I trattamenti e i processi termici speciali per componenti motori aeronautici prodotti con le nuove tecnologie additive EBM.

Antonio Magnacca

Il futuro del settore aerospaziale,
Le nuove tecnologie dei materiali e di produzione .
Polo Tecnico Fermi Gadda Aula Magna 14 Marzo 2017

I contenuti della presentazione.

- Le tecnologie additive EBM
- La pressatura isostatica a caldo
- I trattamenti termici post processing.
- I risultati
- QA.

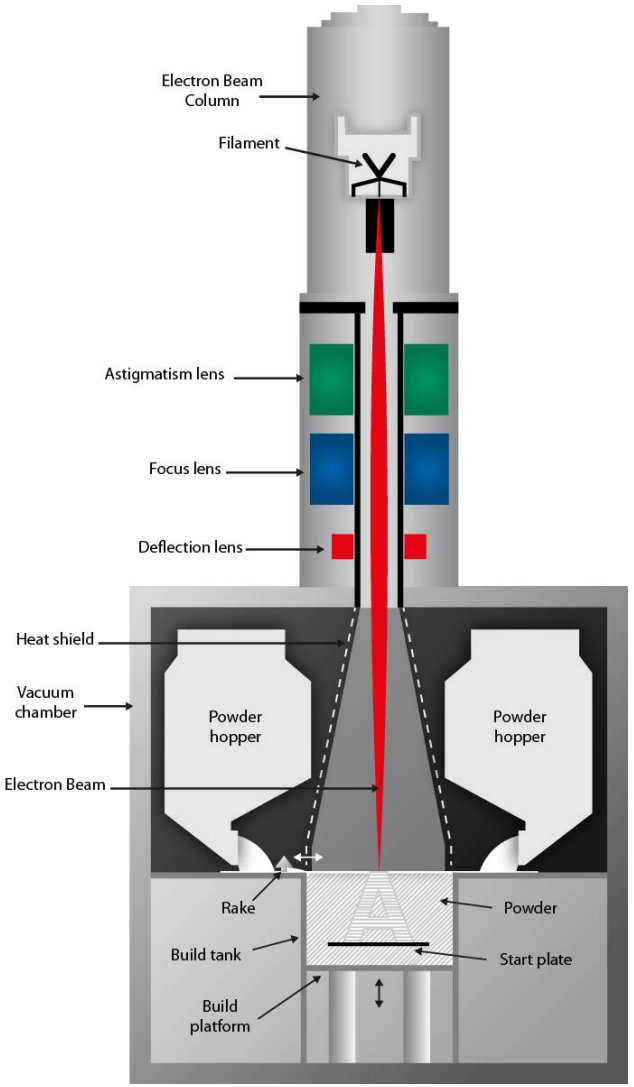
Electron Beam Melting (EBM®)

High Power (3.000 W)
- Allows for high melting capacity
- High productivity

No moving parts in the EB-gun
- Extremely fast beam control
- Power & focus continuously varied
- Enables **EBM MultiBeam™**

Vacuum Process
- Clean & controlled environment
- Allows processing reactive materials

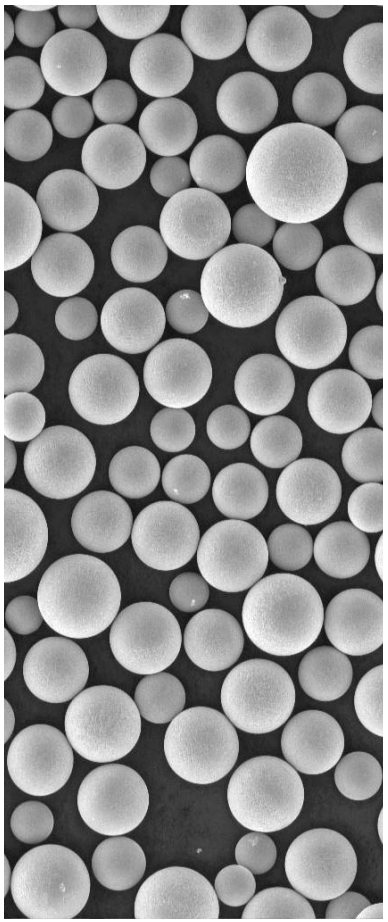
Hot Process (650ºC for titanium)
- No residual stresses
- No martensitic structures
- Faster melting



