



Advances in the implementation of a UT contactless inspection system in the manufacturing process of thermoplastic components for aeronautical use, within the framework of the H2020-DOMMINIO project.

Roberto Giacchetta¹, Ricardo Gonzales¹, David Sánchez¹, Alfredo Morales², Francisco Ansedes³ and Eduardo Moreno^{1,4}

1 Dasel, Spain, E-mail

2 Aciturri Aeronáutica SL Spain, E-mail

3 AIMEN Centro Tecnológico

4 ICIMAF, Cuba, moreno@icimaf.cu

Abstract

In recent decades, the aeronautical industry has undergone a drastic transformation in the manufacturing philosophy in response to the growth of aircraft production (by 60% in the last 10 years), due to the increase in passenger transport demand. Although the pandemic has contracted the sector 66% during the last years 2020-2021, it is expected to normalize by 2024. The transition to the use of more advanced composite materials, together with the increase in aircraft performance and the rate of productivity is a challenge. Also, the necessity to produce effective structures and components using ecological materials and technologies have been increased, with the consequence of reducing cost, weight and fuel consumption. The DOMMINIO project from the European H2020 program, aims to develop new integrated design methodologies and knowledge based on manufacturing and optimization for the production of new multifunctional fuselage parts. A new technology is applied manufacturing by Laser ATL (Automatic Tape Layout) technique, using the automated deposit of thermoplastic tapes on a mold. Additionally, the DOMMINIO project deals with ensuring the quality of the components during the manufacturing process by a novel non-destructive control based on Ultrasound contactless technologies. To this end, DASEL has developed non-contact transducers that are coupled to the technological process of layer deposition, performing a non-contact quality control. This paper presents the results of the first year of the project, emphasizing the detection of delamination or lack of consolidation in real time.

KEYWORDS: Aircraft Ultrasonic NDT, thermoplastic plate elements, Lamb waves, Air contactless ultrasonic technology.

1. Introduction

Domminio is an EU funded collaborative research project focused on the development of an innovative digital methodology to design, manufacture, maintain and pre-certify multifunctional and intelligent airframe parts [1].

This project uses thermoplastic matrix composite materials, processed with an ATL (Automated Tape Laying) process (Figure 1). This is based on the in-situ consolidation of composite material in tape format, which is consolidated layer by layer applying pressure (with a compacting roller) and temperature (by means of a laser source). Then the idea is to deposit layers sequentially, obtaining a consolidation between them, so that at the end of the lamination process the part is finished, without the need to carry out a subsequent curing cycle [2].

In this process, defects may appear that can affect the behavior of the part in the service. The most common defects are porosity, delaminations and foreign objects that may fall during the laminating process, or other defects derived from the tolerances of the ATL equipment, such as gaps or overlaps between tapes or wrinkles in the tapes [3]. Since this process does not require further processing, these defects could be detected during the lamination process. This is one of the fundamental tasks sought by the DOMMINIO project.

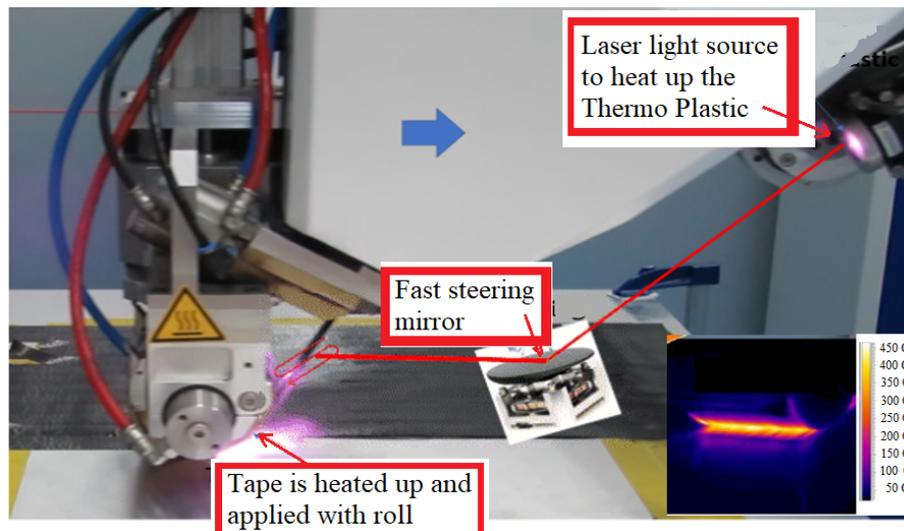


Figure 1. ATL system for the formation of thermoplastic plate.

As a part of the project Domminio, it includes a development of an ultrasonic contactless inspection system for the online quality control of the previous manufacturing of thermoplastic aeronautic components. This specific part in the project is considered as the fundamental objective presented at this congress. The UT contactless technique is based on ultrasonic air transducers that, according to the low frequency and relatively low thickness of the aeronautic components, should produce Lamb waves. This is a kind of guided waves that present the dispersion phenomena where the phase and group velocities depend on frequency and thickness. In this work,

it is also considered the use of standard high frequency ultrasonic technique based on phase array for testing final thermoplastic components in order to complement the previous technology.

