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A Review paper on Advanced Signal Processing Methods for Flaw Detection of Mechanical Components

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Abstract— **This paper begins with a review of Ultrasonic testing which is one of the safest and renowned Non – Destructive Evaluation (NDE) techniques adopted worldwide for Non – Destructive Testing (NDT) of mechanical components. A growth of crack in structure can eventually causes the structure to fail. Early detection and location of cracks are critical in order to prevent accidents. Crack detection using ultrasonic techniques has attracted researchers' interests. Pulse-echo of ultrasonic signals is used widely to identify the receiving time of echoes. The noisy ultrasonic signals caused by material inhomogeneity and other effects add difficulty to extracting pulse echoes. The corresponding echoes should be non-stationary, and therefore, Fourier transform-based method cannot be used to detect crack effectively. Wavelet analysis has better time-frequency resolution capability and has been used in flaw detection of materials.**

Index Terms— **Non – Destructive Testing, Hilbert Transform, Cross-correlation Function, Split Spectrum Processing, Fourier transform, Wavelet.**

I. INTRODUCTION

Non Destructive evaluation (NDE) is a term that is often used interchangeably with NDT (Non Destructive Testing). NDE is used to describe measurements that are more quantitative in nature. It realized that detection of flaws was not enough and it needed to obtain quantitative information about flaw size, shape and orientation to serve as an input to fracture mechanics calculations to predict the remaining life of a component. NDT techniques use ultrasonic transmission of the sound wave of high frequency for determining the characteristics of materials and detecting defects or to locate changes in the properties of these materials. The pulse-echo method in which a piezoelectric transducer transmits ultrasonic energy the signals reflected from the opposite side of the field, or discontinuity, empty or elements included in the material are received by the same transducer where energy converted into an electrical signal is processed by a computer and displayed on a screen [1]. The display can show the relative thickness (depth), or localized defects. The goal of NDE of engineering materials is the detection, localization and classification of internal or external defects as quickly and as accurately as possible. The highest possible performance detection, the most exact size and the exact orientation of defect have to be obtained. The practical difficulty of extracting the information needed to characterize materials led to use different methods of signal processing. In nondestructive testing, the presence of noise due to the internal structure of some complex materials often obscures the signal from the default, which makes difficult the detection and identification. Advanced signal processing techniques such as Hilbert Transform, Cross- correlation Function, Split Spectrum Processing [2] are reviewed in this paper. Wavelet techniques are analysis tools used for understanding and interpreting the flaws in an accurate manner. The techniques of signal processing to improve signal to noise ratio (Split spectrum processing, wavelet transformation), which then allows us to measure the delay different echoes (Transformation of correlation, Hilbert transforms). The paper is organized as follows: in Section II a brief review about different signal processing techniques. Finally the conclusions enclose the paper.

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II. SIGNAL PROCESSING METHODS

A. *Hilbert Transform*

The pulse-echo method where acquired ultrasonic signal must be processed by signal processing tool to compute the relative thickness (depth), or detect and localize defects and compute the material velocity [3]. The main objective of the method is to measure the time of flight and the thickness between the front of the material and its internal discontinuity to locate the exact location of the echoes signal.

There are two basic difficulties with accepting the idea of an instantaneous frequency as follows: The first difficulty is from Fourier spectral analysis. In Fourier analysis, the frequency is defined for the sine or cosine function covering the whole signal length with constant amplitude. As elaboration of this method, the instantaneous frequencies also have to relate to either a sine or a cosine function. So, there is a need of one full oscillation of a sine or a cosine wave to calculate the local frequency value. As per this definition if anything shorter than full wave will be considered and larger than will be discarded. This definition is not suitable for non-stationary signals because frequency changes from time to times. The non-unique way of defining the instantaneous frequency in Hilbert transform is second difficulty. The difficulty is not serious since the introduction of the means to make the signal analytical through the Hilbert transform among time-frequency analysis methods; it may be the best one. But still it has some deficiencies.

B. *Cross- correlation Function*

The ultrasonic velocity measurements are useful to determine parameters of the material. So, we use the correlation processing to calculate the time delay and have an accurate measurement of velocity. The signal interaction consists of a series of bursts offset against each other, with variations of amplitude and sign due to interfaces encountered. The location of maximum cross function gives the location sequences for which these two signals show the similarities, and therefore the direct measurement of distances between interfaces.

C. Wavelet

The Wavelet Transform is a new method of simultaneously analyzing and processing transient non stationary signals in both time and frequency domains. Researchers are very much interested in this method. Various applications such as multi resolution analysis, image compression and speech coding researchers are interested. The wavelets are popular de-noising tool used. By the coefficient of similarity between the signal and the wavelet used continuous Wavelet can be defined. Based on the theory of multi resolution analysis, discrete wavelet transform is obtained by sampling coefficients of scale and time and gives a good location interfaces and better detection of defects.

