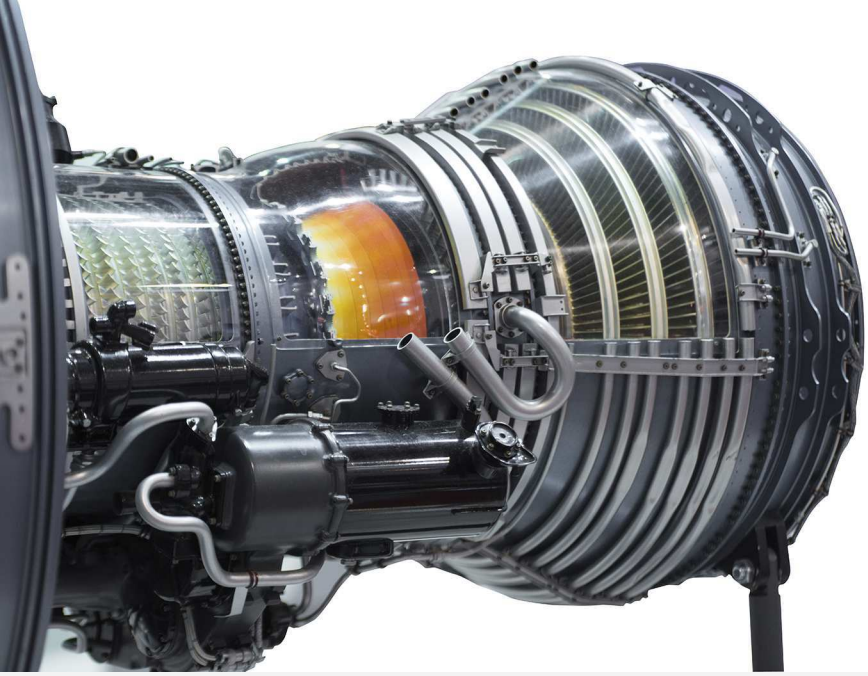

National Aeronautics and
Space Administration

technology solution

Materials and Coatings

Low-Density, High-Creep-Resistant Single-Crystal Superalloy for Turbine Airfoils

Super lightweight, durable material increases fuel efficiency and lowers costs

In today's aircraft turbine engines, blade performance and durability are achieved using advanced nickel-based superalloys combined with sophisticated internal cooling schemes and thermal barrier coatings. To achieve further improvements in thrust-to-weight ratio, innovators at NASA's Glenn Research Center have developed a new single-crystal superalloy with reduced density. Reduction in the turbine blade weight through lower alloy densities has a cascading effect throughout the entire rotor, because other elements in the rotor (e.g., the disk, hub, and shaft) can be smaller and lighter while still supporting the blade. Thus the overall design changes can lead to a total engine weight savings of 8 to 10 times the blade weight savings alone. The resulting increase in efficiency and reduction in cost make this groundbreaking material an invaluable resource for aircraft, aerospace, and military sectors.

BENEFITS

- Operational efficiency: Significant weight reduction throughout the system without loss of thrust or power
- Cost reduction: Lower weight increases fuel efficiency
- Durability: State-of-the-art creep resistance, strength, and performance under high temperatures and environmental stress

THE TECHNOLOGY

The nickel-based alloy blades used in airfoils for the last twenty years are sturdy but relatively dense and heavy. Lower-density single crystal alloys have been developed, but they require a comparatively complex production process and therefore greater expense. Some types of single-crystal superalloys also were limited by microstructural instabilities that could weaken the long-term mechanical properties of the applications. Glenn's scientists successfully used computer modeling techniques to cast alloys that had lower density than that of the superalloys currently in use even the most state-of-the-art materials.

Most of the superalloy's creep-strengthening properties come from the use of molybdenum as a refractory metal, and the density of this element is close to that of the nickel base. Cobalt is used to stabilize the microstructure of the alloy, and since cobalt is less dense than other stabilizers such as ruthenium, the overall density of the alloy is reduced without loss of performance. Chromium is added to the alloy to assist in oxidation resistance, but at sufficiently modest levels that the overall alloy strength is not diminished. With these innovations, the new superalloys demonstrate significantly better creep strength as a function of density during creep rupture testing at temperatures of 1800° and 2000°F. These new low-density superalloys were also determined to be microstructurally stable during testing. These features have a significant impact on the design and manufacture of aircraft rotors overall, because weight reduction in the blade means that supporting parts can be designed to weigh less as well. In this way, these pioneering low-density superalloys can result in an 8 to 10 times multiplier in total engine weight savings, which translates into reduced fuel consumption and reduced emissions. For these reasons, NASA is also studying the use of this superalloy for the rim of advanced, hybrid-material disks.

Faster, lightweight, and environmentally friendly wind turbines.

Lightweight components help steam turbines run more efficiently and trim costs.

APPLICATIONS

The technology has several potential applications:

- Any applications at high temperatures requiring creep resistance combined with damage tolerance and low density, including but not limited to:
- Gas turbine engine blade, vanes, and hybrid disk rims at high temperatures
- Aerospace propulsion and land-based power generation

PUBLICATIONS

Patent No: 7,261,783

More Information

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NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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