Air-coupled ultrasound inspection of complex aluminium-CFRP components

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1. INTRODUCTION

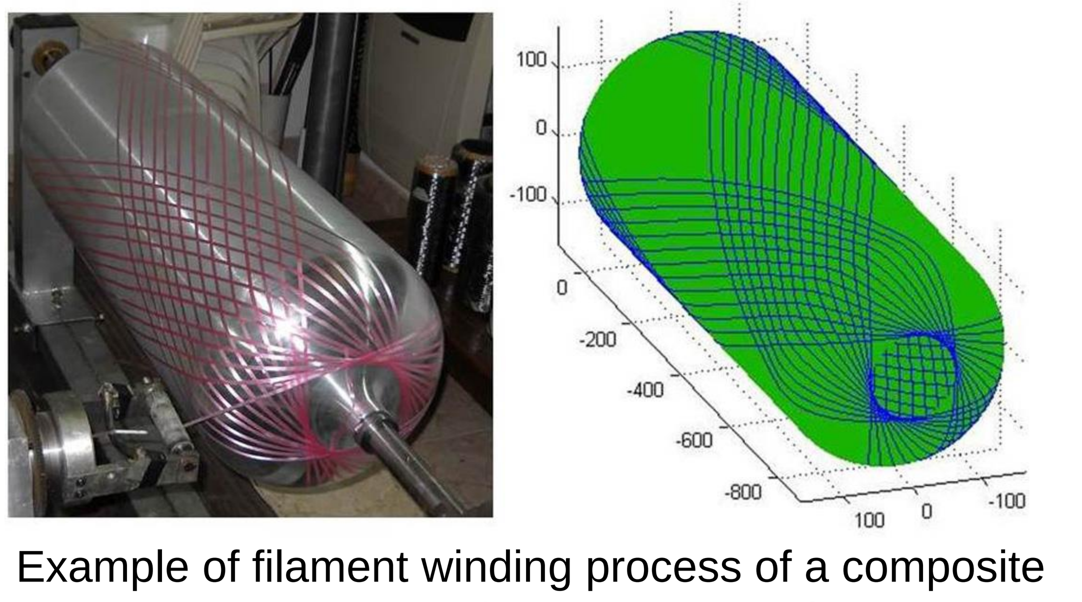
Composite Overwrapped Pressure Vessels (COPVs) are widely used to contain high-pressure fluids. COPVs consist of a thin metallic liner covered with a composite material based on structural fibres. The main function of the liner is to avoid direct contact between composite and chemical agents which can degrade the resin matrix.

In the **filament winding process** for COPV production, a metallic core is wrapped with impregnated carbon filaments. After that, the matrix can be cured at ambient temperature without use of an autoclave.

The COPV's structural integrity can be assured using suitable designs, controlled manufacturing processes and effective Non Destructive Evaluation (NDE) methods. However, **the ultrasound inspection of these components is challenging by several factors.** Because no vacuum compaction process is applied, the sound attenuation in the laminate is high. Moreover, the strong reflection at the liner-fibre interface avoids inspecting from the metallic-side using conventional techniques.

This work explores the possibility of inspecting COPVs by air-coupled ultrasound after the manufacture process.

