

Non destructive characterization in air of plates using ultrasonic Lamb waves

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I. Introduction

The aim of this Thesis is to contribute to the development of an air-coupled non destructive inspection system based on ultrasound waves (Lamb waves), in order to inspect and characterize plate materials of high commercial value in industrial environments.

Conventional ultrasound inspection has been a standard non-destructive testing method for a long time. In most cases, though, a liquid medium, such as water or gel, is used to couple the transducer to the sample. Unfortunately, the physical contact of some important materials with a liquid medium destroys its properties. In these cases, air-coupled ultrasound systems allow to test and evaluate materials where liquid couplants can not be used.

The use of air as a coupling media implies several benefits since measurements are carried out without contact with the surface of the material under inspection and consequently the transducers can be moved at relative high speed during the inspection reducing the test time. However, air-coupled ultrasound systems have two important drawbacks: attenuation of the ultrasound in air, and energy losses at the transducer-air interface (typically near 40 dB). Therefore, there is a need to improve the dynamic range of the system, to be able to inspect materials with great attenuation.

II. Thesis description

Lamb waves are elastic waves that propagate in a solid plate with free boundaries. The inspection technique consists of launching a plane wave to the surface of the plate with an angle such as to maximize the efficiency of the plate wave excitation. The angle is a simple function of the sound speed in air and the plate mode velocity, as can be seen in Fig. 7. If the material or its properties change, this implies a change on the plate mode velocity, and the optimum angle also changes. Consequently, the transducer angle must be adjusted to continue exciting efficiently the plate mode. The concave geometry of the employed arrays permits to steer the acoustic emitted and received beams by simply choosing the physical aperture which central radius forms the desired angle with the normal of the plate surface, without any mechanical action. And it provides great advantages because the impact point is kept and no beam shape deformation exists, independently of the steering angle.

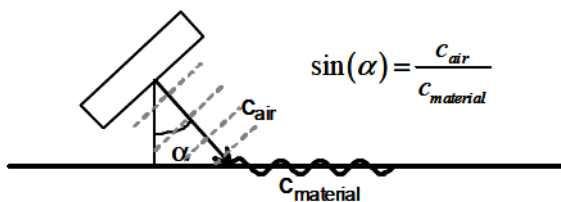
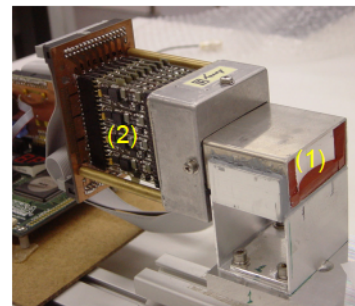


Fig. 7 Lamb wave generation

The system proposed is based on a 0.8 MHz concave ultrasonic transducer array (showed in Fig. 8) and its electronics which is able to generate and receive Lamb waves avoiding the mechanical transducer steering to coupling Lamb waves to the material surface, necessary in the traditional systems. The system will feature a real time adaptation to the solid media wave velocity and the possibility of selecting the Lamb wave mode without modifying the transducer array inclination to the material to be inspected.



(1). Concave ultrasonic transducer array
(2). Electronics

Fig. 8 Concave air-coupled piezoelectric array

The schematic diagram of the setup to test the plates is presented in Fig. 9 and a picture of the developed system is also showed in Fig. 10. As it can be seen, the system is composed by three main parts, emission, reception and control. A personal computer controls the system, in emission configuring the excitation and in reception capturing and processing the data. The transmitting transducer generates an ultrasonic wave travelling in air that impacts in the plate and generates a Lamb wave, which travels along the material. If the material changes or has any defect, the wave properties also change and can be detected when the received signal is processed.

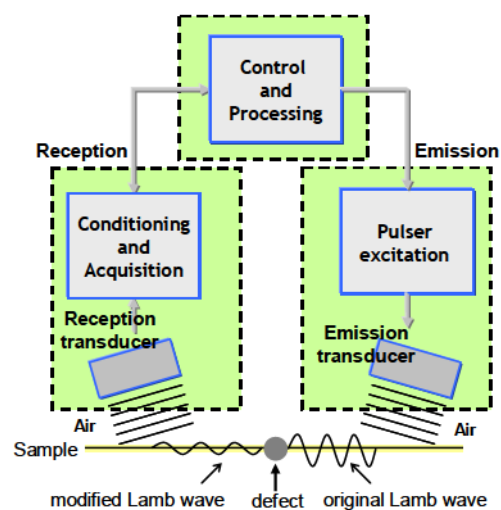
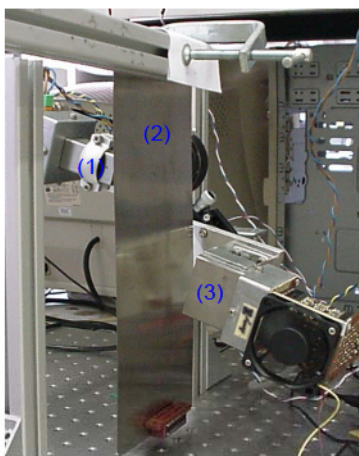


Fig. 9 Block diagram of the air-coupled ultrasonic system

But this process is too complicated or impossible in materials with high attenuation or when it is needed to

inspect long distances, due to the attenuation and the insertion losses. To achieve this goal, it is necessary to increase the dynamic range. The main contributions of the thesis to increase the dynamic range are:

- Characterize the array to obtain the transducer electrical parameters of the Butterworth-Van-Dyke model, and optimize a matching network that maximize the transfer of power and improve the transmitting efficiency of the transducer.
- Design the electronic circuit needed to increase the signal power, and suitable to be employed with an array of 32 elements.
- Emit coded burst to improve the signal-to-noise ratio.
- Decrease/reduce noise in reception.
- Use signal processing techniques and pulse compression techniques (like Chirp and Golay codes) to increase the signal-to-noise ratio.



- (1). Transmitter array
- (2). Material under inspection
- (3). Receiving array

Fig. 10 Measuring system

III. Results

Applying the contributions listed in section II, it is possible to generate Lamb waves in metallic and plastic plates, and even some papers, using ultrasonic air-coupled concave array transducers, and so evaluate its properties and parameters by direct or indirect measurements (wave velocity, attenuation...). As example, Fig. 11 shows the received signal of a Lamb wave generated in a 0.25 mm thickness stainless steel plate, when the emitter transducer has been excited with a square wave burst of 800 kHz, 28 cycles, ± 150 V.

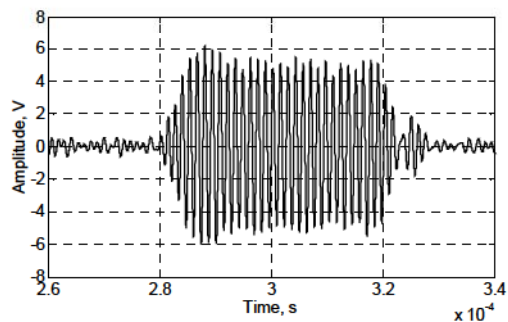


Fig. 11 Received signal of a Lamb wave generated in a 0.25 mm thickness stainless steel plate

And Table 1 summarizes the group velocity values obtained for some measurements performed with stainless steel of different thickness.

Thickness (mm)	Group velocity (m/s)
0.2	1793.3
0.25	1936.8
0.4	2348.6
0.5	2603.4

Table 1. Group velocity measurements in stainless steel 304, for different thicknesses.

As results of the thesis research, papers [1-5] have been published.

IV. Acknowledgments

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V. References

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