Designing with composites: Optimizing for performance and manufacturing

» The choice to design with composites is often driven by market demand and cost. The promise of mass reductions, performance improvements and material and assembly cost reductions is enticing, but realizing a design with fiber-reinforced plastic (FRP) remains challenging. As FRP become the material of choice, based on design potential, traditional methods of analysis, design and manufacturing will not suffice. Based purely on the nature of the material itself, a composite design must be optimized not only for finished part performance but for manufacturability as well. Specifically, analysis and design must be performed *in the context* of the manufacturing process. Therefore, composite design requires a serious commitment to what I'll call *concurrent* engineering processes.

FRP parts are "inseparable assemblies" made up of tens to hundreds of plies that vary in number, and therefore thickness, across the desired part geometry. A combination of the part geometry, the material form *and* the manufacturing process affects the fiber orientations within the part; therefore, understanding all three characteristics is critical during the design phase. Fibers that deviate from the analyst's defined orientations will affect structural performance due to a significant impact on modulus and strength. In addition, in-plane or out-of-plane deformations that occur during production will result in increased manufacturing cost and effort to resolve issues downstream.

Preliminary analysis of composite parts is often performed based on idealized geometry and fiber orientations that meet loading conditions. However, without the understanding of fiber deviation, material knockdown factors are used to reduce the material's mechanical properties. The result is an overbuilt composite part, which neither achieves the structural performance nor the desired mass reductions. Virtual visibility into the deviation and deformation of the material during the manufacturing process can minimize the risk of overdesigning parts. Often referred to as "simulation of manufacturing producibility," »

FIG. 1

The image at upper left is the part in CAD with a single ply's fiber orientations displayed in white, yellow and red (the colors indicate progressively significant "deviation from desired") that resulted from the simulated manufacturing lay-up process. The lower right is the part in CAE displaying the same ply's fiber orientations passed from the CAD model after the manufacturing simulations.

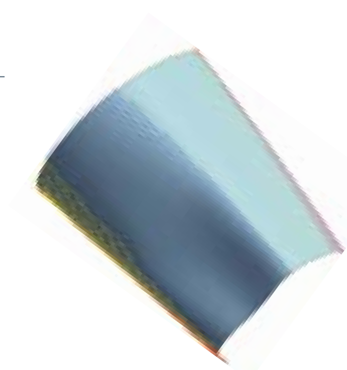

FIG. 3

A vector fiber field is displayed on the CAD part that represents the variance between the analyst's desired fiber orientations and the orientations mapped/defined during the detailed design phase. The vectors are shown in blue, yellow and red, depending on the degrees of variance, where blue is little-to-no variance and red is greater variance. The visualization depends on the desired amount of tolerance.

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FIG. 2

The part in CAD can have the manufacturing process defined, refined and simulated to determine the best method with which to produce the part and how best to meet the analyst's desired fiber orientations. These two images demonstrate two different methods used for hand lay-up and the affect each had on the fiber orientations in blue, yellow and red. Yellow and red show deformations, where red indicates actual wrinkling of material.

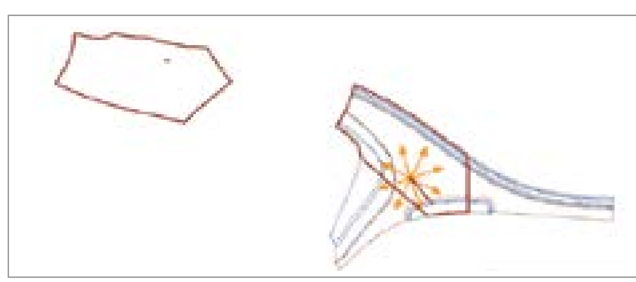

FIG. 4

Consistency in manual lay-up can be assisted by both standard laser projection and with plybooks that display the simulated manufacturing process that was used in CAD to obtain a flat pattern. The plybook features drawings (example shown here) that shows one or more boundary views and a flat pattern view. The boundary views can display the simulated manufacturing process, in orange, that was used to derive the flat pattern generated for lay-up.

this software-based capability is where the true fiber orientations can be known and then can be exchanged with those who do the analysis, as illustrated in Fig 1, p. 12.

Taking a closer look, the detailed design process is started by importing the material lay-up from the analyzed finite element model and applying it to the CAD part. Next, the designer and manufacturing engineer, together, elect the best lay-up process and simulate it in the CAD environment, making the detailed part the basis for understanding the resulting material fiber orientations (Fig 2). The resulting material properties and true fiber orientations are then passed back to the analyst's pre-/post-solution, ensuring that local fiber orientations are known; thus, the analyst no longer is relying on theoretical orientations. The result is a part identified by correlating non-linear analysis with real part behavior, and can be designed within tight safety margins.

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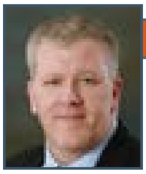
Delivering an optimized composite part requires that the fiber orientations of the production part fall within tolerance of an analyst's *desired* part, which requires *consistent* manufacturing. Today, the majority of composite parts are still produced with manual lay-up processes, which innately introduce the risk of inconsistency. Although consistency increases when automated manufacturing processes are employed, additional constraints are introduced, which can affect fiber orientations, thus impacting designed performance. In the case of automated tape laying and fiber placement methods, for example, intended fiber orientation can be constrained by material radius-of-curvature limits. To ensure consistency, then, it is always necessary to compare the as-manufactured fiber orientations with the as-designed orientations (Fig. 3), and to communicate the simulated lay-up process used in part and flat pattern development (Fig 4). Consistency can be achieved by simulating the manufacturing process in the context of the desired fiber orientations, ensuring delivery of an optimized composite part for performance *and* manufacturing. CW



ABOUT THE AUTHOR

David Leigh Hudson is director of product and market strategy for the Fibersim product portfolio at Siemens PLM Software (Waltham, MA, US), a business unit of Siemens Digital Factory Div. Hudson joined the company when Siemens acquired Vistagy Inc. in December 2011. During his tenure with Vistagy, prior to assuming a product portfolio leadership position, he served as technical services manager, supporting sales, services and distribution channels for the Asia-Pacific region. He received a BS in mechanical engineering from the University of Wisconsin at Milwaukee and a BS in accountancy at Bentley University (Waltham, MA, US).