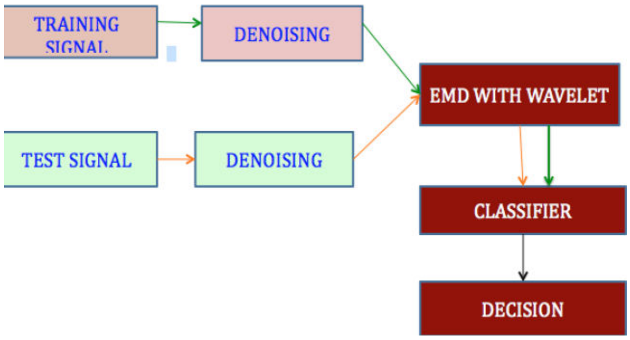

Figure-1. Vibration signal analysis block diagram.

6. RESULTS AND DISCUSSIONS

The results that are obtained from the vibration signal of the rotating machine equipment, analysis of different fault signals that are generated from the machinery through the sensors. Analyses are done for the different input signals.

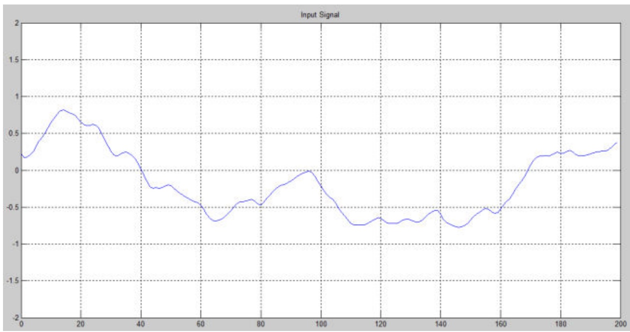

Figure-2. Test signal 1 of rotating machine.

The Figure-2 shows the input signal recorded from rotating machinery through the sensor.

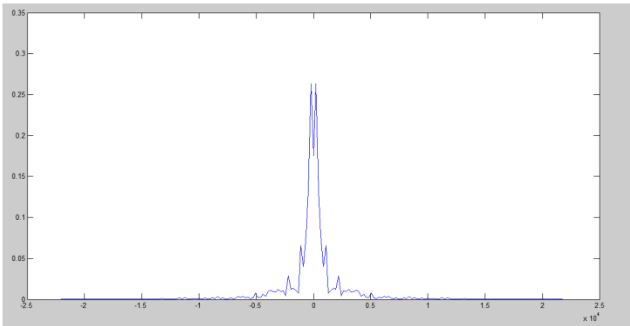

Figure-3. Spectrum of test signal 1.

The Figure-3 shows the spectrum of input signal 1 with hidden noise. Its position of a scale is between two extreme points.

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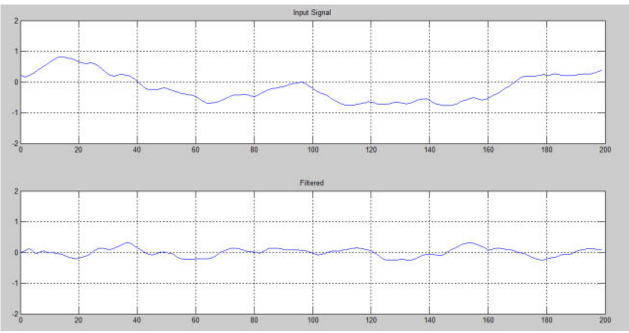

Figure-4. De-noising of test signal 1.

Figure-4 shows, the de-noising of test input signal signal1. Butterworth Band Pass filter is used to remove the noise in the test input signal at frequency of 700 to 12000Hz

This filtered signal undergoes through modified EMD with double density wavelet, where the parameters of test input signal such as wavelength, peak frequency, IMFs and EMD are estimated and these parameters are compared with training signal parameters in classifier. If the test input signal parameters are matched with fault signals parameter of machinery, the decision maker decides machine running in abnormal condition.

```
imf =

  Columns 1 through 12

         0   -0.0221    0.0129    0.0461    0.0103   -0.0496   -0.0363    0.0251    0.0336   -0.0064   -0.0189   -0.0000
         0    0.0069    0.0004   -0.0130   -0.0263   -0.0330   -0.0278   -0.0113    0.0145    0.0447    0.0648    0.0662
         0    0.0305    0.0453    0.0470    0.0378    0.0200   -0.0039   -0.0316   -0.0608   -0.0890   -0.1143   -0.1353
         0    0.0066    0.0122    0.0169    0.0209    0.0240    0.0263    0.0279    0.0287    0.0290    0.0285    0.0275
         0   -0.0026   -0.0052   -0.0078   -0.0105   -0.0131   -0.0157   -0.0183   -0.0209   -0.0235   -0.0261   -0.0286
         0    0.0066    0.0130    0.0191    0.0251    0.0309    0.0365    0.0420    0.0472    0.0522    0.0571    0.0618
    0.0042    0.0033    0.0023    0.0014    0.0005   -0.0004   -0.0013   -0.0022   -0.0030   -0.0039   -0.0047   -0.0055

  Columns 13 through 24

    0.0071    0.0004   -0.0008   -0.0001    0.0001    0.0010    0.0026    0.0071    0.0130    0.0070   -0.0161   -0.0305
    0.0597    0.0564    0.0493    0.0306   -0.0029   -0.0423   -0.0763   -0.0963   -0.0980   -0.0830   -0.0564   -0.0277
   -0.1519   -0.1640   -0.1717   -0.1751   -0.1742   -0.1692   -0.1602   -0.1472   -0.1303   -0.1100   -0.0867   -0.0609
    0.0259    0.0238    0.0213    0.0182    0.0148    0.0109    0.0068    0.0023   -0.0025   -0.0075   -0.0127   -0.0180
   -0.0312   -0.0337   -0.0362   -0.0387   -0.0412   -0.0437   -0.0461   -0.0485   -0.0508   -0.0532   -0.0555   -0.0578
    0.0663    0.0706    0.0747    0.0787    0.0825    0.0861    0.0896    0.0929    0.0961    0.0990    0.1018    0.1045
   -0.0063   -0.0071   -0.0079   -0.0086   -0.0093   -0.0101   -0.0108   -0.0115   -0.0121   -0.0128   -0.0135   -0.0141
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- Response time =0.6423sec.

7. CONCLUSIONS

The proposed machinery abnormality detection system is used for the analysis of fault signals of machine using modified EMD with double density wavelet method. The result shows that the proposed system removes the hidden noise and made analysis by comparing the parameters of test input signal with the parameters of training signal. This system is highly accurate to decide the machine works in normal or abnormal condition. The proposed system is best suitable for the machinery industry to monitor the machinery works in normal condition.

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