Quintus TECHNOLOGIES

Heat Treatment of PM parts by Hot Isostatic Pressing

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Hot Isostatic Pressing

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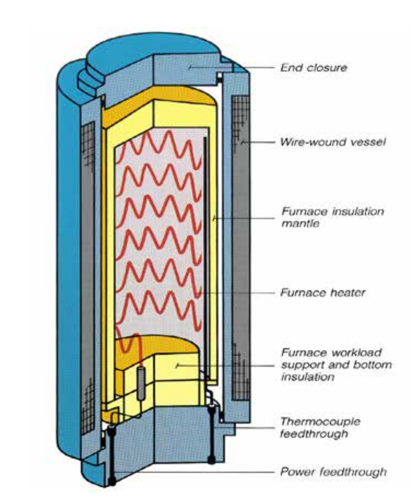
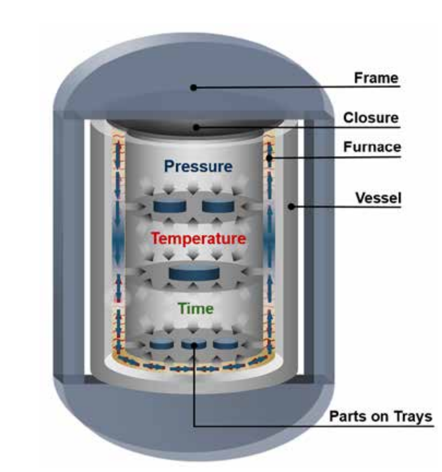
A combination of elevated temperature and pressure heal internal voids in metal and ceramic materials to substantially improve strength



Basic info

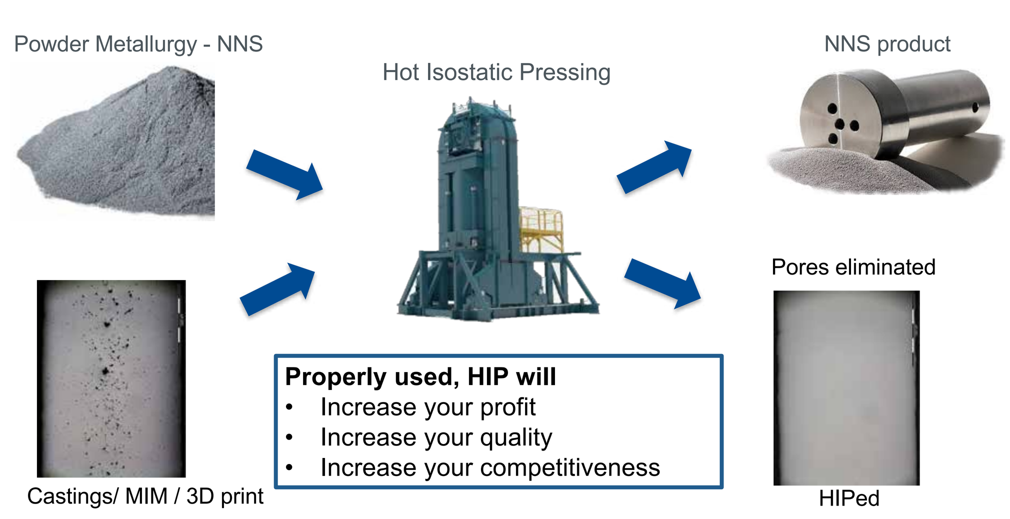
- Definition:
  - *"Applying a pressure, distinctly higher than the yield strength of the material at the HIP temperature"*
- Main applications:
  - Pore elimination of solids
  - Consolidation of powder
  - Diffusion bonding
    - E.g. Steel/Cu, Ti/SS etc.
- Mechanisms:
  - Mechanical deformation
 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



