How to Avoid Coloring of Parts in Hot Isostatic Pressing for MIM

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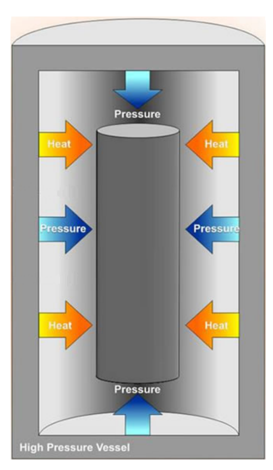
Hot Isostatic Pressing

Basic info

- Combining high temperature and isostatic pressure
- Definition:
  - *"Applying a pressure, distinctly higher than the yield stress of the material at the HIP temperature"*
- Pore elimination of solids
- Consolidation of powder
- Diffusion bonding
  - E.g. Steel/Cu, Ti/SS etc.
- Mechanisms:
  - Mechanical deformation
  - Creep
  - Diffusion



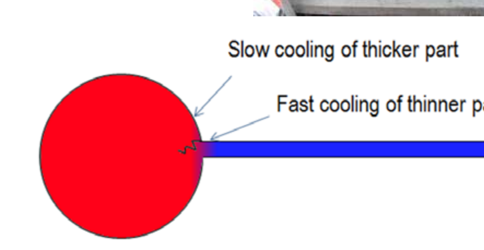
Heat Treatment in HIP

Recent developments in HIP equipment

- URQ® – Uniform Rapid Quenching
  - Possibility to perform quenching in a HIP
- URQ® enables combination of HIP and Heat Treatment in the same equipment, in the same cycle (HPHT).
  - Not only elimination of pores but also possible to choose your strength vs ductility ratio by heat treatment
  - Many advantages over conventional heat treatment

Conventional quenching

- Typically performed by moving the hot object into a much colder medium
- Typical mediums:
  - Water
  - Liquid salt
  - Oil
  - High speed low-pressure air
- Thermal shock when hot object are dropped into a much colder medium
  - High thermal gradients
  - High thermal stresses
  - Plastic strain
- Risk of distortion and quench cracking

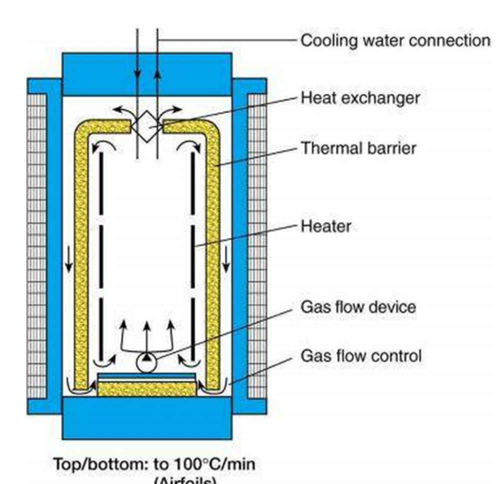


Drawbacks with conventional quenching

- Inflexible
  - Quenching medium temperature can not be changed when in operation. Very slow to react to temperature changes
- Moving operations needed
  - From solutionizing furnace to quench bath
  - From quench bath to ageing furnace
- Hot component exposed to air
  - Risk of surface oxidation
- Cleaning operations needed
  - E.g. removing salt or oil from component
  - Hard to clean internal holes, threads etc.

The URQ® concept

- Heat exchanger placed outside the furnace inside the pressure vessel
- The hot gas inside the furnace is lead through the heat exchanger during rapid quenching

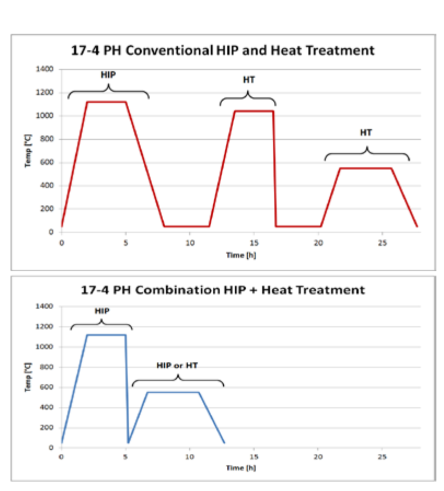


URQ® - Uniform Rapid Quenching

- Quench with cooling rates over 2000 °C/min
- High density gas:
  - Increases the heat transfer between the gas and component surfaces, $\alpha > 1000$ W/m^2°C
- The high HIP pressure remains during quenching
- Flexible heat treatment
  - Tailor-make recipes with infinite many holding, heating and quenching steps
- Inert argon gas as pressure medium
  - No risk of decarburization of the component surface
- Possible to measure temperature/cooling rate inside component during quenching with thermocouples
- And of course the regular benefits of HIP
  - Improved ductility
  - Improved fatigue properties
  - Lower scattering of material properties

Advantages of heat treatment in HIP

- The fast cooling capabilities in Quintus HIP systems enables a combination of HIP and Heat Treatment (HPHT).
- Cooling rates up to 300 °C/min are achievable with ordinary URC, and up to 3000 °C/min with URQ.
- Additional process steps included in the HIP system gives:
  - lower production costs
  - fewer process steps in the production chain
  - increased quality control
- Reduced time at elevated temperature also reduces grain growth.



