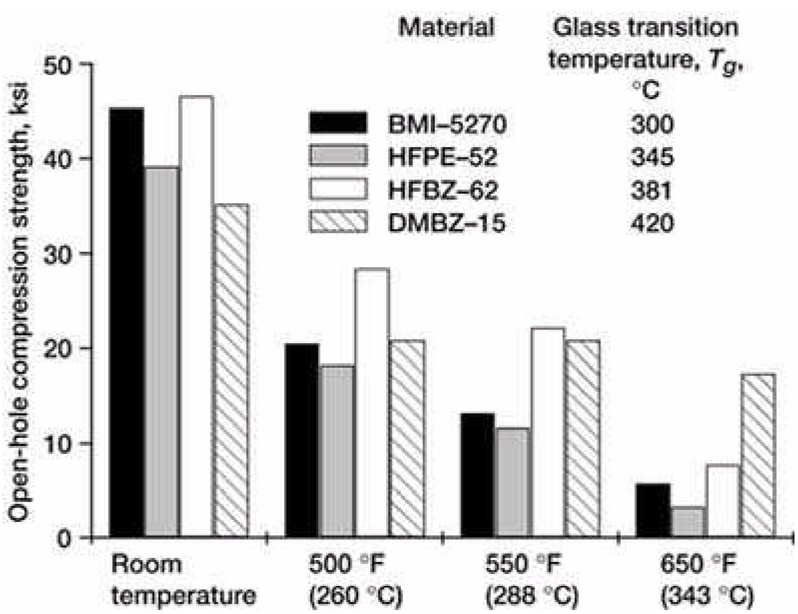
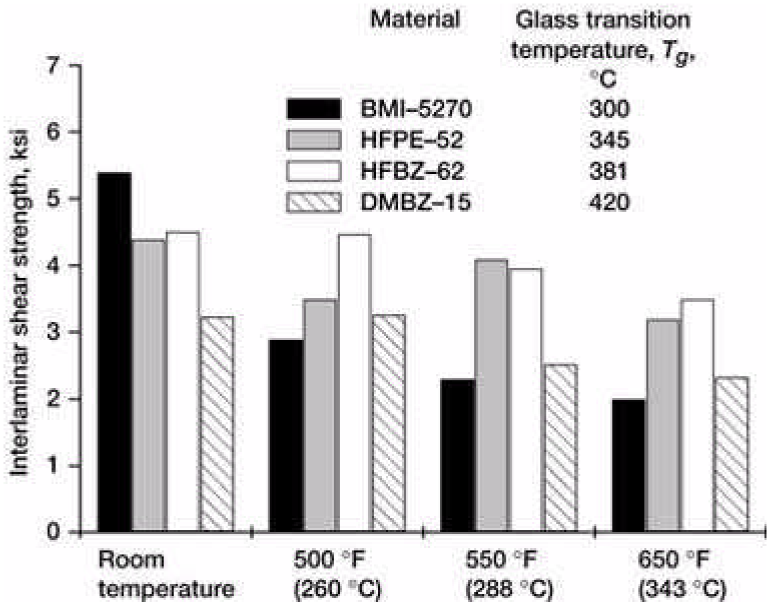
High-Glass-Transition-Temperature Polyimides Developed for Reusable Launch Vehicle Applications

Polyimide composites have been traditionally used for high-temperature applications in aircraft engines at temperatures up to 550 °F (288 °C) for thousands of hours. However, as NASA shifts its focus toward the development of advanced reusable launch vehicles, there is an urgent need for lightweight polymer composites that can sustain 600 to 800 °F (315 to 427 °C) for short excursions (hundreds of hours). To meet critical vehicle weight targets, it is essential that one use lightweight, high-temperature polymer matrix composites in propulsion components such as turbopump housings, ducts, engine supports, and struts. Composite materials in reusable launch vehicle components will heat quickly during launch and reentry. Conventional composites, consisting of layers of fabric or fiber-reinforced lamina, would either blister or encounter catastrophic delamination under high heating rates above 300 °C. This blistering and delamination are the result of a sudden volume expansion within the composite due to the release of absorbed moisture and gases generated by the degradation of the polymer matrix. Researchers at the NASA Glenn Research Center and the Boeing Company (Long Beach, CA) recently demonstrated a successful approach for preventing this delamination--the use of three-dimensional stitched composites fabricated by resin infusion.



Open-hole compressive strength of stitched polyimide/AS4 composites.

Data given at room temperature, 500, 550, and 650 °F for BMI-5270 (T_g = 300), HFPE-52 (T_g = 345), HFBZ-62 (T_g = 381), and DMBZ-15 (T_g = 420).



Interlaminar shear strength of stitched polyimide/AS4 composites.

Data given at room temperature, 500, 550, and 650 °F for BMI-5270 (T_g = 300), HFPE-52 (T_g = 345), HFBZ-62 (T_g = 381), and DMBZ-15 (T_g = 420).

Concentrated solutions of a series of Glenn-developed high-glass-transition-temperature T_g polyimides (T_g = 345 to 420 °C) were successfully infused into stitched carbon fabric preforms to fabricate composites. DMBZ15 stitched composites display the highest open-hole compression strength at 650 °F (343 °C) of all the resins tested (see the top bar chart), whereas HFBZ composites exhibit the highest interlaminar shear strength at 650 °F (343 °C) (see the bottom bar chart). HFPE composites have shown excellent thermo-oxidative stability, as they retain 50 percent of their mechanical properties after isothermal aging at 550 °F (288 °C) for 2000 hr and maintain 60 percent of their room-temperature mechanical properties at 650 °F (343 °C). The mechanical properties of these high-T_g polyimide composites far exceed the performance of a leading commercial high-temperature bismaleimide, BMI 5270. These stitched composites hold the promise of performing at high temperatures without delamination under the high moisture and heating rate conditions encountered in many reusable launch vehicle applications.

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