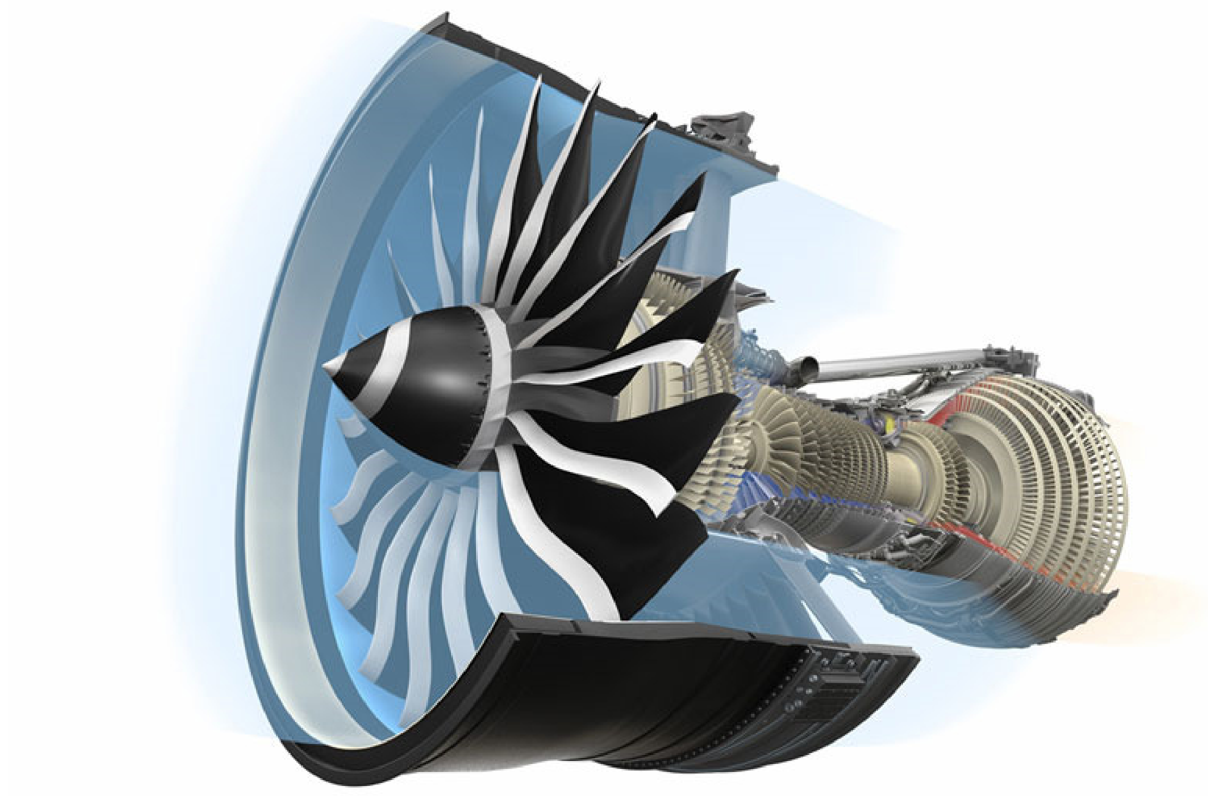


NICKEL BASED SUPERALLOYS IN GAS TURBINE ENGINES

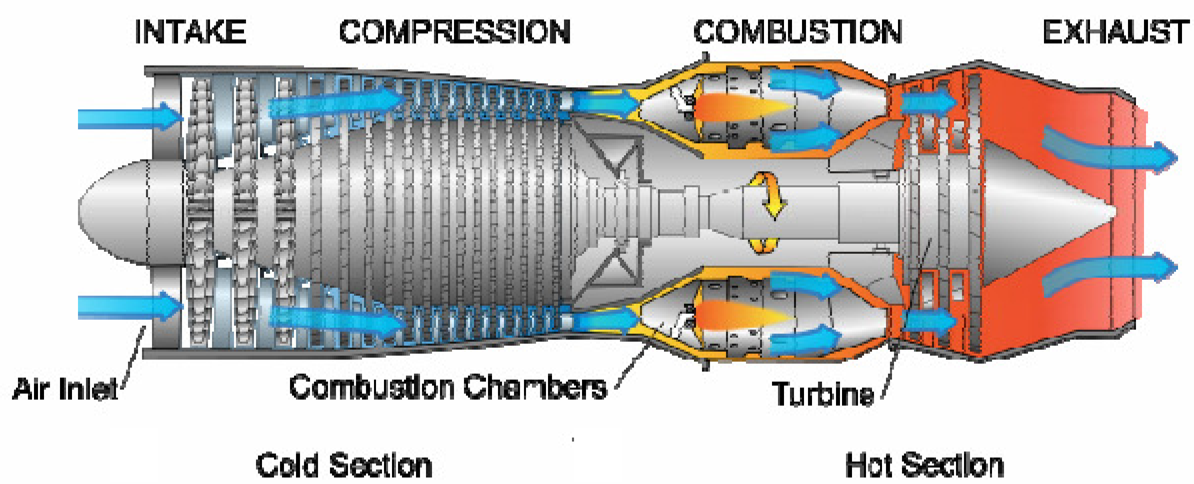
By Lee Sheets

MSE 395 – Final Presentation

BACKGROUND

- Turbine engines are used in a variety of energy technologies including:
  - Nuclear (steam engine)
  - Land generators for grid augmentation
  - Marine (boat engines)
- Efficiency enhancement
  - Increased operation temperatures
  - Lighter material (aviation applications)

