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Mode Identification of Guided Ultrasonic Wave using Time- Frequency Algorithm

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1. Introduction

The ultrasonic guided waves are waves whose propagation characteristics depend on structural thickness and shape such as those in plates, tubes, rods, and embedded layers. If the angle of incidence or the frequency of sound is adjusted properly, the reflected and refracted energy within the structure will constructively interfere, thereby launching the guided wave. Because these waves penetrate the entire thickness of the tube and propagate parallel to the surface, a large portion of the material can be examined from a single transducer location. The guided ultrasonic wave has various merits like above. But various kind of modes are propagating through the entire thickness, so we don's know the which mode is received. Most of applications are limited from mode selection and mode identification. So the mode identification is very important process for guided ultrasonic inspection application. In this study, various time-frequency analysis methodologies are developed and compared for mode identification tool of guided ultrasonic signal. For this study, a high power tone-burst ultrasonic system set up for the generation and receive of guided waves. And artificial notches were fabricated on the Aluminum plate for the experiment on the mode identification.

2. Time-frequency analysis algorithm

The time-frequency analysis algorithm for the mode identification tool has various kind of method. Most well known algorithms are bellows.

- Adaptive spectrum
- Cone shape distribution
- Choi-Williams distribution
- Gabor spectrum
- Short time Fourier transform
- Wigner-Ville distribution
- Dispersive STFT

Although conventional methods such as the short-time Fourier transform (STFT) and the continuous wavelet transform have been effectively used for the analysis of guided ultrasonic waves But the guided ultrasonic wave signals may not be accurately analyzed by these methods. Advanced adaptive time-frequency analysis method whose time-frequency tiling is varied to the dispersion characteristics of the signal to be analyzed. In the dispersion-based time-frequency tiling, each time-frequency tiling is adaptively rotated in the time-frequency plane, depending on the local wave dispersion.

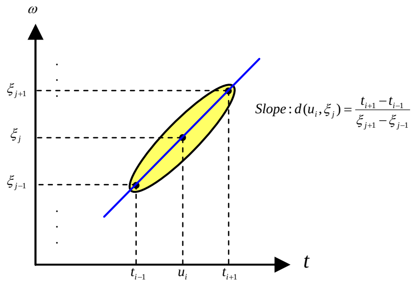


Figure 1. The determination of the rotating parameter by the dispersion relation.

To calculate the D-STFT, the dispersion relationship of a wave within a waveguide must be known in advance. However, in general, the dispersion relationship is not known in actual situations, so a procedure to determine the dispersion relationship is required.

3. Experimental setup

Figure 2 depicts the experimental configuration for the guided ultrasonic signal acquisition.

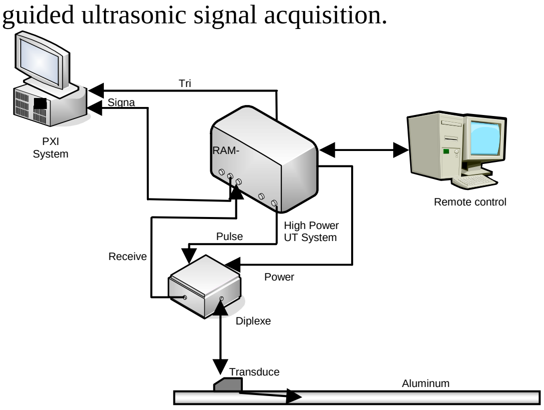


Figure 2. Schematic diagram of the experimental system

The experimental system is configured with tone-burst pulse-receiver (RAM-5000, RITEC), PXI system with LabVIEW(PXI-5112, National Instrument) and control computer for tone-burst pulse-receiver.

