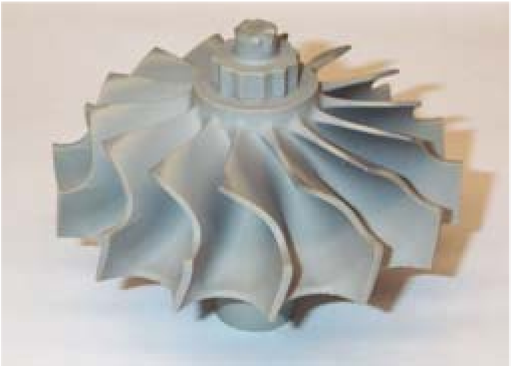
Silicon Nitride-Based Turbine Components Improved Through New Forming Process

As-Processed Surface Strength Increased by 40%

A new forming process developed by Saint-Gobain in partnership with DOE's Distributed Energy Program has increased the as-processed (AP) strength of silicon nitride-based components for use in gas turbines by approximately 40%. The improvements to the AP surfaces will significantly increase the reliability of the turbine components.

Background

For more than a decade, Saint Gobain has collaborated with gas turbine manufacturers in the development, fabrication, and testing of high temperature turbine components. In the early 1990s, the high temperature silicon nitride material, NT154, was found to possess properties making it highly suitable for use in gas turbine operating conditions.

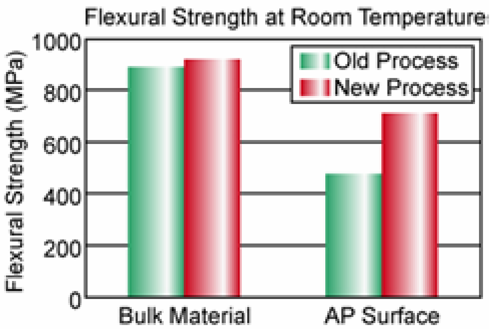


Dense NT154 rotor

The current microturbine program was begun using NT154-based material and process technology. An environmentally-friendly, aqueous closed loop process (CLP) and robust, glass encapsulated hot isostatic press (HIP) densification process were initially employed. The highly reliable CLP was utilized to reestablish the strength retention of NT154 at both room and high temperatures; however, implementation of a proprietary, new HIP process resulted in a 40% increase in the components' AP strength.

Technology

The targeted, room temperature AP strength of 700 MPa was achieved in both the laboratory and production HIP furnaces. Reproducibility of the AP strength directly correlated with the AP surface finish, which in turn, was heavily impacted by the surface finish of the green components prior to HIP processing. The new HIP process helped to retain the green surface finish and minimized the reaction layer formed due to the glass encapsulant.

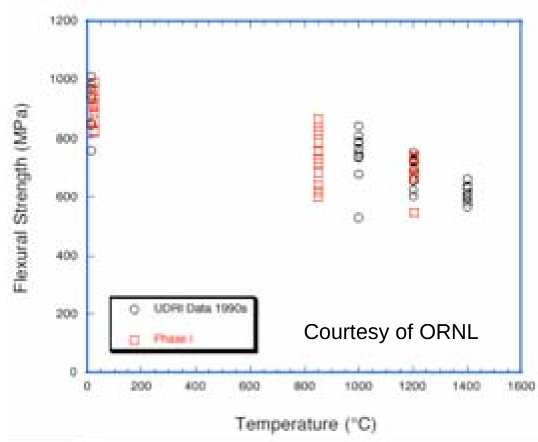


A 40% improvement in the as-processed surface strength has been obtained in the current program.

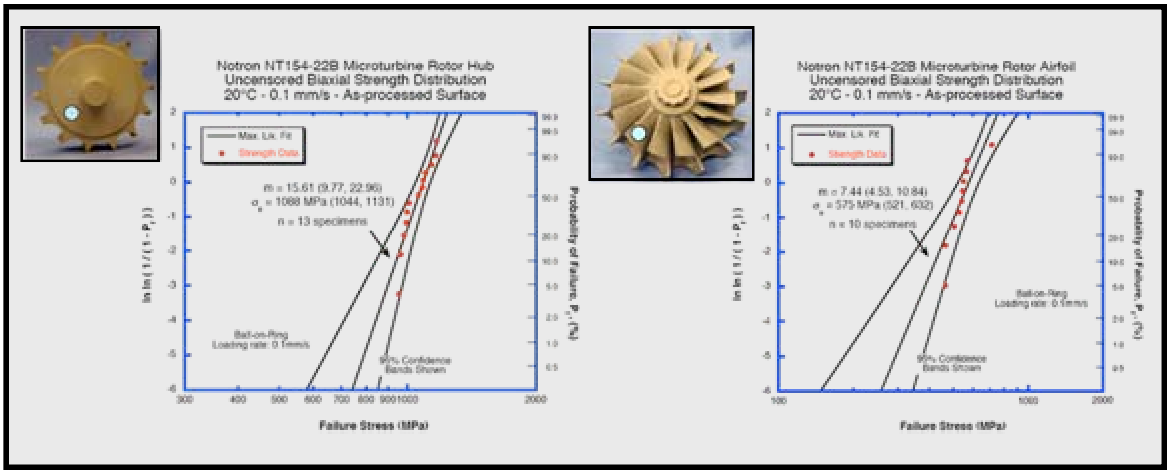
Green-machined rotors of a complex shape were densified with the new HIP process for improved AP surfaces. The rotors had an excellent average surface roughness of 30-33 μin on the AP surfaces. Based on coordinate measuring machine data, the rotors exhibited a maximum part-to-part variation of 0.006 in – an indication of the consistency of the process.

Furthermore, a measured concentricity within 0.003 in for the rotors indicated uniform shrinkage.

The process reproducibility of the selected net shape forming technique was further highlighted by measuring various critical dimensions of the net shape formed rotors prior to densification. All the deviations from the nominal green dimensions were well within the three sigma values for the target dense tolerance. The AP surface strength of one of the dense rotors was evaluated by ORNL. Core-drilled disks from individual blades were tested in biaxial flexure to establish the AP strength of actual components. The average AP strength of 527 MPa is comparable to those of other candidate gas turbine grade silicon nitride materials.



The current mechanical performance of NT154 is consistent with data from the early 1990's.



Benefits

Improved AP surfaces will increase the reliability of turbine components made with NT154. These improvements are a good compliment to the excellent room and high temperature bulk properties of NT154. In addition, the net shape forming technique has been shown to produce dimensionally consistent parts.

Future Work

Future work will involve further optimization of the new HIP process, as well as the net shape forming process, to consistently reproduce high AP strengths on net shape formed turbine components. In addition, effort will be focused on improving the recession resistance of silicon nitride by employing surface modification and environmental barrier coating approaches both in-house and in collaboration with end users. Saint-Gobain will continue to be a key ceramic component manufacturer to original equipment manufacturers of gas turbines. This will involve supplying NT154 samples and components for future engine development and testing.

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