Nickel based Superalloys - Applications & Science behind

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What is a 'Super'alloy?

A **superalloy**, or **high-performance alloy**, is an alloy that exhibits several key characteristics: excellent mechanical strength, resistance to **thermal creep deformation**, good surface stability and resistance to corrosion or oxidation.

These alloys are intended for high temperature applications – to withstand loading at temperatures near their melting point.

Applications:

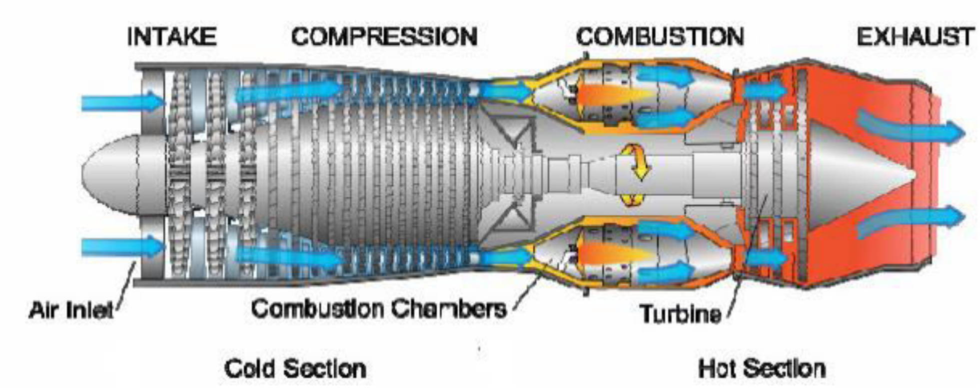
The Ni superalloys are used in load-bearing structures to 90% of their melting point. The following are the areas in which these alloys are used:

- Aerospace
  - Blades and jet/rocket engines
- Marine industry
  - Submarines
- Nuclear reactors
- Heat exchanger tubing
- Industrial gas turbines

Applications: Gas Turbine

They are used in those areas of the engine that are subject to high temperatures and which require high strength, excellent creep resistance, as well as corrosion and oxidation resistance.The hot section of the engine is the region where Ni-base superalloys are used:

Companies: Rolls Royce and General Electric



Applications: Aircraft Engines

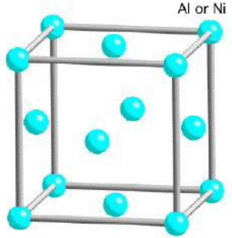
Among the most demanding applications for a structural material are those in the hot sections of turbine engines. The preeminence of superalloys is reflected in the fact that they currently comprise over 50% of the weight of advanced aircraft engines. The widespread use of superalloys in turbine engines coupled with the fact that the thermodynamic efficiency of turbine engines is increased with increasing turbine inlet temperatures has, in part, provided the motivation for increasing the maximum-use temperature of superalloys. In fact, during the past 30 years turbine airfoil temperature capability has increased on average by about 4 °F (2.2 °C) per year.

Applications: Oil & Gas Industry

- Nickel Alloys in the Oil and Gas industry Nickel-based superalloys are increasingly finding applications in the oil and gas sector.
- The environments encountered in oil and natural gas production are frequently corrosive and challenging.
- Often significant levels of hydrogen sulfide, carbon dioxide, chlorides, and free sulfur are present.
- In some of these environments high pressure and temperatures up to 450°F (232°C) can be encountered.

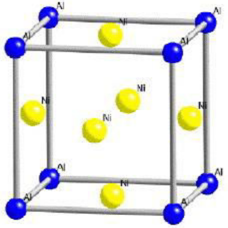
Major Phase in Super-Alloys

Gamma



- Continuous matrix (called gamma)
- Face-centered-cubic (FCC)
- High percentage Co, Cr, Mo, and W.

Gamma Prime



- Primary strengthening phase in nickel-based superalloys is Ni3(Al,Ti)
- Coherently precipitating phase with an ordered FCC crystal structure.

