PRACTICAL USE OF COMPOSITE PROCESS SIMULATION

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ABSTRACT

The simulation of composites processing is an activity that has matured over the past 25 years. It has grown from simple analyses focused on isolated details of the manufacturing process to full thermal, flow, and stress analyses of fully configured composites assemblies. As our understanding of the behaviour of the materials has increased, numerical tools able to capture these behaviours have been developed. Unfortunately these tools are inherently complicated and composite process simulation has become an expert activity that has been limited in its industrial use. Until recently, composite process simulation required deep understanding of composites at a material level in addition to understanding the thermodynamics, structural mechanics, and fluid dynamics in the complete system. To make composite process simulation more accessible in industrial applications, new integrated tools have been developed that aim to lower the level of expertise required.

Successful composite process simulations require the analyst to understand behaviour across many analysis scales, from the fiber and matrix (micro-scale) to the ply and laminates (meso-scale) to fully-configured structures (macro-scale). Diverse raw material forms are involved, including preimpregnated unidirectional tape, dry fiber forms that are later impregnated with resin, chopped short-fiber chips, single filaments or tows that are individually placed, three-dimensional fabric architectures, and so on. In addition, many different manufacturing

techniques have developed over time, typically characterized by a material deposition stage followed by a material curing stage. The different material forms each have multiple techniques for being deposited on tooling, and there are multiple ways of curing the resulting part. If designers are to be able to select appropriate manufacturing processes, they must understand the complications and risks associated with each. Given the large number of potential processes, this requires an analyst with significant knowledge and experience.

The manufacture of composite parts is a difficult activity. Care must be taken to ensure that the part stays within the thermal requirements of the materials, avoiding excessive exothermic reactions that might lead to compromised material performance or even fire during the cure. Material defects including porosity and wrinkling may develop during the cure. The parts develop residual stresses during cure, often resulting in as-manufactured profiles that differ significantly from the as-designed profiles. Fortunately, composite process simulation can be used to assist designers in the creation of robust composite manufacturing processes that result in parts and assemblies that meet all the design requirements.

There are many numerical tools available for composites process analysis, ranging from very simple to quite complex, but all these tools require an expert user in order to be used effectively. Recently, new tools have been developed that that reduce the level of required expertise, providing not only workflow guidance to analysts but also integrated tools that perform producability assessments at different stages of the design process. As a result, more engineers can evaluate their designs in context of the whole manufacturing process, reducing, across the whole organization, the time and costs associated with designing and producing good parts consistently. This paper explores the strategies these integration tools use to increase the information available to designers at all stages of the design process without requiring those designers to be experts in all aspects of the manufacturing process.