4. Evaluation of time-frequency algorithm

The guided ultrasonic signal is acquired from the aluminum plate embedded 50% EDM notch. Fig. 3 shows the received signal from the aluminum plate. Every algorithm is calculated for evaluation and comparison from the received signal. Fig. 4 shows all the calculated result to time-frequency domain

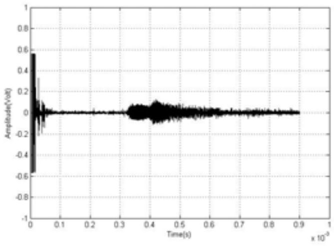
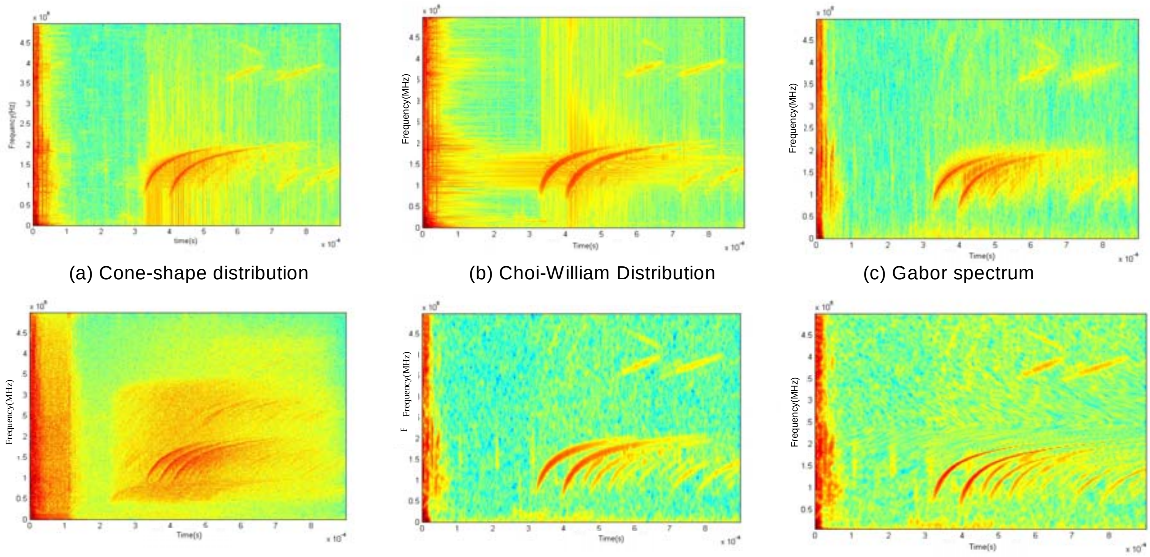


Fig. 3 The guided ultrasonic wave signal from the aluminum plate at 2.25MHz

frequency resolution. It is not possible to achieve both good time and frequency resolution simultaneous. But the calculation result is fairly good.

The D-STFT algorithm display good time–frequency resolution and there is no interference between signals components. Moreover it can show very well the dispersion property of signal. But the D-STFT algorithm requires much more time to get the calculation result.



(a) Cone-shape distribution (b) Choi-William Distribution (c) Gabor spectrum

(d) Wigner-Ville Distribution (e) Shor Time Fourier transform (f) D-STFT

Fig. 4 The calculated time-frequency algorithms result from received signal

The cone-shape distribution shows good time-frequency resolution. But it introduces cross interference between two components occurring in the same time period.

And the Choi-Willams distribution introduces cross interference between two components occurring in the same time period or the same frequency band, and losses some information on modes. The Gabor spectrogram has adjustable time-frequency resolution and instantaneous mean frequency.

When the order is low, the time-frequency resolution is low, but there is less cross interference. When the order is high, the time-frequency resolution gets better at the price of introducing cross interference. The suggested order is three of four. In this case, the order of Gabor spectrogram is four.

The Wigner-Ville distribution has high time-frequency resolution and correct instantaneous mean frequency. The problem is that it has severe cross interference whenever the data samples contain multiple components. Therefore some noisy components are occurred near main component.

The STFT-based spectrogram is most popular method for mode identification tool of guided ultrasonic mode identification. But the selection of windows provides a tradeoff between the time and

5. Conclusion

Various Joint Time-Frequency Analysis(JTFA) methodology were developed and compared for finding the optimal mode identification tool from the received guided wave signal. Each method has its own characteristics for resolution and representation of dispersive. The D-STFT was the most effective algorithm for ultrasonic guided wave mode identification tool and it can represent the detail aspect of dispersion characteristics of guided ultrasonic waves.

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ACKNOLOGMENT

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