Analysis prediction and correlation of Fiber Metal Laminate (FML) crack propagation in Semi-Wing Full-Scale test

Willy Roger de Paula Mendonça [1], Danielle Fatima Nunes Rebello da Silva [1]
[1]*Embraer S.A., São José dos Campos, Brazil*

This study will demonstrate the correlation between the simulation and the experimental results obtained for artificially inserted crack propagation in the Semi-wing full-scale test developed by Embraer. The crack developed on the lower wing skin, which was manufactured in FML. The crack selected for this study was one of the several cracks inserted in the Semi-wing lower wing cover. These cracks were inserted for the development of the crack propagation analysis methodology in FML. In addition, the application of cracks in a Full-scale test allowed the evaluation of several damage scenarios that could hardly be reproduced with accuracy in tests with structural subcomponents, such as: design details in assemblies, geometric details without simplifications, redistribution of load flow among components structural and so on.

Several studies about crack propagation in FML have been published in the last decade, mostly related to propagation in coupons and subcomponents. Figure 1 illustrates the semi-wing used in the Full-Scale test and highlights the lower wing cover manufacture in FML with bonded stringers.

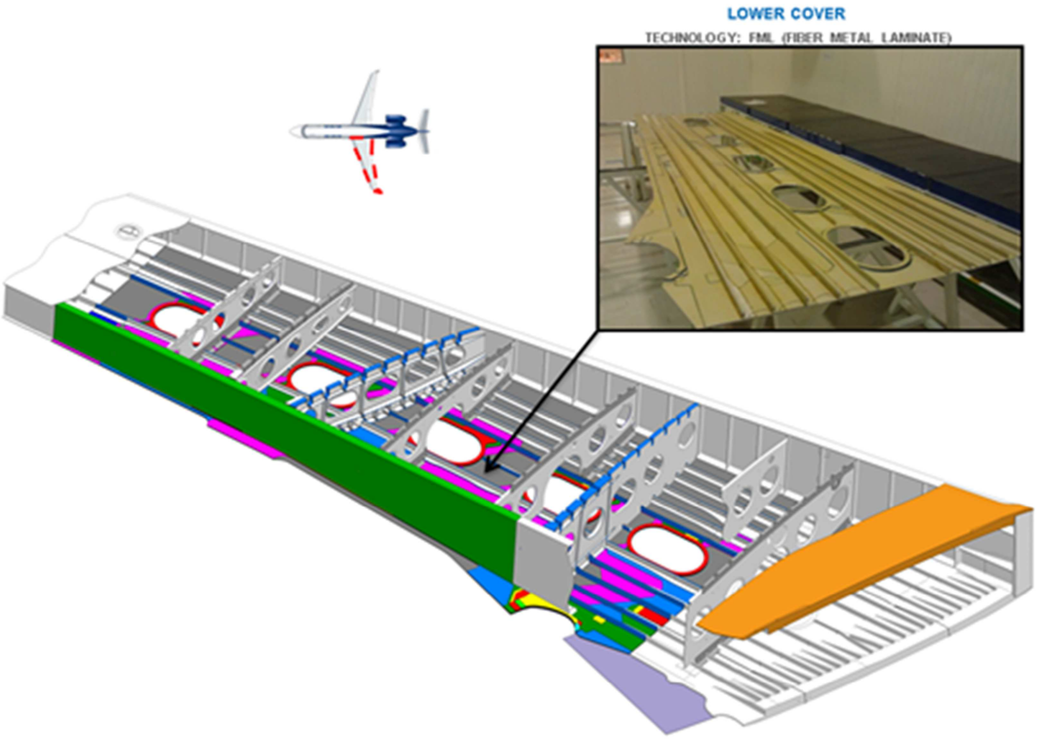

Figure 1. Lower wing cover applied in semi-wing test

This semi-wing is similar to that existing in the RJ-145 aircraft and has been tested on fatigue prior to the propagation test. The fatigue test lasted 120.000 Flight Cycles (FC) which corresponds to two lives of the aircraft operation. It should be mentioned that no cracks initiated naturally in FML during the 120.000 FC.

The results presented in this study were obtained from a damage that simulates a failure in the window frame, made of FML. Figure 2 shows this artificial damage. Figure 3 illustrates the structure in the surroundings of the crack; it is possible to visualize the crack inserted in the frame and the adjacent stringer in the lower wing cover.

From this test were obtained the experimental results presented in Figure 4, where it is also possible to observe the simulation of crack propagation. The experimental results were measured for each tip crack in FML, emphasizing that the FML in this region is composed of different layups along the crack path.