TURBINE ENGINES



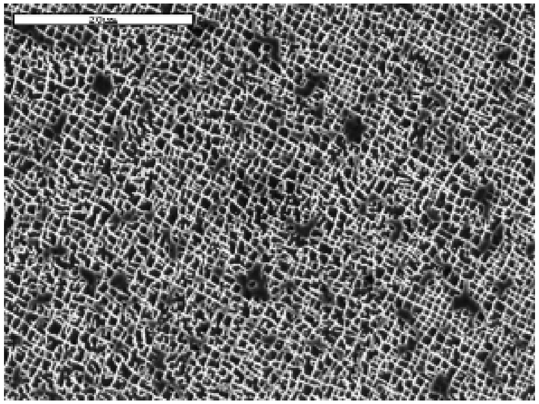
- The hot section of the engine is the region where Ni-base superalloys are used
  - High pressure turbine

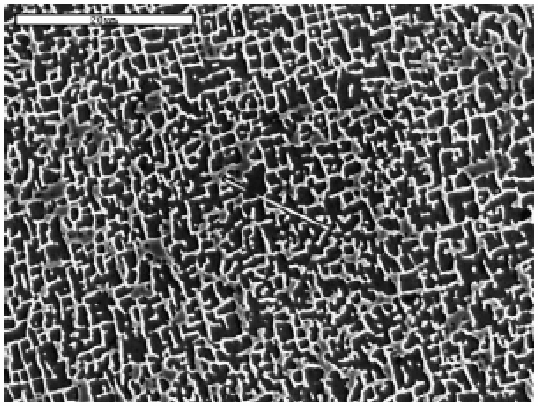
ALLOYING ELEMENTS

- Many elements are used to create desired phases within the material
- Commonly:
  - Precipitation strengthening (Ti, Al)
  - Corrosion and Oxidation Resistance (Cr, Al)
  - Grain boundary strengthening (B, carbides)
  - Rhenium has become important in turbine blades, but has many issues

PHASES

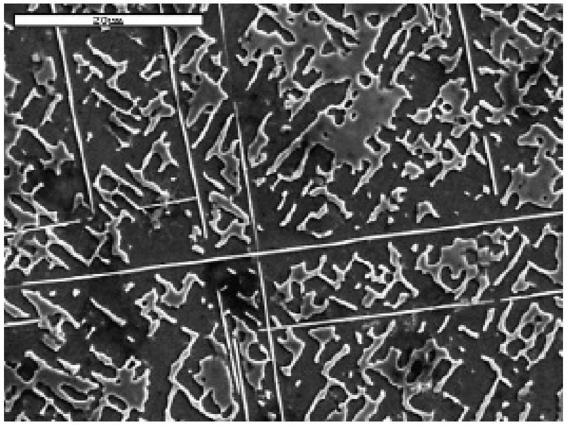
- Typical Phases
  - Gamma Matrix (γ)
    - FCC Ni solid solution
  - Gamma Prime (γ')
    - FCC $Ni_3(Al,Ti)$
    - Coherent particle strengthening
    - Microstructure after initial HT and after simulated aging





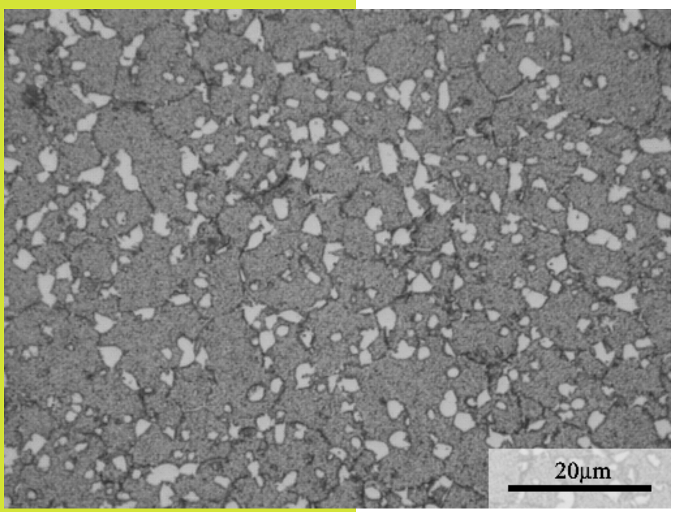
PHASES

- Additional phases
  - Gamma double prime (γ'')
    - Ni_3V or Ni_3Nb
    - Strengthener at low T, issues at high T
  - Sigma (σ)
    - Topologically close packed (TCP) phase
    - Embrittles material
    - Decrease lifetime by 50%

