MONITORING FIBER STRESS DURING CURING OF SINGLE FIBER GLASS AND GRAPHITE-EPOXY COMPOSITES pdf

1: Acoustic Emission Technology-Marvin Hamstad, Ph.D.

NASA Technical Memorandum Monitoring Fiber Stress During Curing of Single Fiber Glass-and Graphite-Epoxy Composites Madhu www.enganchecubano.comar, Ranga P. Kosuri, and Kenneth J. Bowles.

Curing at ambient temperatures, which reduces dimensional changes and internal stresses in the finished product, Lower-cost tooling, Reduced curing times and continuous operation, and Improved resin stability resins do not have to be stored at low temperature and have extended shelf-life. The primary challenges facing the current state-of-the-art e-beam resins are the lack of toughness, hot-wet operating temperature limits, consolidation rheology, cost of e-beam equipment, and the general perception of safety concerns. Long-term durability of composites may require optimization of the fiber-matrix interface that forms during e-beam processing. The needs of the Navy ship, Army ground vehicle, and infrastructure applications are quite different from the needs of aerospace applications. For many of these applications, material costs can become a cost driver. Non-autoclave processes and low-temperature-cure resins are required for large-scale composite structures such as vehicle hulls, ship masts and other topside structures, as well as for bridges, docks, and piers. The higher specific properties offered by carbon fiber may even be cost competitive with certain E-glass applications. Fiber-reinforced polymer matrix composites are becoming increasingly important in many applications such as bridges and highways, off-shore oil platforms, and piers for both new construction and rehabilitation of existing infrastructure. In these applications, the service temperatures are relatively low and the matrix must be low cost polyester, vinyl ester, or phenolic , cure at room temperature, and be available in large volume. In rehabilitation applications, low-cost prepreg and hand-layup, pultrusion of reinforcing strips and secondary bonding, filament winding, and VARTM are examples of typical fabrication processes. For bridge decks, pultrusion and VARTM of polyester and vinyl ester have been demonstrated successfully using glass fiber preforms. The issue of long-term durability is especially important in these applications, which have lifetime requirements of 30 to 75 years. DoD has a huge infrastructure of piers and docks in need of rehabilitation and should leverage materials and process technologies being developed for civilian infrastructure applications. As mentioned earlier, ship, ground vehicle, and infrastructure applications currently use this processing technology. However, advancements in resin formulations to improve fire, smoke, and toxicity properties, while retaining the desirable attributes of low viscosity and room temperature cure, are needed. To meet the needs of aerospace, VARTM resins must not only be processible under vacuum pressure RTM uses much higher positive pressure , but also deliver acceptable structural performance, including mechanical properties and geometric tolerances. Rehabilitation of steel bridge girders through application of composite materials. Page 25 Share Cite Suggested Citation: The National Academies Press. VARTM processing of low-permeability carbon preforms for topside structures is in the early stages of development. VARTM is a low-pressure process that offers reduced tooling costs. Fiber volume fractions and associated properties are lower than those of higher-pressure processes such as RTM and autoclave. Parts may have to be redesigned and may add weight. The process uses one-sided tooling, and strict control of geometry is not yet possible and may add to assembly costs. Advances in preform technologies may allow for improved properties and dimensional tolerances. Future studies should consider these cost-performance trade-offs. Virtual manufacturing and simulation should play an increasingly important role for accelerated insertion of materials and processes into DoD systems. In the case of VARTM, advancements in intelligent processing will allow for risk and cost reduction but require advancements in three-dimensional flow simulation in porous media as well as models to predict input properties such as the permeability tensor as a function of fiber architecture, compaction, and distortion. However, it is largely a manual process. Research in automation using simulation, sensing, and control systems should be pursued to advance this process from prototype to a production-ready process. Translation of Fiber Properties to Composite Properties Precisely how the distribution of individual fiber strengths affects the reliability of a composite structure containing billions of