FILAMENT WINDING PROCESS



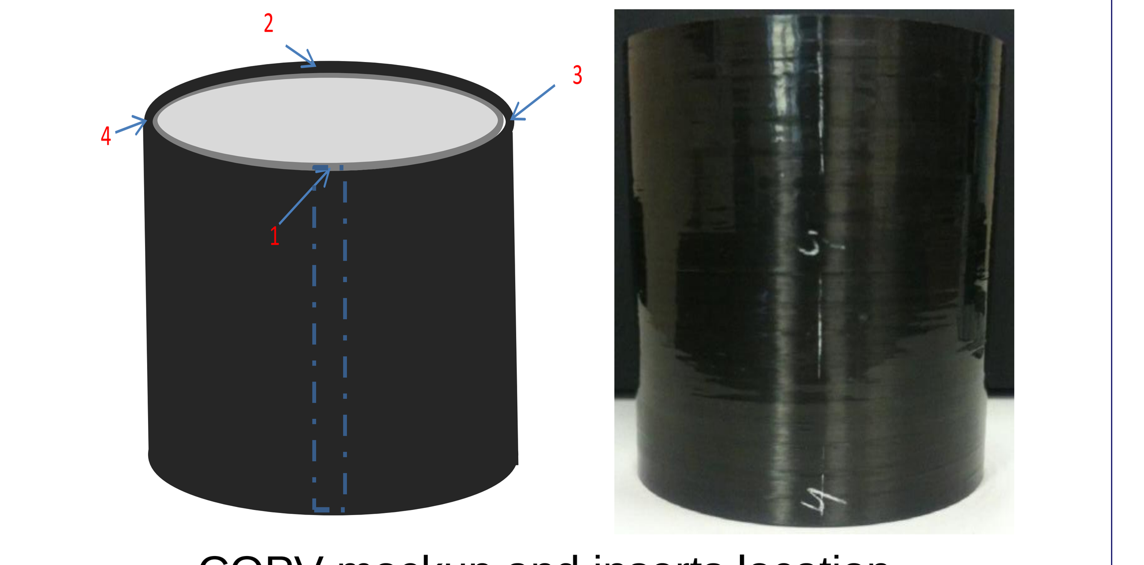
Example of filament winding process of a composite overwrapped pressure vessel.

2. MATERIALS AND METHODS

An **aluminium cylindrical liner of 130 mm length with 114 mm of outer diameter and 3 mm of wall thickness** was used to produce a reduced mock-up of a COPV. It was winded with carbon fibres in a 4-axis machine controlled by the FILWIND software (both from Kohlenia, Argentina). The resin curing was at ambient temperature and no autoclave was used.

Rectangular **polypropylene inserts** of 130 mm length, 38 mm width and 0.1 mm thickness were introduced on the sample. One artificial defect was placed at liner-overwrap interface to simulate disbond. The other three inserts were disposed between layers 4th and 5th, 8th and 9th, and 13th and 14th, to simulate delaminations at different depths.