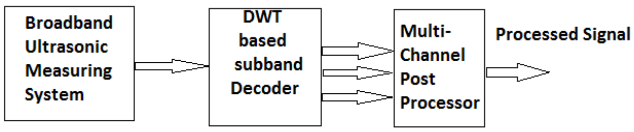

Fig. 1 DWT based flaw detection algorithm [2]

Fig. 1 shows the components of the DWT based ultrasonic flaw detection algorithm. An ultrasonic measuring system requires data acquisition. The experimental setup for data acquisition requires a pulse generator to produce short electrical pulses which drives the ultrasonic transducers. The ultrasonic echoes are received by the receiver section. The received echo signals are then digitized. The digitized ultrasonic signal is decomposed into sub bands by using DWT and provides time-frequency representation. The flaw detection algorithm is to select a number of windows in order to discriminate the flaw echoes from the clutter echoes. In wavelet transform, window represents a group of scales which function as a band-pass filter similar to band-pass filtering in Split Spectrum Processing [4]. Inverse Discrete Wavelet Transform is applied to each window operation and the resulting time-domain signals are then fed into the post-processor. In the final stage post-processor is a decision block that reconstructs the time-domain signal from the incoming channels according to order statistics rules.

a. Wavelet Packet

Wavelet packet transform is further development of the wavelet transform. More detailed analysis for the signal can be provided by Wavelet packet. In wavelet packet transform the signal which is not subdivided can be decomposed in low frequency signal as well as high-frequency signal. According to the character of the analyzed signal, wavelet packet transform can select the relevant frequency band and match the frequency band with the signal spectrum. The advantage of wavelet packet transform enhance the time-frequency resolution of signal and also make the wavelet packet transform have a wider application value [5]. The wavelet packet de-noising method is applied to the ultrasonic signal that is detected from the material. One of the advantages of wavelet packet, it can decompose both the low-frequency and high-frequency signal and in uniform condition it makes the details of the de-noised signal richer than the wavelet de-noising. The proposed method is efficient in improving the signal strength and reducing the noise, improves the signal-to-noise ratio. The method can obtain the de-noising effect, effectively filter out noise, and also lay the foundation for the feature extraction of subsequent signals. It assures the reliability and the efficiency of the method for detecting and measuring cracks in material, and they also provide application value for engineering practice.

D. Split Spectrum Processing

The basic principle of Split Spectrum Processing (SSP) is to decompose the received wideband signal into a number of sub-bands. By splitting the spectrum the variation of the reverberation in all sub-bands can be observed. The target signal will not have any variation but it will have almost the same power because some bands have large variation and some have almost the same signal level[6]. This property is used to enhance the target signal with respect to the reverberation.

The split spectrum processing depends upon the number of band pass filtering channels, the correlation between the different observations, and statistical information in each channel. By increasing the number of channels there is likelihood of separating flaw and echo information also increases. In order to enhance the visibility of flaw echo concealed by clutter, split spectrum processing method employs a post-processor for combining all the incoming information from sub bands. This post-processor reconstructs the time domain signal with the objective of obtaining maximum flaw-to-clutter ratio. Minimization technique can be effective in suppressing the clutter echoes when flaw echo information exists in all the observation channels.

III. CONCLUSION

In this paper, we have reviewed recently developed signal processing methods: Hilbert transform and wavelet transform. The Hilbert transform are sensitive to cross the length of the ultrasonic signal. It allows detection of the envelope signal locating and met interfaces and it ignores the sign gradients encountered because it considers only the absolute value. The wavelet transform, gives location interfaces accurate. It offers a basic change and levels for the analysis of the accuracy of interfaces. The studied signal processing methods for non-destructive testing of material, are feasible and can accurately and efficiently characterize any material and determine the location and the size of its defects and they also provide application value for engineering practice.

REFERENCES

[1] Xianfeng Fan, Ming J Zuo, and Xiaodong Wang, "Application of stationary wavelet transforms to ultrasonic crack detection," *IEEE Electrical and Computer Engineering, Canadian Conference*, pp. 1432 - 1436, May 2006.

[2] T. Bouden, S. Dib, K. Aissaous and M. Grimes, "Signal Processing Methods for Materials Defects Detection", *IEEE Ultrasonics Symposium (IUS)*, pp. 1-4, 20-23 September 2009.

[3] T. Bouden , F. Djerfi , S. Dib and M. Nibouche ,"Hilbert Huang Transform for enhancing the Impact-Echo Method of Non Destructive

Testing", *IEEE J.Automation & Systems Engineering*, pp. 172-184, 2012.

[4] Erdal Oruklu and Jafar Saniie, "Ultrasonic Flaw Detection Using Discrete Wavelet Transform for NDE Applications", *IEEE* vol.2, pp.1054-1057,23-27 August 2004.

[5] Yongqiao Wei, Rui Tang, Li Hou, Fenglan Jia, Zhijun Sun and Bo Li, "Study on Noise Reduction Using a Wavelet Packet for Ultrasonic Flaw Detection Signal of a Small Diameter Steel Pipe with a Thick Wall", *International Journal of Acoustic and Vibration*, vol.19, no.3, pp. 198, September 2004.

[6] Gopika Syam, Sadanandan G.K, "Flaw Detection using Split Spectrum Technique ", *Dept. of Electronics & Communication, Toc H Institute of Science & Technology, Ernakulum, IJAREEIE* , Vol. 3, Issue 3, March 2014.

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