Non-destructive testing of composite structures: from prototype qualification to online production inspection

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Abstract

This paper deals with the structural quality assessment of composites structures during their life cycle. Thus, this talk will start by a presentation of the main Non Destructive Testing methods preconized during composite prototypes qualification. The benefits of X-ray computed Tomography and Acoustic Emission will be illustrated thanks to industrial projects addressing among others the qualification of composite bearing cages and of a composite crane boom. Then, we will focus on applications dealing with online inspection of composite structures production. An ultrasonic phased array inspection method was developed in order to monitor continuously the integrity of a pultruded thermoplastic tape during its manufacturing. This system has to detect lacks of resin impregnation and dry fibers in real time with an inspection cadency in agreement to industrial requirements. Finally, infrared thermography systems will be presented for the monitoring of the thermoplastic 3D filament winding process (SPIDE TP) and of the Quilty Stratum Process (QSP). The objectives of these systems are respectively to detect disbonds, inter-tape porosities… following the thermoplastic tape welding (SPIDE TP) and to check the temperature distribution on the thermoplastic lay-up preform before press-forming (QSP).

1. Composite prototypes qualification

The life cycle of composite structures is briefly described in order to highlight applications of Non Destructive Testing on each step of their life cycle. For composite prototypes qualification, this paper presents an example of X-ray Computed Tomography to assess the structural integrity of composite bearing cages. This study illustrates the ability of X-ray Computed Tomography to visualize very finely porosities inside the cage. The porosity rate was also evaluated in order to compare quantitatively the quality of different prototypes with different shapes and materials (PA/glass fibers, PEEK/Glass fibers).

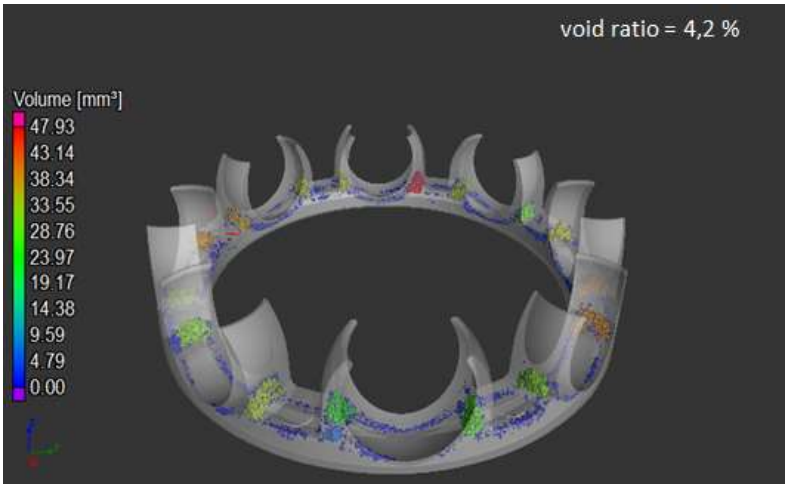

Figure 1. X-ray Computed Tomography: location and dimensioning of porosities

Then, the mechanical strength of a composite crane boom prototype was validated using mechanical tests instrumented using acoustic emission method. The full-size trial is presented and the acoustic emission signals are analysed in order to explain the fracture mechanisms. This example illustrates perfectly the benefits of using acoustic emission instrumentation during mechanical tests: detection of early damages, damage location, damage mechanisms identification and early breakage prediction.

2. Online inspection of composite structures production

2.1 Online inspection of pultruded thermoplastic tapes

To reduce the cost of quality control of composite parts, an online inspection was implemented on a pultruded thermoplastic tapes manufacturing line instead of a finished products quality check. This online ultrasonic phased array inspection was set up on the pultrusion line located at CETIM in Nantes. The objectives are to detect in real time during the manufacturing of composite tapes the presence of imperfections as porosities, lacks of resin impregnation...This will ensure a good structural integrity of the finished products obtained thanks to these composite tapes. First, the industrial requirements and theirs influences on the non-destructive testing system are presented. The ultrasonic phased array system is designed to take into account the tape flexibility, the particularities of production process, the scrolling speed up to 4 m/min, the water absorption property of polyamide tapes... Different experimental setups and ultrasonic phased array scans were tested and were evaluated in terms of defects sensitivity, cadence and reliability. The performances of the online inspection system were validated on reference tapes with various qualities of resin impregnation and then online during the manufacturing of unidirectional glass fibers tape.

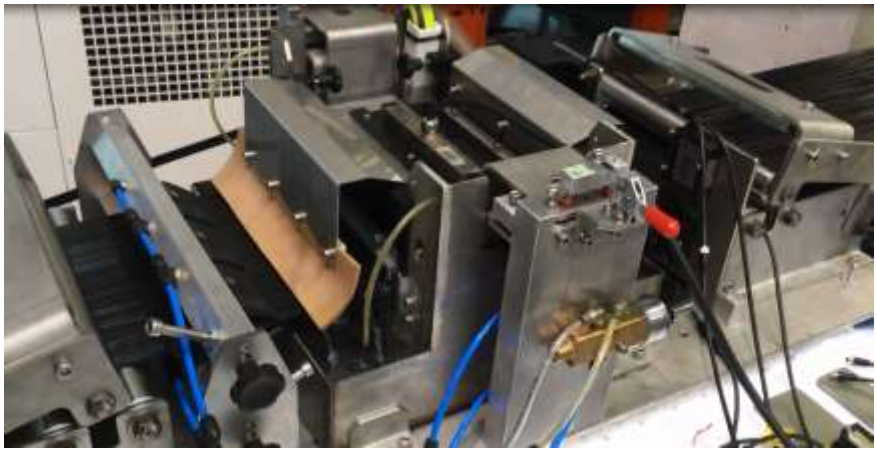

Figure 2. Online ultrasonic phased array inspection system of pultruded thermoplastic tapes

2.2 Online inspection of filament winding process

SPIDE TP is a high speed tape laser heated winding process allowing to produce thermoplastic composite parts of various dimensions and shapes (pressure vessels, tanks…). Several composite layers are laid up to manufacture the structures. Due to the winding process, imperfections between the layers in the thickness or along the axe of the structure can appear as for example delaminations, overlaps or gaps between layers.
A comparison has been made between active pulsed thermography and passive thermography in order to select the most relevant technique, by considering the sensitivity but also the operational aspects. Passive thermography appears as the most relevant technique, giving a satisfying sensitivity and higher flexibility in terms of implementation, even though active thermography gives a better sensitivity and defect definition. So, CETIM implemented a passive infrared thermography system on the deposit head to detect in real time and during the manufacturing of the structures, the presence of imperfections as overlaps, gaps or delaminations between the tapes… Validation tests have been successfully performed during a production at a speed up to seven meters/min.

3. Conclusions

This paper deals with the benefits of using X-ray computed tomography and acoustic emission method during the qualification stage of composite prototypes. This discussion is based on results obtained during industrial projects. Then, online inspection methods designed and implemented on composite manufacturing process (QSP, SPIDE TP) located at CETIM are presented and are evaluated in terms of performances, reliability and sensitivity to searched defects.