2. Theoretical model

2.1 Lamb wave propagation

Lamb wave is one of the guided waves presented on plates (Shear Vertical, or SV) [4] [5]. This elastic wave mode appears when the wavelength is less than the thickness plate. In this case, the phase velocity (and then the group velocity) depend on the frequency and thickness of the plate. In Figure 1, it shows one example of the dispersion curves for a material considered in the work, where it is shown two fundamental modes: antisymmetrical and symmetrical modes.

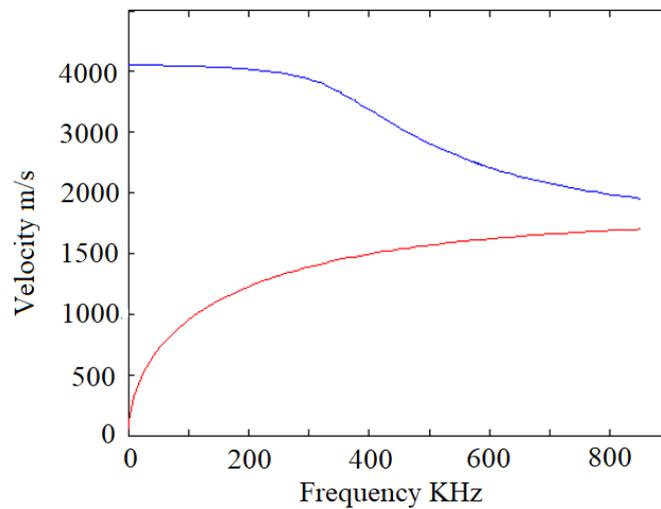


Figure 2. Dispersion curves for a 2 mm thickness plate. The blue curve corresponds to the symmetrical mode. The red one to the antisymmetrical mode.

2.2 Lamb wave pulse excitation.

Figure 3, shows a diagram of the experimental setup used for the excitation of Lamb waves. A first transmitter transducer T_x excites a longitudinal wave in the air surrounding the plate. The incident angle is obtained from the following Snell expression:

$$\sin(\alpha) = \frac{c_{air}}{C} \quad (1)$$

Where C_{air} is the velocity of longitudinal waves in air (360 m/s). The value of C is obtained from dispersion curves. In this work, it is used the antisymmetrical mode (Figure 2, red curve) with a given frequency as expressed below. Then (1) is a necessary condition for the excitation of a desired Lamb mode (that assume a “refraction” angle of 90°).

The Lamb wave mode propagates through the plate and produce a leakage phenomenon in the air that can be detected with a second receiver transducer R_x . In a pulse excitation at T_x , it is possible to obtain an RF signal over R_x , according to Figure 3. This is the fundamental implementation of the contactless technique developed for testing this material.

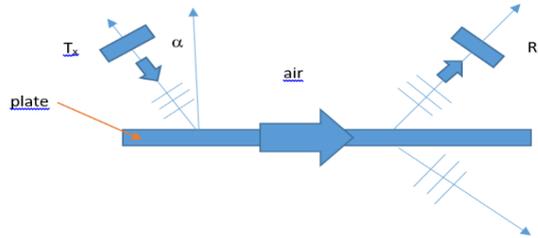


Figure 3. Diagram of the UT contactless inspection system. Tx=transmitter, Rx=receiver.

3. Material and Method.

It is shown on Figure 4, the basic configuration of both transducers developed for this project. Both of these transducers have a central frequency of 250 KHz. An angle around 10 to 15 was used in order to obtain a desired antisymmetrical Lamb wave mode. Both transducers move as a whole with fixed distances over all the plate. Then it is possible to obtain an RF signal at each position and then a C-Scan picture, with details of a possible defect according to the amplitude changes of Lamb wave mode.

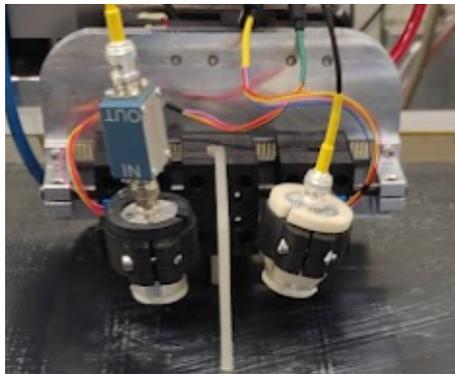


Figure 4. Experimental configuration with the two transducers Tx and Rx with a central frequency of 250 KHz

The next Figure 4 shows two of the samples used in the experiments of the Domminio project. On the left side there is a thermoplastic plate made by classic technology that will be used as a reference. On the right, there is a thermoplastic sample developed using the new ATL technique. The idea is to compare the new ATL process with the classic one. Both samples were tested with pulse echo phase array technique (5 MHz) and the ultrasonic contactless technology using antisymmetrical Lamb wave mode.