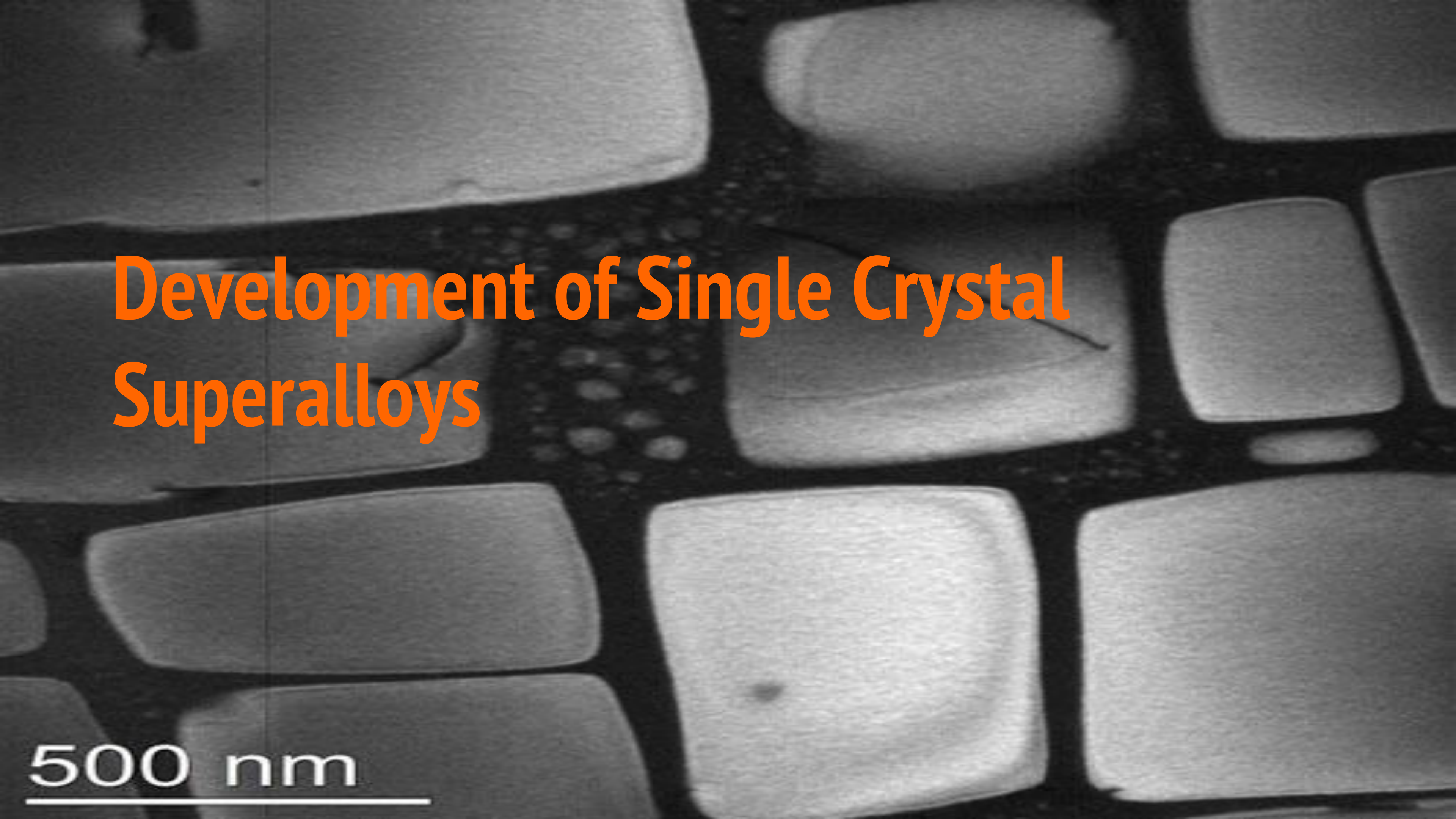
Carbides

- Carbon, added at levels of 0.05-0.2%
- combining reactive elements like titanium, tantalum, and hafnium to form carbides
- e.g., TiC, TaC, or HfC.
- common carbides have an fcc crystal structure

Topologically Cubic Packed Plane

- Brittle phases that can form during heat treatment or service.
- Act as crack initiators because of their brittle nature

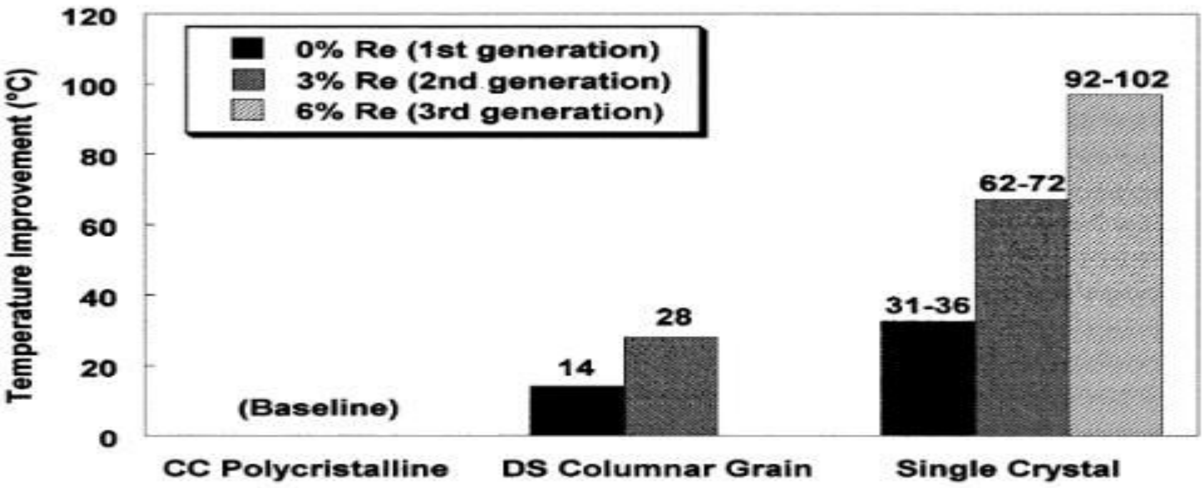
Development of Single Crystal Superalloys



The Thermal Efficiency and Engine Performance is closely related to the capability of materials to withstand higher and higher temperatures.

Single Crystal Structure

- Lack of grain boundaries along axial stress direction -> High Creep Strength
- Major modification as compared to the polycrystalline materials -> suppression of the grain boundary strengthening elements C, B, Zr and Hf.



SC Superalloys

Third generation -> high creep resistance at temperature above 1100 C. The stress rupture life at 1150 C and 100 MPa of the MC-NG alloy is over 150hours
First generation -> rupture life less than 10 hours

Additions of both rhenium and ruthenium could pave the way for the development of improved third generation superalloys with

1. Reduced density
2. Better phase stability compared to third generation alloys containing high levels of rhenium

A super-alloy is born: The romantic revolution of Lightness & Strength

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ARTICLE

Received 26 Jan 2010 | Accepted 6 Aug 2010 | Published 7 Sep 2010

DOI: 10.1038/ncomms1062

Nanostructural hierarchy increases the strength of aluminium alloys

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WELL,

THAT'S ALL FOLKS!

THANKS FOR WATCHING

WE HOPE YOU LEARNED SOMETHING NEW