Fast and Accurate

Additive Manufacturability Analysis

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This article focuses on the design optimization of complex 3D composites structures made by additive manufacturing processes.

There are commercial CAD-CAM software solutions for detailed offline path programming, but there is a growing need for innovative tools and methodologies for trade off studies very early in the design stage. A new innovative solution has been developed on top of the CATFIBER© software, allowing both designers and stress engineers to quickly analyze complex double-curved geometries. It also includes a variable stiffness approach with tow-steering, and structural analysis of the manufacturing defects using Digimat© software.

Design Analysis Framework Description

Today, more and more CFRP structures are manufactured by automated processes such as fiber placement robotic systems (Figure 1).

The design trade-off analysis can be done on a simplified quasi-isotropic laminate (with full plies), in order to just analyze the surface curvature impact, independently of plies shape. But thickness effects, material excess, staggering rule, part productivity rate, could not be correctly estimated.

The engineering and manufacturing requirements may quickly interfere, and a difficult compromise between feasibility, strength and cost needs to be found, especially with double-curved layup surfaces.

Figure 1: **Automated Fiber Placement robotic system (Coriolis Composites)**

Moreover, such analysis systems are not able to reach a good compromise between performances, level of details and results accuracy. The expected computation time is a few seconds to a few minutes so that several analysis runs can be done in parallel within a few hours only.

Designers and stress engineers need robust tools and methodologies to help them test many combinations, such as material width, maximum number of tows by course, and maximum fiber deviation angle. The solution should be able to analyze complex and representative laminates such as large aerospace panels with double curvature and hundreds of plies.

An automatic ply splicing algorithm, based on both engineering and manufacturing requirements, allows to quickly and easily generate a manufacturable design proposal. This algorithm also uses a patented rosette transfer feature, allowing steered-path propagation and then variable-stiffness modeling (Figure 2).

Ply course centerlines and splice cuts are first computed, then the ply boundary is filled with (tow) strip surfaces. This allows us to capture all the process and material specificities, such as triangle of gaps, tow overlaps, minimum course length (MCL), and minimum distance between tow cuts (Figure 3).

The design analysis system is also able to compute and output several manufacturing cost indicators, to help designers sort the manufactural design proposals (number of courses by sequence, number of tow cuts and drops, buy-to-fly ratio).

The design analysis tools were implemented on top of Coriolis Composites CATFIBER© Offline Programming solution, through a dedicated infrastructure made of scripts (Python or Visual Basic) and a Microsoft Excel© spreadsheet. This allows us to easily launch several background runs from a very light user interface.

Structural Strength Analysis

To verify the structural strength of the optimized Layup design proposal, it is important to have a quick and easy transfer of all the as-manufactured composite properties onto a structural mesh used for sizing purposes. This mapping is done using the Digimat Platform© and concerns the transfer of

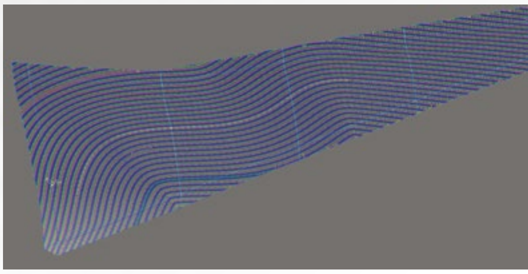

Figure 2: **Steered-paths on wing skin surface.**

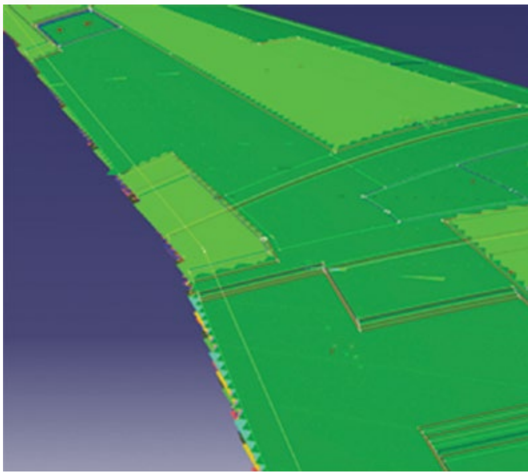

Figure 3: **Plies build-up with tape courses covering.**

the as-manufactured fiber orientation, the exact location of the gap and resin-rich area. Using Digimat, such information can be transferred automatically to the Finite Element Model used for sizing activities by Stress Engineers. In this case, Digimat can generate the composite layup command cards with the local as-manufactured fiber orientation for each ply. In addition, the effect of the gaps on the local stiffness can be handled in two ways, depending on the reconsolidation process. The first one considers that the gaps have an effect on the local thickness while the second one considers that the gaps are filled by resin and affects the local fiber volume fraction of the composite. Using a micro-mechanical model of the material, this local variation of the fiber content is computed at each Gauss point of the FE Model (Figures 4 & 5).

Digimat can generate the composite layup command cards with the local as-manufactured fiber orientation for each ply.

References

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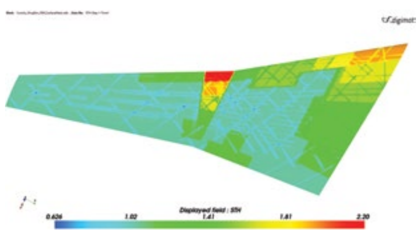

Figure 4: **Thickness map analysis (quasi-isotropic laminate) with tow gaps capture with Digimat© software.**

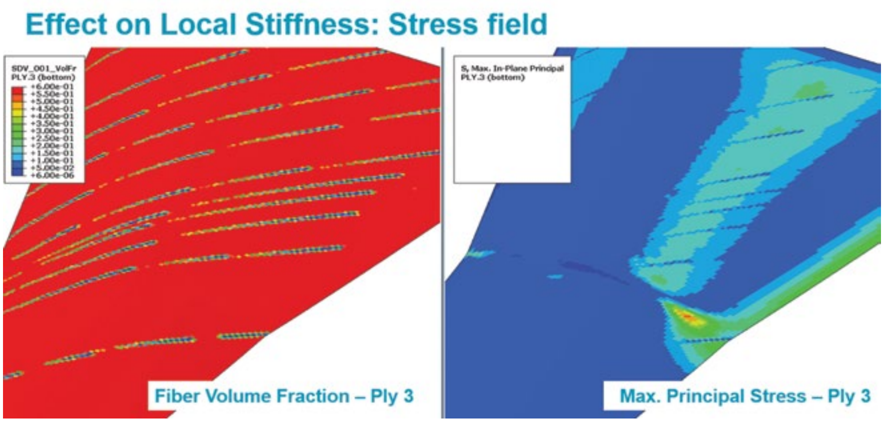

Figure 5: **Local stress field per ply and effect of gaps computed by Digimat©**

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For Details About Digimat©: www.mscsoftware.com/product/digimat