Advantages of Hot Isostatic Pressing

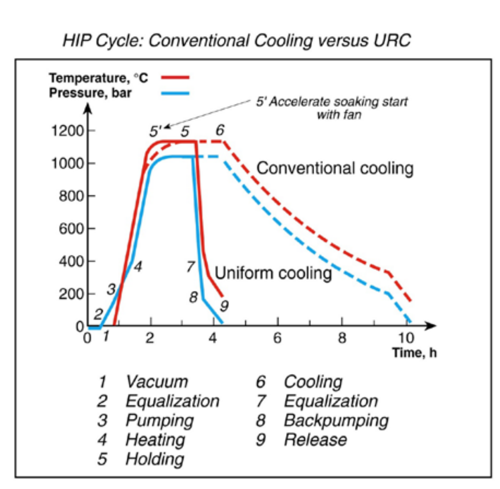
- 100% of theoretical density
- Superior material properties
  - Fatigue, Ductility, Red. of Area
  - Impact strength, Hardness, etc.
- Reduced scatter in material properties
  - Predictive component life
  - Low weight design
- Decreased scrap loss

Most Common HIP Usage Today



Properly used, HIP will
- Increase your profit
- Increase your quality
- Increase your competitiveness

Uniform Rapid Cooling (URC®)

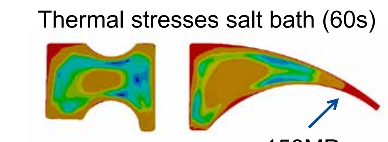


- A wire wound thin walled cylinder is the only way to achieve rapid cool performance with control.
- Quintus is the sole supplier of the patented URC® solution.
- Cooling is fast enough for heat treatment of the load.
- Up to 100% faster turn around time is achieved!!

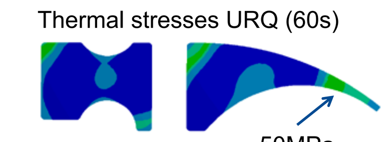
Uniform Rapid Quenching (URQ®)

- With Quintus latest developments quenching can be achieved directly in the HIP
- Cooling rates over 2000 K/min can be achieved with a maintained high pressure
- With Quenching directly in the HIP there will be:
  - low thermal gradients ➔ low thermal stresses
  - low risk of distortion and cracking
- Programmable temperature distribution with good accuracy during the cooling phase
- ***The ultimate Heat Treatment machine!***

Thermal stresses salt bath (60s)



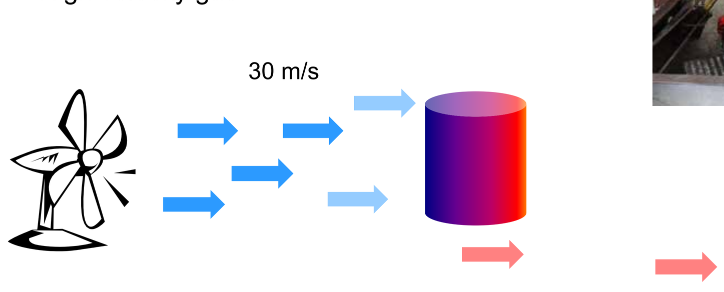
Thermal stresses URQ (60s)



Heat Treatment in HIP

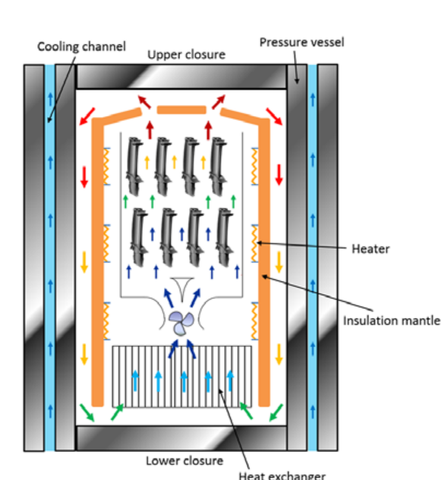
Conventional quenching

- Typically performed by moving the hot object into a much colder medium
  - Water, oil, salt, polymer etc.
- High velocity gas



The URQ® concept

- Forced gas cooling with high pressure
  - Slow gas velocity < 0.5 m/s
- Heat exchanger placed outside the furnace, but inside the pressure vessel
- The hot gas inside the furnace is lead through the heat exchanger during quenching
- Quench with cooling rates over 2,000 K/min
  - Depends on load, temperature interval, design
- High density gas:
  - High heat transfer between gas and component surfaces, α > 1000 W/m²C
- The high HIP pressure remains during quenching
- Flexible heat treatment
  - Tailor-make recipes with multiple many holding, heating, quenching and cooling steps

