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Feasibility of Thermoplastic Composites as Precursors for Carbon Fibre Reinforced Carbon Matrix Composites

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ABSTRACT

Carbon fiber reinforced carbon matrix composites, or carbon-carbon (C-C) composites, are high performance lightweight materials used in applications where retention of high strength and stiffness properties in ultrahigh temperature (>3000 °C) environments is critical, e.g. leading edges of the space shuttle, aircraft brake discs. However, their commercial application is currently limited by high production and labor costs, and long production times. A significant contributing factor to this is the low carbon yield of the thermosetting resins currently used in the manufacturing process. Phenolic resins, the most commonly used matrix system for C-C composites, produce highly porous microstructures when pyrolyzed, thus C-C composites produced from these resins require multiple cycles of chemical vapor infiltration (CVI) to fill in gaps and reduce porosity. High performance thermoplastic polymers like polyether ether ketone (PEEK), polyetherimide (PEI), and low-melting polyaryletherketone (LMPAEK) are highly aromatic compounds which have been reported to yield high percentages of carbon residue when pyrolyzed and may reduce the number of impregnation cycles required to obtain a mechanically robust material. The thermoplastic nature of these polymers also makes them promising candidates for fused filament fabrication type additive manufacturing processes which could be used to cost-effectively manufacture geometrically complex C-C components. To demonstrate the feasibility of exploiting thermoplastic composites as C-C precursors, commingled yarns containing AS4 carbon fibers and one of PEEK, PEI or LMPAEK matrix systems are compression moulded into well-consolidated carbon fibre reinforced polymer composite materials and then subjected to varying heat treatments to stabilize, carbonize, and graphitize the different matrix systems. Thermogravimetric analysis (TGA) will be used to estimate the carbon yield that can be expected from these precursors. Fourier-Transform Infrared Spectroscopy (FTIR) and Elemental Analysis will be used to characterize the chemical changes after thermal treatment. Short beam strength tests will be used to quantify the interlaminar shear strength of the different C-C composites.

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