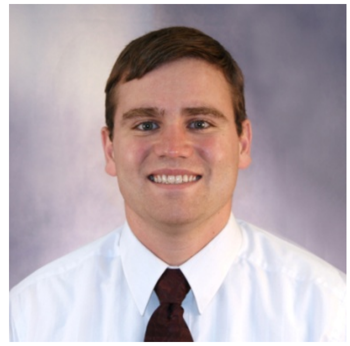
Physics Based Modeling of Processing and Final Product Performance for Engineering Composites with Discrete Inclusions



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With the increase in industrial and societal demands for materials with increased functionality, there is a strong desire to enhance the design process through the development of realistic modeling tools that cover a wide range of manufacturing and final product application scenarios. This research seeks new analysis and design procedures to effectively, and efficiently, represent the relationship between the processing conditions and the final product performance for composites fabricated from a wide variety of engineering inclusions. The past, present, and future projects to be discussed in this talk span a wide size spectrum, from the nano- to the macro-, and cover industrial applications ranging from niche military aerospace multifunctional aircraft panels to large volume, low price, automotive components.

Composites have enjoyed widespread industrial use, and with recent advances in the fabrication of materials with multi-scale inclusions, it is becoming increasingly important for the design engineer to have accurate and effective tools to aid them in the creation of advanced multifunctional products. The demand for accurate process and product prediction methods has significantly increased, both with the demand for high performance materials and with the desire to reduce production costs.

There have been a wide variety of processing models developed during last century for predicting inclusion orientation, but it is well understood that existing models drastically over predict the alignment rate. In addition, the most effective models are formulated exclusively for rigid inclusions, neglecting inclusions of current interest to industry such as long glass/carbon fibers, carbon nanotubes, and of unique interest to Baylor, renewable coconut fibers. It is surprising that existing theories remain employed since they inherently misrepresent the final processed product's material. Existing models limit the design engineer to, at best, a qualitative insight to the final product capabilities, and thus understanding the relationship between process and product is yet to be attained.

This presentation will begin with a classical study into the equations of motion for fiber inclusions within a melt flow and introduce the work developed from presenter's current and recent studies in formulating relevant constitutive equations of motion for rigid inclusions. The classical closure dilemma is introduced, and results from several of the presenter's published closures are discussed. Recent work in the area of spherical harmonic expansions seeks to alleviate, entirely, the closure issue, which plagues many classes of engineering problems, and preliminary results will be presented. The work transitions to the prediction of structural properties and presents a statistical study relating inclusion orientation to the material stiffness tensor. Physics based, analytic expressions that relate the orientation distribution function to the expectation and the variance of the stiffness tensor will be discussed.

The talk concludes with recent work in the area of electrical and thermal conductivity predictions for multi-functional CNT thin film networks based on the presenter's work with the AFRL. Previous methods yielded results that are orders of magnitude from the observed results and unable to accurately capture experimental observations. The presented model is the first physics-based modeling technique to address the relationship between macroscale (bulk) planar electrical conductivity and stochastically dependant, orientationally biased, single walled nanotube (SWNT) networks. Results from nanostructure variations correspond with theoretical and experimental results available in the literature.