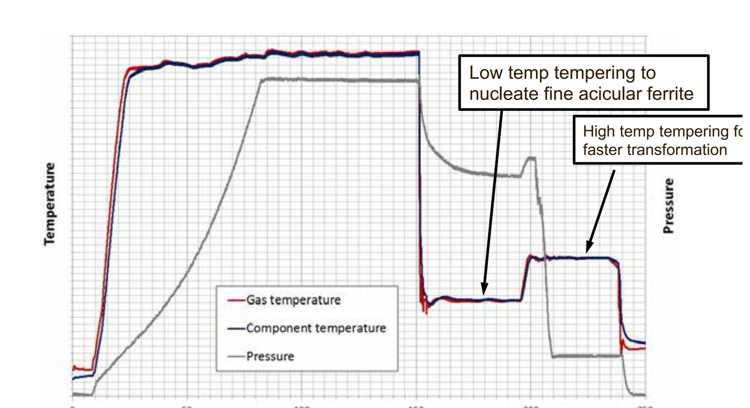


Example of a URQ® cycle

- Material development with URQ®
  - Heat treatment with dual-step-tempering for a cast iron (with Indexator AB)

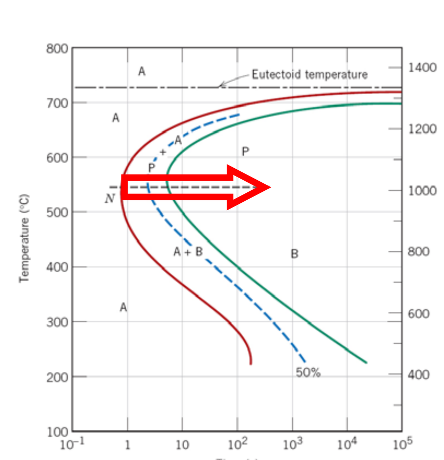
	ADI
Yield stress	1257 ± 11 MPa
Ultimate stress	1604 ± 16 MPa
Ductility, A5	8.1 ± 1.4 %

Notice the scattering below 1% !



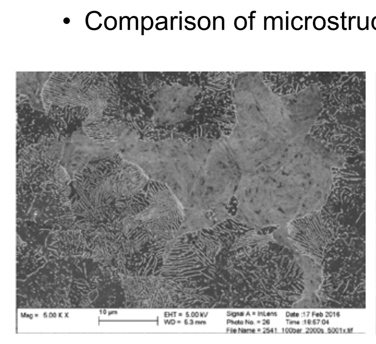
Advantages with URQ®

- The fast cooling capabilities in Quintus HIP systems enables a combination of HIP and Heat Treatment (HPHT).
- High isostatic pressure during quenching =>
- Slower phase transformation kinetics in the Fe-C system
  - Delays pearlite transformation
  - Lower cooling rate needed
  - Less alloying element for hardenability
- Reduced time at high temperature also reduces grain growth
- Additional process steps included in the HIP system gives:
  - Lower production costs
  - Fewer process steps in the production chain
  - Increased quality control
- And of course the regular benefits of HIP…
  - Improved ductility
  - Much improved fatigue properties
  - Lower scattering of material properties

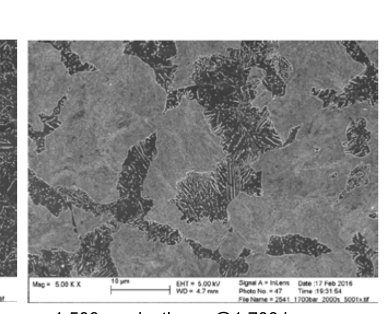


Advantages with URQ®

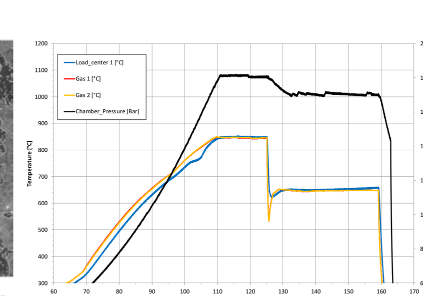
- TTT experiments for a 4340-steel in a URQ-HIP (with Swerea Kimab)
  - Low and high pressure
  - Comparison of microstructure and hardness