Figure 4. Left: Thermoplastic manufactured with compression molding . Right: Thermoplastic sample made by ATL process.

4. Results.

The Figure 5 shows the results for the first reference thermoplastic sample, which is considered as a flawless sample. Two images, the B-Scan from phased array or PA (left) and Contactless Lamb wave C-mode are displayed. Both images are considered as reference images of a sample without defect, obtained with a classic method. The PA shows a clear bottom echo of the sample and the C-mode although shows some variation in the colors it could be considered as homogeneous. Then both images could be considered in the possible amplitude variation accepted for a flawless sample. The idea is to compare this image obtained with a classic thermoplastic method in Figure 5 with the ATL process as it will be shown in the next figure.

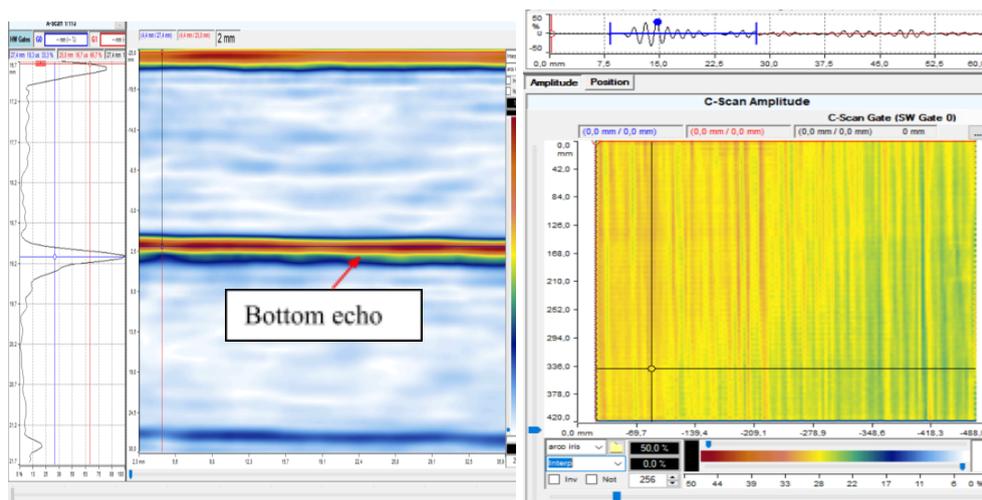


Figure 5. Images examples from a thermoplastic reference sample obtained from standard procedure for a flawless sample. Left B-mode phased array image. Right. C-Mode Contactless Lamb wave mode.

Figure 6 shows the first results obtained from an ATL sample with the same UT method as the previous case. In this case, the results show two fundamental aspects. First in the

PA, B-Scan it is not possible to obtain at the bottom echo as in the previous classic method case. The C-Scan Lamb wave mode, also shows an increment in the non-uniform color related with the previous case. Then this first ATL sample still needs to be adjusted in the next future as a part of the project. The most important thing is the capacity of the contactless ultrasonic method developed based on antisymmetric Lamb wave mode.

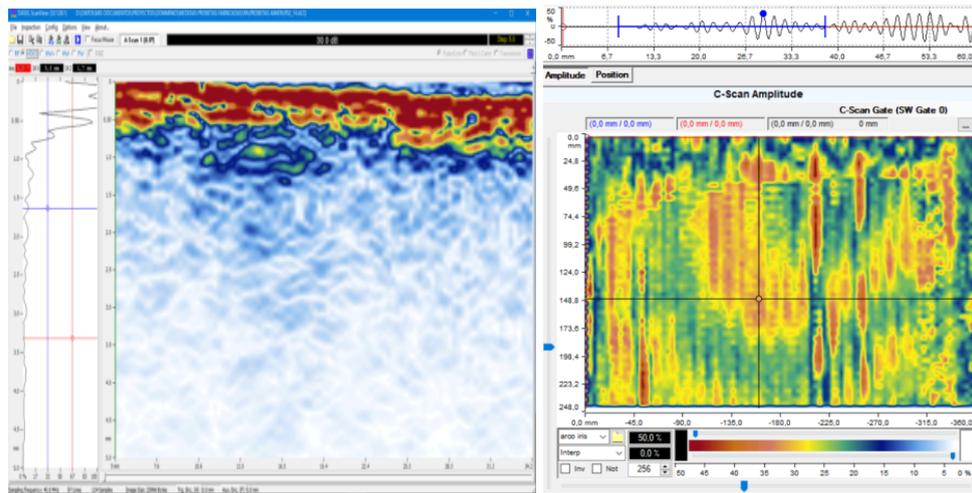


Figure 6. Images example for the ATL thermoplastic sample. Left B-mode phased array image. Right. C-Mode Contactless Lamb wave mode.

4. Conclusions

An ultrasonic contactless technology was developed in the Domminio project for testing the thermoplastic samples made by two technologies, the classic and the ATL. The results shows that the ATL technology should be improved. This could be considered as a first stage in this project. Of course, several works should be done in the ATL and in the own ultrasonic contactless technology, in the next future.

Acknowledgements

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