Rheology of Carbon Fiber Thermoplastic Polymer Composites

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ABSTRACT

The rheology of fiber–reinforced thermoplastic composites will be presented with specific focus on several topics studied over the past three decades. Interest in the elongational viscosity of collimated, discontinuous fiber systems was initiated by the introduction of impregnated, stretch broken fiber tow with the goal of establishing stretch forming forces. This work followed the classic solution by Bachelor in developing a micromechanics model for extensional viscosity of these systems for temperature dependent and shear thinning polymers. Next, the remaining individual components of the viscosity tensor, including the three shearing viscosities and the two additional elongational viscosities, were developed in a logical extension [1]. These models utilized the concept of hyper-concentrated systems and thereby provided rheological models for fiber concentrations significantly greater than conventional rheological models with dilute restrictions. This work was revised and extended to the flow of prepreg platelet systems consisting of planar reinforcing geometries and the absence of lubricating liquid matrices. The consolidation of the prepreg platelet systems, as the first stage of composite response to pressure gradients, was developed in order to establish the initial platelet geometry and fiber orientation state prior to molding flows [2]. Molding flows were then modeled for highly anisotropic viscosity tensors that changed with molding conditions such as mold geometry and flow path [3]. Validations of these simulations were demonstrated for both prepreg platelet systems and conventional sheet molding systems [4]. The more recent work focuses on the viscoelastic bending of collimated fiber systems with application to both continuous and discontinuous fiber systems. The target applications are flexural deformation in sheet forming and extrudate rheology in extrusion deposition additive manufacturing. Finally, an attempt to anticipate what advances will be developed in the next three decades will be described.

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BIO

Dr. R. Byron Pipes was elected to the National Academy of Engineering in 1987 in recognition of his development of an exemplary model for relationships between corporate, academic and government sectors to foster research and education in the field of composite materials. As co-founder and director of the Center for Composite Materials at the University of Delaware, he developed an industrial consortium of over forty corporate sponsors from the USA, Japan, Germany, France, Italy, United Kingdom, Belgium, Sweden and Finland. Today, almost 40 years after its founding, the University of Delaware Center is the largest and most successful of its kind in the United States. Research expenditures have exceeded $100 million. In 2013, Dr. Pipes developed the Composites Design and Manufacturing HUB (cdmHUB) to meet the simulation needs of the growing composites industry. To date, the cdmHUB is supported by five corporate sponsors (Boeing, Rolls Royce, Cytec, Dassault Systemes and Henkel) as well as DARPA. His most recent research programs focus on the development of composites manufacturing with emphasis on additive manufacturing.

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