

The use of full waveform reflection measurements on thin-layered laminates.

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Abstract

In conventional C-scan experiments, for each single measurement only one value is preserved. Moreover, the thinner the target, the more complex the reflected signal becomes, making the use of transmission measurements necessary. In our method, we preserve the full time-signal. In that way, we can handle the complexity of the recorded time-signal in reflection measurements, which is important in situations where transmission measurements are hardly possible from a practical point of view.

We use two techniques to process the time-signal: deconvolution and multiple-elimination. Deconvolution sharpens the source signal, and multiple-elimination removes the undesired multiple reflections that are generated within the different layers of the material. We apply the same techniques as used in the seismic industry. The experience in reflection techniques in seismics allows us to obtain information about each separate layer in the target. The theory is verified with practical measurements, obtained by a scan-system with a 12 bit A/D converter, sampling at 100 MHz. The process is very usefull for the inspection of a horizontally layered medium, and for the detection of delaminations.

Principles

The principle of acoustic inspection is based on the fact that the interaction between a wave and a structure – e.g. a laminated material – will influence the behaviour of the wave. In ultrasonic inspection, a wave is generated by means of a transducer. This wave travels through a coupling medium – e.g. water – to the target material. There, it will interact with the structure, and part of the energy will be transmitted through the material and propagate towards a transducer at the other side of the material. In transmission measurements, this resulting wave is recorded.

Due to the interaction with the material, part of the wave-energy will be reflected back to the first transducer, where it can be recorded too. The latter is done in reflection measurements.

Conventional method

In conventional methods, transmission measurements are used, and only one value is preserved for each single measurement. The preserved value is the maximum measured amplitude of the recorded wave in a pre-defined time-window. This value is an indication for the attenuation of the wave in the material, and thus for the damping in the material. A

void inclusion, for example, will be the reason that most of the energy from an incoming wave will be reflected back. Due to this interaction, the propagating wave will have less energy.

Interpretation of these values can give indications about some material properties. This method does not provide information about the depth-location of possible defects. In some applications however, it is important to know whether a defect – eg a delamination – occurs at the top, in the middle, or at the bottom of the material. Besides, it is not always possible to access the target material from both sides at the same time. The use of reflection measurements, followed by signal processing, deals with this problem.

Advanced method

In the advanced method, the complete arriving wavefield is recorded, as a function of time. A high sampling rate is necessary to convert the analog signal into digital samples. In a laminated structure, two reasons may cause the recording wavefield to look complicated. When the separate layers are thinner than the length of the wavefield – as emitted by the transducer – the individual reflections occurring at the boundary of two layers will interfere with each other. Also, waves may be submitted to multiple interactions in the material. When part of the energy of an incoming wave is reflected at the boundary between two layers, the resulting backtravelling wave can interact with other boundaries, causing multiple reflections.

However, the behaviour of a wave interacting with a laminated structure can be predicted, by means of the wave theory. Given the acoustic parameters of the separate layers, we can predict the recorded wavefield for a given source signal. The knowledge of this theory also enables us to perform the inverse

process on a recorded wave. Given the recorded arriving wavefield, we are able to obtain the acoustic parameters of each individual layer – if we know the source signal.

The techniques that we use to perform this inverse process are based on the inversion techniques that are extensively used in seismics.

conclusion

The use of reflection measurements enables us to obtain a more detailed knowledge of the properties of the individual layers in a laminated material. To achieve this, an A/D-converter with a high sampling rate (100 MHz/12 bits), transducers with a well-known source-signal, and knowledge of the wave-theory is necessary.