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Formulation, processing, and thermal resistance of high-performance carbon-fiber composites

ABSTRACT

Carbon fiber composites outperformed metals with greater strength to weight properties. Although traditional carbon fiber/epoxy composites can meet multiple application requirements at service temperature up to 120 °C, the 5th generation engine and military fighters have pushed the sustained service temperature into 316 to 538 °C. The conventional high-temperature polyimide system, PMR-15, was designed for hot zones applications such as engine nozzles and missile fins while suffering drawbacks such as low toughness, toxicity during processing, and severe cracking under repeating temperature cycles.

In this dissertation, efforts have focused on resolving these major issues of conventional polyimide composites by the development and optimization of a novel polyimide system, and examination of its thermal-oxidative stability. To fulfill this purpose, an aromatic asymmetric pyromellitic dianhydride (PMDA) type polyimide terminated with 4-phenylethynylphthalic anhydride (PEPA) end cap was proposed to increase the toughness and processability. The novel resin exhibits greater resistance to thermal oxidation than the nadic-end-capped PI, PMR-15, with less weight loss and no cracking. The thermal stability derives from the intrinsic stability of the PEPA end-cap relative to the nadic end-cap, both in inert and oxidative conditions. These features, coupled with its unusually high ductility, indicated the potential to expand the property space for high-temperature polymers, affording greater flexibility to designers of composite parts for high-temperature service. The publications, methods, and products resulted from this work have been widely accepted by industries and have significantly advanced the sustainability of the aerospace industry.