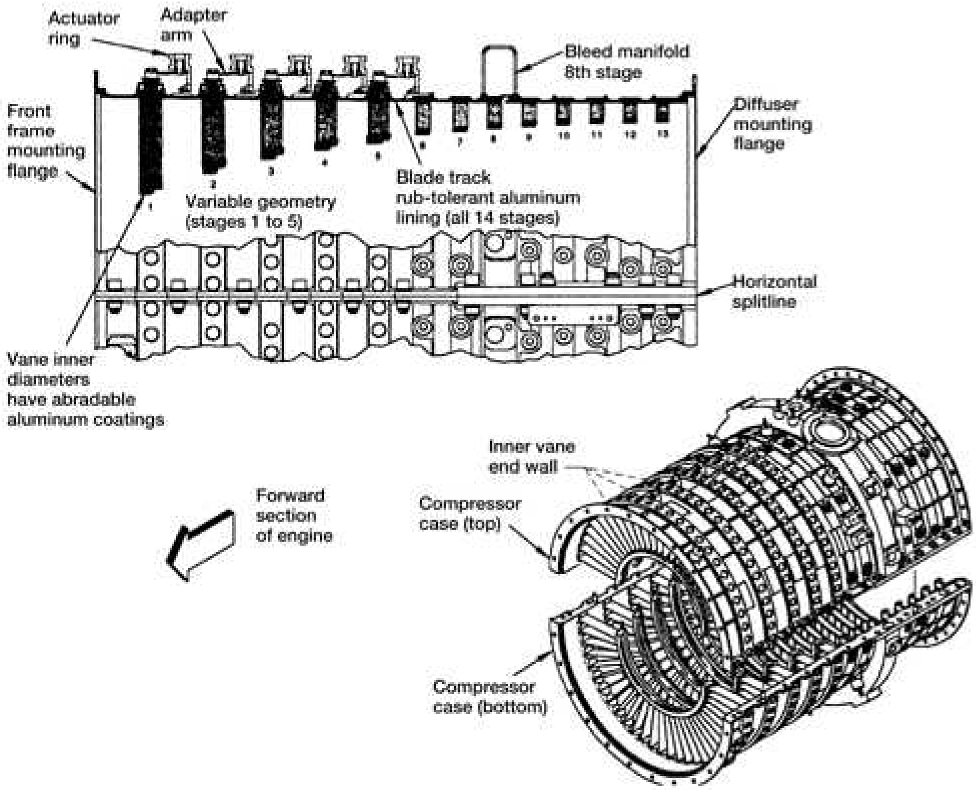
Low-Cost Manufacturing of High-Temperature Polymer Composites

Major goals of NASA and the Integrated High Performance Turbine Engine Technology (IHPTET) initiative include improvements in the affordability of propulsion systems, significant increases in the thrust/weight ratio, and increases in the temperature capability of components of gas turbine engines. Members of NASA Lewis Research Center's HITEMP project worked cooperatively with Allison Advanced Development Corporation to develop a manufacturing method to produce low-cost components for gas turbine engines. Affordability for these polymer composites is defined by the savings in acquisition and life-cycle costs associated with engine weight reduction. To lower engine component costs, the Lewis/Allison team focused on chopped graphite fiber/polyimide resin composites. The high-temperature polyimide resin chosen, PMR-II-50, was developed at NASA Lewis.

The current generation of high-temperature polymer composites is primarily limited to engine components operating up to 260 °C and manufacturing techniques requiring labor-intensive hand layup molding procedures. The Lewis/Allison team is investigating alternative fabrication techniques, such as compression molding, combined with high-temperature polymer composites that can operate in engine environments up to 316 °C. Compression molding offers a more rapid, cost effective manufacturing approach for smaller turbine engine components than hand layup methods. In addition, compression molding reduces manufacturing costs of polymer composites by (1) reducing component mold time in comparison to autoclave processing, (2) reducing fabrication time by minimizing labor intensive hand layup operations associated with autoclaving and individual ply fabrication techniques (such as ply orientation and ply count), and (3) reducing machining costs after component fabrication because of the use of match metal molding tools.

The 1-in. chopped graphite fiber and PMR-II-50 resin were mixed together through a technique called prepregging. Standard commercial prepregging equipment was used to produce a continuous sheet of chopped fiber/PMR-II-50 prepreg. The resin's viscosity and concentration were optimized to produce a PMR-II-50 prepreg with constant proportions of resin and graphite fiber throughout its length. It was critical that the prepreg have a random distribution of graphite fiber throughout the components' thicknesses so that the chopped fiber/resin engine components would not warp during their production. The Lewis/Allison team successfully produced PMR-II-50 chopped graphite fiber prepreg at Quantum Composites in Midland, Michigan.



Allison AE3007 compressor case and vane assembly. (Copyright Allison Advanced Development Company; used with permission.)

Allison is currently evaluating these chopped-fiber polymer composites by molding and testing compressor components for both IHPTET and commercial engine applications. An inner vane endwall used to secure and align stator vanes was chosen as a demonstration component; it is shown in the illustration on the top section of Allison's 3007 compressor. Previously, these endwalls were made from stainless steel, which weighed more than two times the polymer composite and required extensive machining to produce a smooth surface finish. Allison will further reduce the cost of the endwall by reducing the part count of the metallic components by a factor of three when using the chopped graphite fiber/PMR-II-50 composite.

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