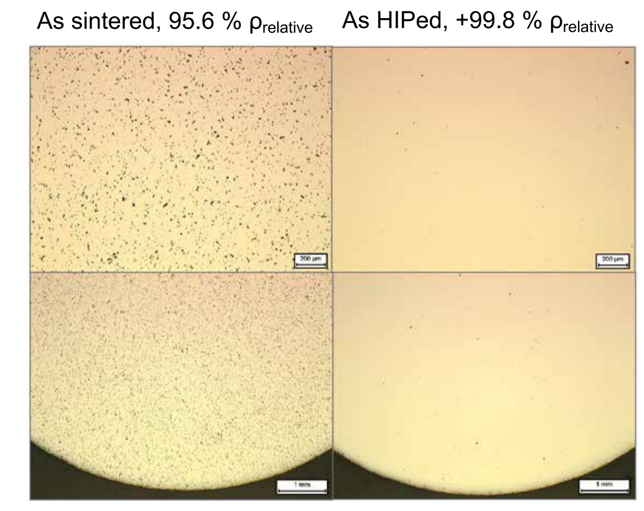
HIP for MIM

As sintered MIM parts

- MIM => residual porosity
- Relative density after sintering is (88) 92-98%
  - Depends on
    - powder particle size
    - binder type
    - powder fraction
    - sintering parameters, etc.
- Residual porosity gives lower mechanical properties compared to bulk material
  - Large effect on fatigue limit and fracture toughness.
  - Moderate effect on yield strength and ductility.

HIPing of MIM parts

As sintered, 95.6 % $\rho_{relative}$ As HIPed, +99.8 % $\rho_{relative}$



In center

At edge

Photos courtesy of Höganäs AB

HIPing of MIM parts

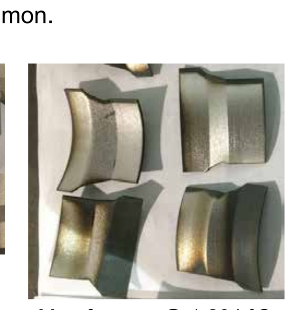
- Discoloration of MIM parts
  - Extra steps in post HIPing, i.e. cleaning, polishing, etc.
  - Extensive extra work to protect the MIM parts
  - Wrapping and other steps costly and work intensive.
  - Other measures, i.e. getters, etc.

HIPing of MIM parts

- Discoloration of High-Chromium parts
  - May require extra sintering step, and then introducing thermal stresses again.
  - Can also change surface composition.
  - Colors can be blue, yellow, black, green, most common.

Mo - furnace @ 1,204 °C

Graphite furnace @ 1,204 °C and 25% Ti - sponge



Mo - furnace @ 1,204 °C and 25% Ti - sponge

HIPing of MIM parts

- Discoloration of High-Chromium parts

Mo - furnace @ 1,121 °C

Graphite furnace @ 1,121 °C and 304SS - mesh cover

HIPing of MIM parts

- Discoloration of High-Chromium parts

Mo - furnace @ 1,100 °C

Graphite furnace @ 1,100 °C and 304SS - mesh cover

HIPing of MIM parts

- Discoloration of High-Chromium parts

Graphite furnace @ 1,100 °C and 304SS - mesh cover

Graphite furnace @ 1,100 °C and optimized HIP - cycle

Heat Treatment of MIM Parts in HIP

Summary and Conclusion

- Inert argon gas as pressure medium
  - No risk of decarburization of the component surface
- Continuous cooling of the gas from the same elevated temperature as the component
  - Low thermal gradients
  - Low thermal stresses
  - Low risk of distortion and cracking
- Flexible heat treatment
  - Tailor-make recipes with infinite many holding, heating, quenching and cooling steps
  - Optimal HIP cycle to avoid discoloration of MIM parts with high-Cr content
- And of course the regular benefits of HIP
  - Improved ductility
  - Improved fatigue properties
  - Lower scattering of material properties

More information on www.quintustechnologies.com/hot-isostatic-pressing