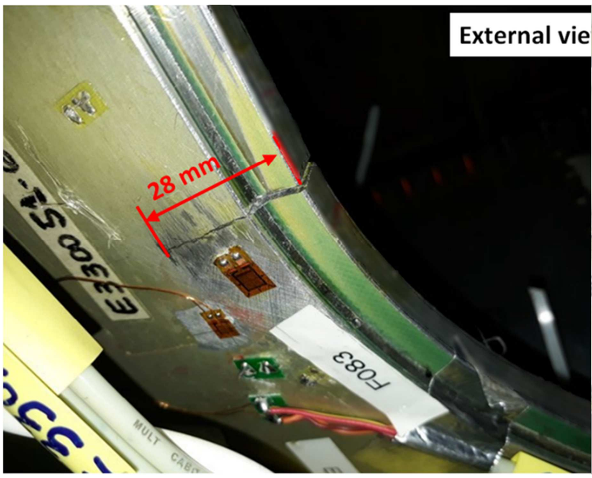

Figure 2. External view of inserted damage

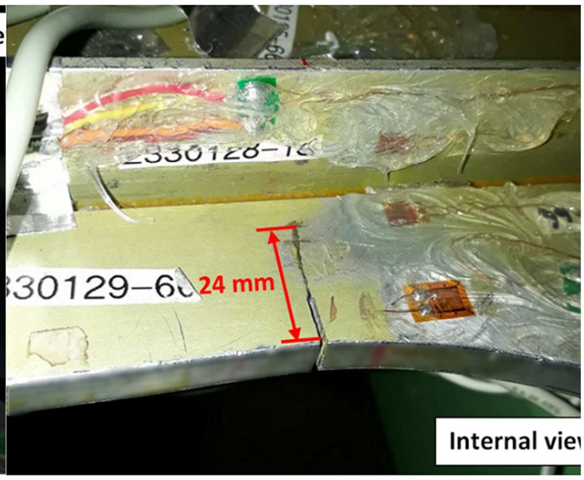

Figure 3. Internal view of inserted damage

The propagation prediction analysis of this crack, used as basis the analytical methodology developed by Rene [1], which was adapted for a thick layer laminate, combined with Finite Elements Analysis (FEA), from which the stress field in the structure was obtained. The model used was illustrated in Figure 5. This procedure allowed to represent more complex structures with greater fidelity.

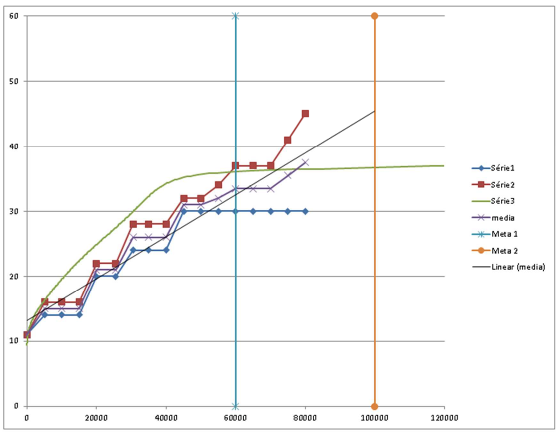

Figure 4. Results correlation

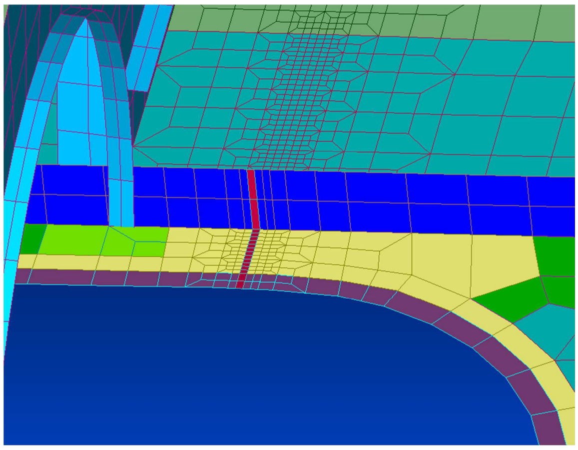
Figure 5. FEA representation

High correlation between analysis prediction and test results can be observed in Figure 4. Thus, the applied methodology was able to represent the structure complexity degree, which it contained layup changes in the skin and bonded stringers. These complexity means, locally, a secondary moment caused by the off-set differences, the stiffener disbond in addition to the delamination in the FML.

This result is an indication of the robustness of methodology applied for crack propagation in the FML for wing structures and also contributes to increase the reliability that has been proved over the years in others researches for coupons and panels made of FML.

Keywords: FML, Crack, Delamination, Semi-Wing