National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

High-Temperature Ni-Based Superalloy Composition

A Phase Transformation Strengthened Superalloy Resistant to Creep

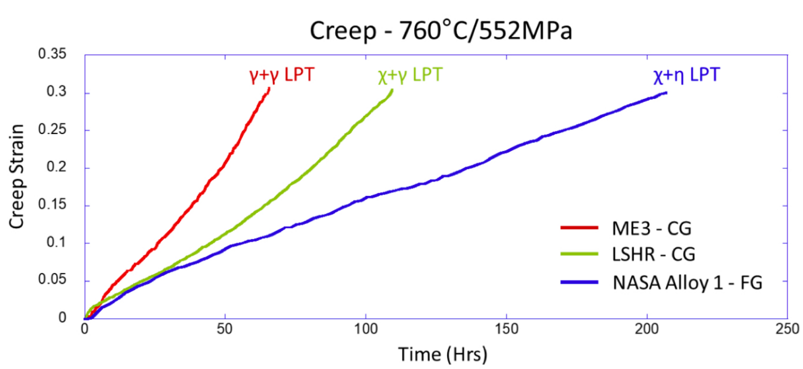
Innovators at the NASA Glenn Research Center have developed a nickel-based superalloy using specific alloying elements to inhibit deleterious deformation at temperatures above 700°C. The drive for energy efficiency in power generation and propulsion places the development of high-performance materials at the forefront of materials science. Turbine engine efficiency and reduction in carbon emissions are directly related to engine operating temperature. With increasing temperatures, materials start to plastically deform under load, a process known as creep, which sets severe limits on performance. Therefore, increased performance in aircraft engines and land-based power generators requires the development of new high-temperature structural materials that are resistant to creep. For example, a main factor prohibiting higher operating temperatures in jet turbine engines is the creep life of the Ni-based superalloy turbine disks. NASA's new superalloy composition significantly improves the creep life of turbine disks and also increases the operating temperature limit.

BENEFITS

- Improves the high-temperature properties of Ni-based superalloys: higher temperature operation allows increased engine efficiency and reduced CO_2 emissions for jet engines and turbines, while also enabling a longer lifetime for turbine blades
- Offers a new phase-transformation strengthening mechanism: resists high-temperature creep deformation in Ni-based superalloys and inhibits the deleterious deformation mode of nanotwinning at temperatures above 700°C

THE TECHNOLOGY

NASA's new Ni-based superalloy uses a powder metallurgy (PM) composition that inhibits the deleterious gamma-prime to gamma-phase transformation along stacking faults during high temperature creep deformation. Ni-base superalloys have excellent high temperature properties, mostly due to the presence of coherent precipitates. At higher temperatures, these precipitates are defeated by the diffusional shear dislocations producing intrinsic and extrinsic faults. Recent studies have found that, during deformation of turbine disk alloys at high temperature, Co, Cr, and Mo segregate to these faults (removing Ni and Al) inside the strengthening precipitates of these alloys. This represents a local phase transformation from the strengthening precipitate to the weaker matrix phase. Therefore, this elemental segregation significantly weakens the ability of a precipitate to withstand further deformation, producing faster strain rates in the alloy at higher temperatures. This invention presents a solution to prevent this type of segregation along these two faults to improve the creep properties of turbine disks and similar Ni-based alloys. By alloying a specific amount of eta phase formers (Ti, Ta, Nb, and Hf), the phase transformation to can be eliminated along 2-layer extrinsic stacking faults (SESFs) in precipitates without precipitating bulk eta phase. Also, by adding a certain amount of D019 formers (Mo and W), the phase transformation to can be mitigated along 1-layer intrinsic stacking faults (SISFs) without producing bulk sigma phase. This alloy composition incorporates both strengthening methods for use in jet turbine disks, though the composition has applications in other high-stress and/or high-temperature environments as are found in power plants, space launch systems, and other critical structural applications.



NASA's new Ni-based alloy presents significantly better creep properties over current alloys (ME3 and LSHR) through phase transformation strengthening.

APPLICATIONS

The technology has several potential applications:

- Aerospace: high-temperature and high-stress structural components for space launch systems and jet turbine engines
- Industrial machinery: chemical processing and waste processing systems
- Marine: turbine engines for ships
- Oil and gas: oil refining process
- Power: steam turbines and gas turbines for electricity generation, structural components for solar thermal power plants, heat exchangers for nuclear reactor systems
- Propulsion: rockets, jet engines, etc.

PUBLICATIONS

Patent No: 11,339,463

"Producing Next Generation Superalloys Through Advanced Characterization and Manufacturing Techniques," Smith, T.M., et al., January 28, 2020, https://ntrs.nasa.gov/search.jsp?R=20200001016.

"Segregation and Phase Transformations along Superlattice Intrinsic Stacking Faults in Ni-based Superalloys," Smith, T.M., et al., September 9, 2018, https://ntrs.nasa.gov/search.jsp?R=20190002833.

"Phase transformation strengthening of high-temperature superalloys," Smith, T.M., et al., November 22, 2016, https://pubmed.ncbi.nlm.nih.gov/27874007/.

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More Information

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