Air-coupled ultrasonic inspection of aerospace parts with a collaborative robot and arbitrary waveform generation

Héctor Calás[1], Fernando Ojeda[2], Alan Caulder[3], Nans Laroche[4], Tomas Enrique Gomez Alvarez-Arena[5]

[1]Applications, AOS/TPAC, France, [1]BDM, AOS/NDT, USA, [1]BDM, AOS/TPAC, USA, [1]Applications , AOS/TPAC, France, [1] Ultrasonic and Sensors Technologies, ITEFI/CSIC, Spain

Inspection of large composite structures represents a critical challenge in the aerospace industry. Air-Coupled Ultrasound Testing (ACUT) has emerged as a promising solution to address that issue. Indeed, this technique does not require any liquid coupling or direct contact with the specimen and provides a good solution for parts that cannot be immersed due to their shape, or sensitivity to water or other coupling liquids. ACUT has been around for more than 20 years, but their industrialization always faces the same difficulties. First, the acoustical impedance mismatch between air and the material to inspect requires transducers that can overcome this impedance difference and ultrasonic device with cutting-edge capabilities in terms of signal sensitivity, digitalization, pulsing capabilities, and frequency range. Secondly, the implementation of the different ACUT techniques is very sensitive to the relative positioning of the transducers with respect to the piece. Then the scanning trajectory of large parts with complex shapes has long been difficult to implement. In this work, we propose to integrate collaborative robots (cobots) into the application of ACUT to plan complex 3D trajectories. The use of collaborative robots offers great precision and efficiency in inspection. They allow unprecedented adaptability to various geometries and components, with an increased capability to ensure local normal incidence, even in complex geometries. Moreover, they can work safely alongside humans, are highly flexible in programming, and can be quickly reconfigured for different tasks. To streamline integration in collaborative environments, we have simplified the communication of robot coordinates by converting them into encoder signals which can be interpreted by the ultrasonic instrument. This conversion maintains the ability to follow complex trajectories, resulting in a high-performance system suitable for both laboratories and industrial environment. In addition, the inspection is performed with controlled excitation pulses to increase the signal to noise ratio. The proposed method also benefits from the Arbitrary Waveform Generation (AWG) capability of the ultrasonic hardware. This feature provides an enhanced control of the shape of the excitation pulse and allows us to increase the amount of transmitted energy which is critical in our application. The integration of ACUT with cobots opens new avenues for automated inspection, promoting opportunities to enhance both quality and efficiency in the aerospace industry. Our results cover three types of parts: Carbon Fiber Reindorced Polymer (CFRP) for detection of delamination, honeycomb for detection of skin disbond, and aluminum sheets with rivets to assess the quality of reinforcement bonding.