MOCK-UP



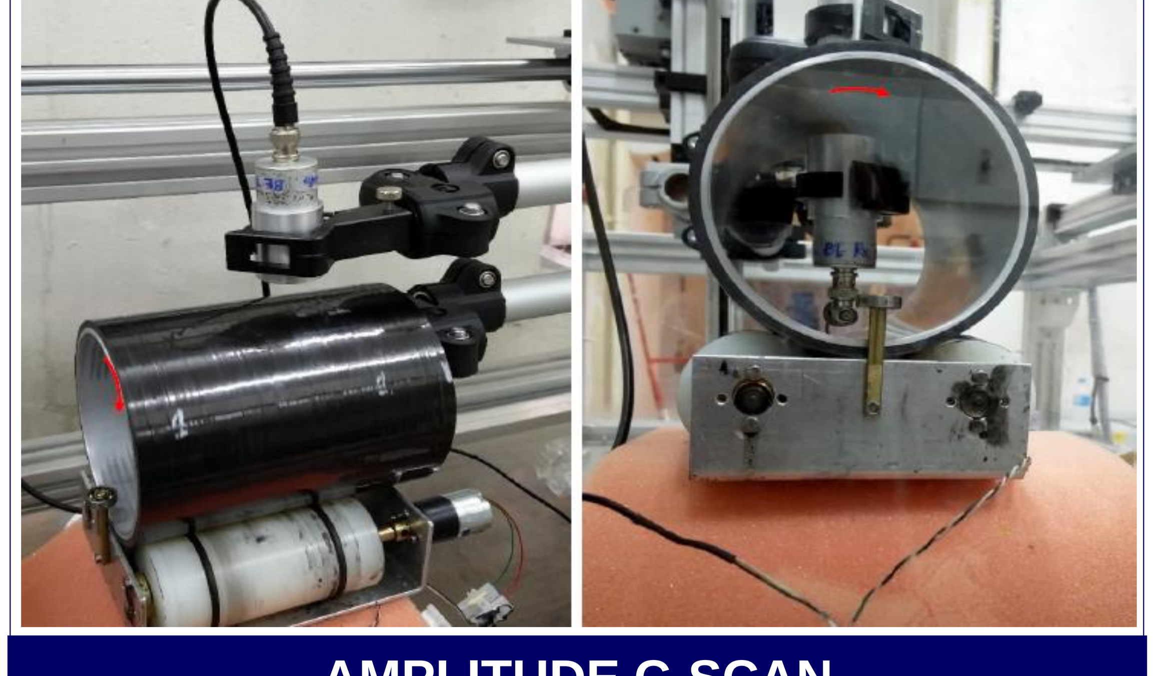
COPV mockup and inserts location

The test sample was mounted on a pair of motorized turning rolls, and the non-contact inspection was performed using two pairs of ACT developed by CSIC, Spain. The AirScope ultrasound system (Dasel SL, Spain) was used for recording the ultrasonic signals.