- 1,500 sec isotherm @100 bar
- 70 % pearlite
- Hardness: 344 HV



- 1,500 sec isotherm @1,700 bar
- 26 % pearlite
- Hardness: 497 HV



- TTT curve 1,500 sec isotherm @1,700 bar

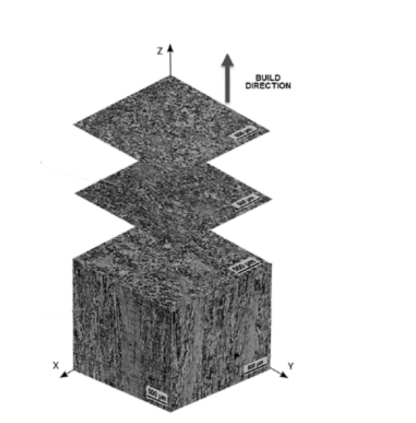
Example: Breaking up anisotropy

- Combining HIP and quenching to break up columnar grain structure for EBM Ti-6Al-4V

Table 1. Processing conditions for Ti-6Al-4V

Cycle nomenclature	Thermal Profile	Pressure and Cooling Rate
HT1(Gleeble)	25C→1020C-10min→700C→1020C-10min→700C→1020C-10min→700C→1020C-10min→700C→25C	-N/A- and 285C/min
HT2	25C→1020C-10min→700C→1020C-10min→700C→1020C-10min→700C→1020C-10min→700C→25C	100MPa and rapid cool
HT3	25C→920C-2 hours→25C	100MPa and rapid quenching
HT4	25C→920C-2 hours→25C	100MPa and standard cool

Courtesy of Oak Ridge National Laboratory



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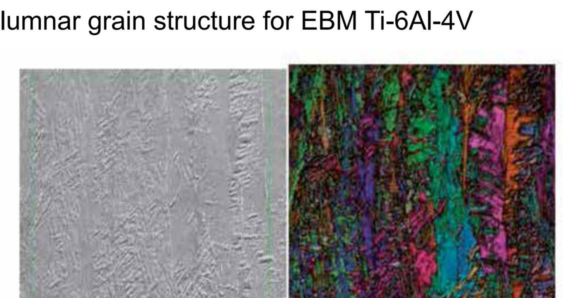

Fig. 5. EBSD map showing the columnar grain structure obtained from the thermal cycling HT1.

Courtesy of Oak Ridge National Laboratory

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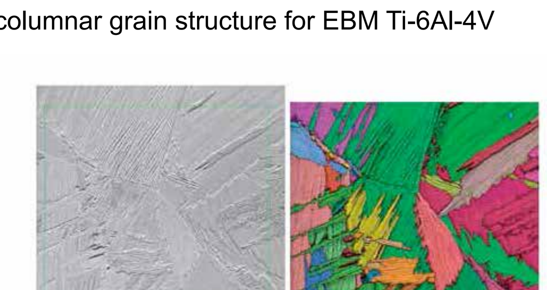

Fig. 6. EBSD map showing the more equiaxed structure obtained by HIP processing HT2.

Courtesy of Oak Ridge National Laboratory

Heat Treatment of PM Parts by HIP

Summary and Conclusions

- **With recent development Quenching can be applied directly in the HIP**
  - Fast turn around times
  - Material optimization
- **HIP + Heat treatment can today be one single process**
  - Material development
  - Process cost saving
  - Increased quality control
- **HIP and metal PM is a perfect combination to achieve high quality parts**
  - Multiple heat treatment cycles can be included in one process step
  - Modification of the microstructure
- **Quintus Technologies would be pleased to conduct collaborative R&D**
  - URQ process optimization?
  - Materials to be evaluated?

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