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continuous fibers is an extremely important question. This issue was noted in the earlier discussion of large-tow strength distributions versus those from small tows. The effect of fiber property variability on design allowables for composite structures must be understood in order to take advantage of incremental improvements in small-tow SAF fibers to achieve weight reduction in legacy systems and to effectively use textile fiber processing that may offer significant cost savings. Although stiffness is important, certification of a detailed design will depend on an accurate strength analysis of the problem. Simply stated, if the individual fiber strength distribution is known, can one predict how this will be translated into a composite tow, then into a fabric consisting of many tows, then into a multilayer laminate, and finally into a composite structure? Precise control of fiber orientation is needed during processing to achieve full translation of the fiber properties into the composite. In high-modulus fibers such as carbon and organic fibers, a misorientation of only 5 degrees in a unidirectional material can cause a modulus drop of 15 to 25 percent depending on the fiber volume loading for a carbon-epoxy composite. These systems are typically two-dimensional weaves of fibers ranging from 1k to 24k in a variety of patterns that offer different ranges of properties in orthogonal directions e. Bridge Over Muddy Run: Transportation Research Record Computational micro-mechanics for probabilistic failure of fiber composites in tension. Composites Science and Technology Advanced three-dimensional preforms offer increased stiffness and strength in the through-thickness direction at the expense of in-plane properties , improved damage tolerance, and potential for improved ballistic performance for composite armor. Mechanical property models exist for the prediction of thermoelastic properties of these various fiber architectures. However, the ability to predict damage evolution and long-term durability is not sufficiently robust and is currently dependent on expensive testing programs. Future research should be directed toward establishing reliable models to relate fiber, matrix, and interface properties, processing effects, and fiber architecture to damage mechanisms and life prediction. In general, fibers with higher strength and modulus are more expensive than fibers with more moderate properties. Early in the development of structural fibers, the selection of a fiber for a particular applicationâ€"especially a military applicationâ€"was driven primarily by performance requirements. With the emergence of non-aerospace, non-military applications, costâ€"given an acceptable level of performanceâ€"has become the driver for fiber selection. Cost has also become a major concern of DoD when making material selections for future military applications. Despite this concern about cost, however, DoD continues to require a high degree of fiber consistency. Demonstration of this consistency by the fiber producer drives up material costs. There are several important factors controlling fiber cost: Commercially available fibers do not have this third cost and, as a result, are significantly cheaper. It is important to recognize that material costs, and specifically fiber costs, are just one factor affecting the cost of a composite part. The recurring costs associated with composite processing, component assembly, and product inspection can be significant. In some applications, material costs are a small fraction of the total cost of the system. In addition, nonrecurring costs may be related to material qualification of the fiber, of the resin, and of the fiber and resin combination in the composite, at both the coupon and the structural levels. The magnitudes of composite material and component qualification or certification efforts and costs vary widely and depend on many factors, including specific product requirements, the criticality of the application, and the degree to which human safety is involved. In military aircraft, for example, the process of design development, material qualification, process development, structural analysis, and testing can be extremely complex and costly due to mission criticality, the need for high reliability under extreme conditions, and survivability requirements. With increasingly stringent requirements and more sophisticated composite products, qualification and certification programs have become more and more complex over the years, and with this complexity has come increased cost. Therefore, if new materials have only marginal though desirable benefits compared to existing systems, end users may be unwilling to expend the resources necessary to qualify them if qualification costs remain at present levels. Conversely, for DoD to take advantage of incremental improvements in current fibers or lower-cost commercial fibers, more efficient approaches to material qualification will be needed. Traditionally, matrices have been thought to protect the fibers. However,

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it is now understood that the matrix will influence the entirety of process-structure-property relationships for the composite system while leaving the fibers unchanged. Further, the properties and structure of the resin matrix are different when reinforced, and this presents a major challenge. Only recently has the industry matured to the point where the fiber, resin matrix, interface, and surface are routinely seen as a system. With the development of computers capable of modeling structures at the molecular scale, the time is approaching when it will be possible to design the optimum composite for a given system performance and cost. This systems perspective will involve modeling the structure and the manufacturing processes Page 27 Share Cite Suggested Citation: This modeling will include the placement of the reinforcing phase, the structure of the matrix phase, and even the degree of bonding at the interface. The methodology could be used to predict and even control the final structure of the composite. In other words, future engineers will not merely analyze the mechanics of the final product, but will apply a systems perspective and employ advanced modeling techniques to create reinforced structures that best meet given system requirements. This approach is the key to reduced cost and accelerated insertion of new materials into DoD systems. Lack of knowledge in this regard can lead to excessive design safety margins that result in increased weight and cost and lower system performance. A better understanding of the effect of constituent variability on composite properties is crucial to taking advantage of fibers on the market today as well as future fibers, as is the development of micromechanical and continuum-based models that include the stochastic process for the prediction of composite behavior. The transition to a systems approach is likely to occur gradually, with full implementation 10 or more years in the future. While this approach is evolving, researchers and material suppliers will continue to make incremental improvements in reinforcing fibers, matrix resins, and composite forms and processes. Accelerated Insertion of Materialsâ€”Composites. Robust Design Computational System.

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