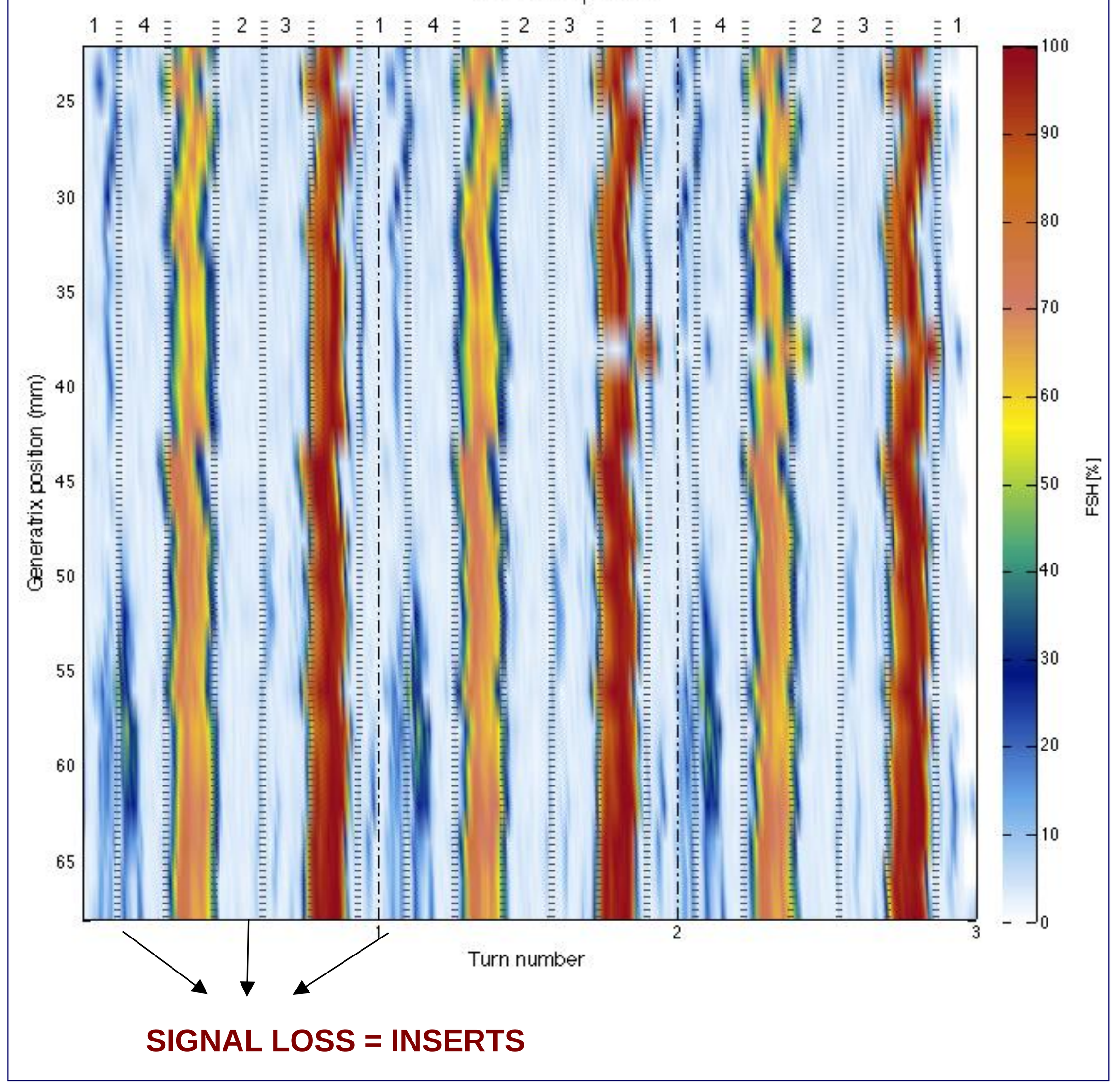
3. THROUGH-TRANSMISSION

In through – transmission mode, **the pair of ACT was moved in tandem along the cylinder axis**, after three turns of the cylinder each time.
The artificial flaws are detected when the signal **amplitude falls below 30**% due to the acoustic energy reflection on the inserts. The scan image revels that inserts 1 and 4 are slightly separated, while defects 2 and 3 are very close together. Moreover, the laminate between inserts 3 and 1 has a better adhesion to aluminum (more signal amplitude) that region between 4 and 2.