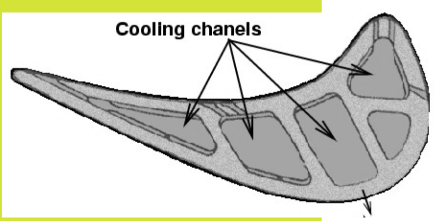


PROCESSING

- Polycrystalline Disk Alloy
  - Disks face much lower temperatures than the blades, but face larger stresses depending on region
  - Fatigue resistance is key, creep is also important
  - Powder metallurgy used
    - Expensive
    - Time consuming
    - Energy and cost intensive



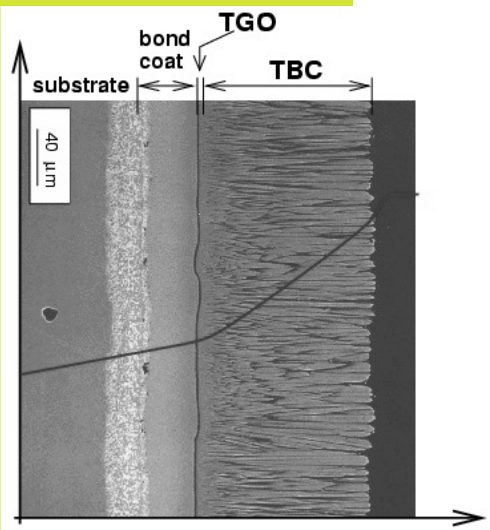
PROCESSING



- Single-Crystal Blade Alloy
  - Blades made in a variety of ways, but this has best balance of properties, creep resistance
    - Longest engine life ~
  - Slow process, creating few blades per heat
  - Cast and columnar blades cannot perform at as high temperatures, are used outside of aviation applications

THERMAL BARRIER COATING

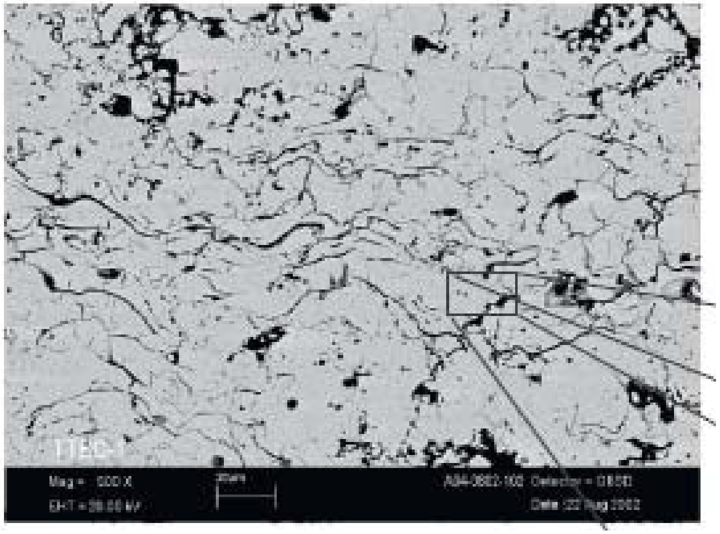
- TBC - Ceramic coating deposited onto bond coat
  - Yitria stabalized zirconia used as TBC
  - Bond coats are typically an intermetallic compound, often platinum aluminide
    - Required due to inability of ceramic to bond with metal



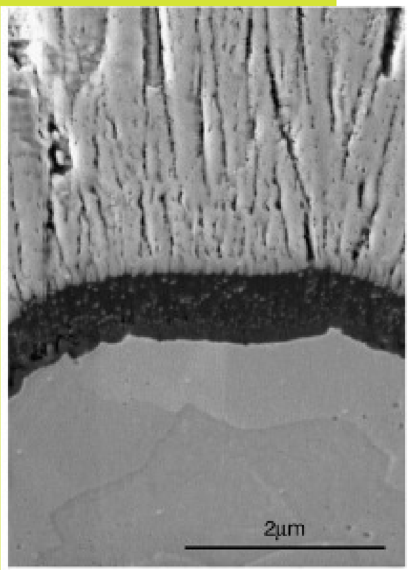
- Two main processes
  - Air-plasma-sprayed (APS)
  - Electron-beam physical-vapor-deposition (EB-PVD)

THERMAL BARRIER COATING

- APS
  - Used for land based applications
  - Liquid zirconia sputtered onto base layer, forming polycrystalline pancakes.
    - These sinter together during operation temperatures increasing the thermal conductivity



THERMAL BARRIER COATING



- EB-PVD
  - More reliable technology, aviation applications
  - Vacuum chamber, tungsten filament is used to shoot electrons to heat plasma into gas which deposits onto surface of bond coat.
  - Columnar ceramic structure created
    - More able to withstand debris impact during operation

CONCLUSIONS

- Ni-base superalloys have many benefits to conventional alloys but still have a long way to go to increase engine efficiency
  - Withstanding higher temperatures for longer periods of time
  - Increased fatigue and creep resistance
  - Thermal barrier coatings need further work in processing and mechanical properties
  - Reduce processing and element energy costs