THROUGH-TRANSMISSION SETUP



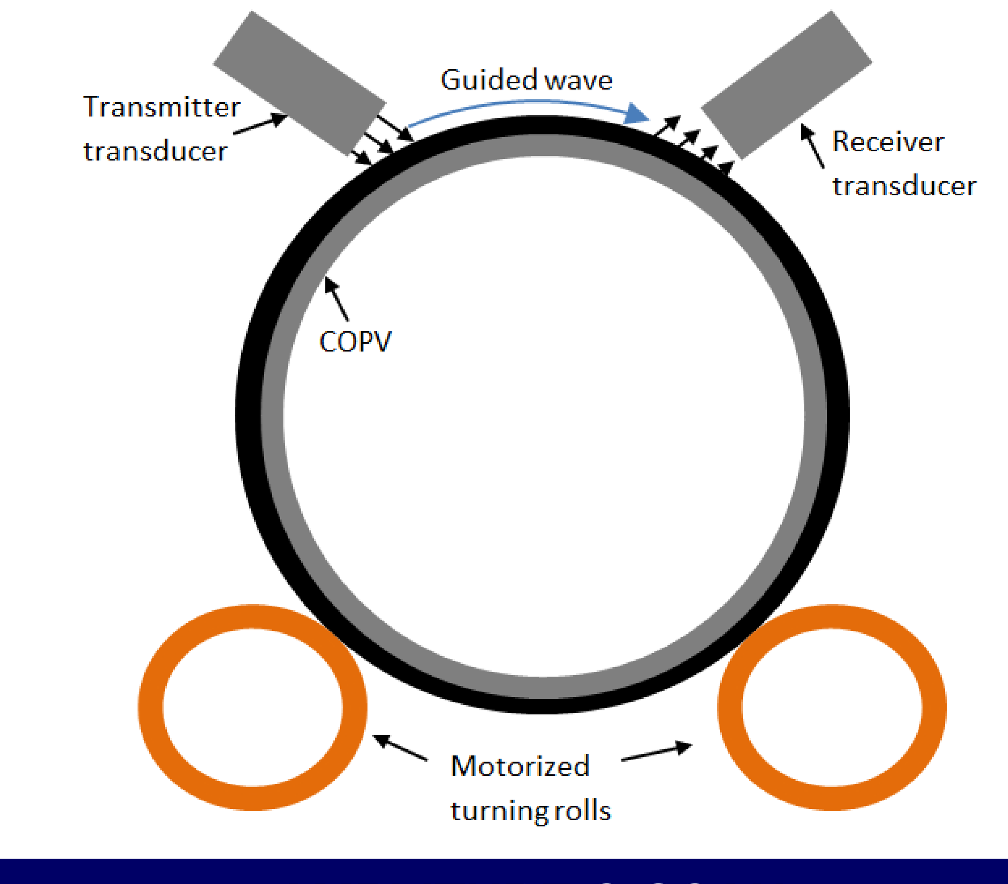
AMPLITUDE C-SCAN



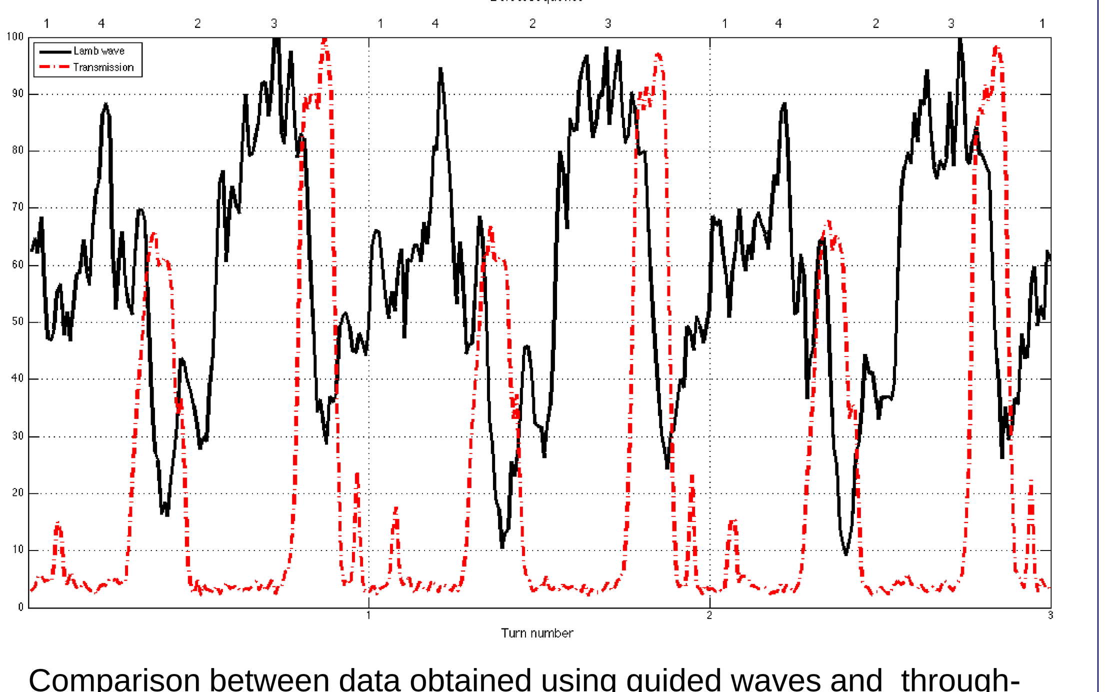
4. PITCH-CATCH

This configuration presents the main advantage **of avoiding the access to both sides of the test sample**. In this particular case, both ACTs are placed on the outer side of the cylinder with oblique incidence over the surface. A pair of 250 KHz wideband transducers was used, with square section of 12x12 mm (Fig. 3). In particular, the pitch-catch configuration allows the **generation and detection of guided waves** for testing the composite structure.
The maximum amplitude of the guided waves is correlated with the inserts position. In fact, inserts allow the laminate to vibrate more easily than if it is bonded to the liner.

PITCH-CATCH SETUP



AMPLITUDE C-SCAN



Comparison between data obtained using guided waves and through-transmission mode. Signals were taken at 36 mm from the cylinder edge.

5. CONCLUSIONS

Air-coupled ultrasound offers a great potential for rapid inspection of COPVs. Both configuration modes (pulse-echo and pitch-catch) are complementary and provide a qualitative detection of defects. Through-transmission mode offers a good sensitivity and SNR. However, requires to access to both sides of the test sample. On the other hand, the single-side, pitch-catch mode allows using guided waves and performing the inspection from outside, which reduces the scanning system complexity. The guided wave test also enables the possibility of characterizing material properties such as fibres orientation.

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