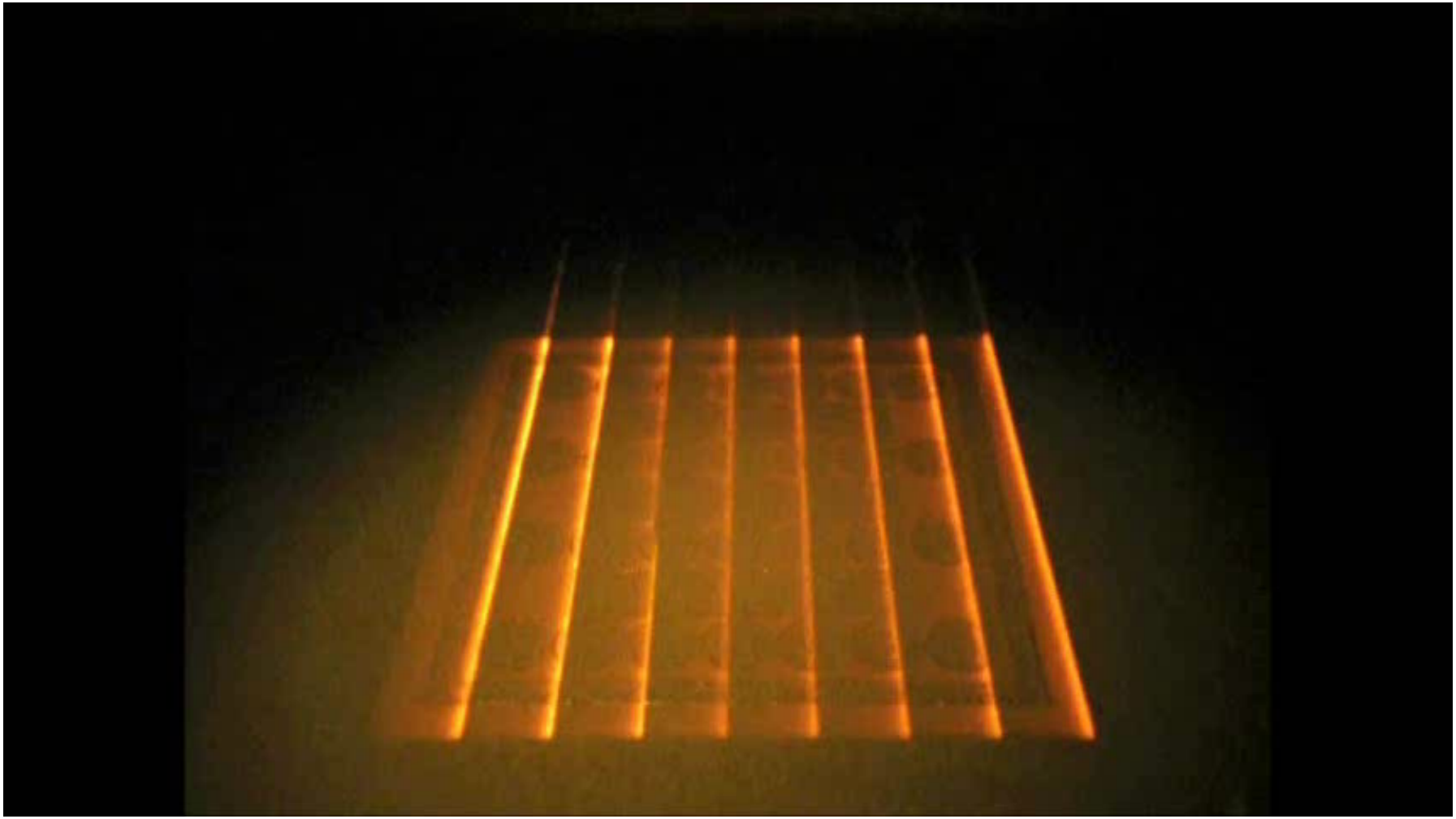
Success factors for production

Bodycote

- ✓ Reliability - Stable machine systems
  Stable manufacturing process
- ✓ Economy - High production rate
  Competitive powder cost
- ✓ Quality - Material quality
  Geometric accuracy
  Surface quality
- Added values with AM - Freedom in design
  Cellular structures
- Develop new material and alloys difficult to produce with popular technologies.



EBM build cycle



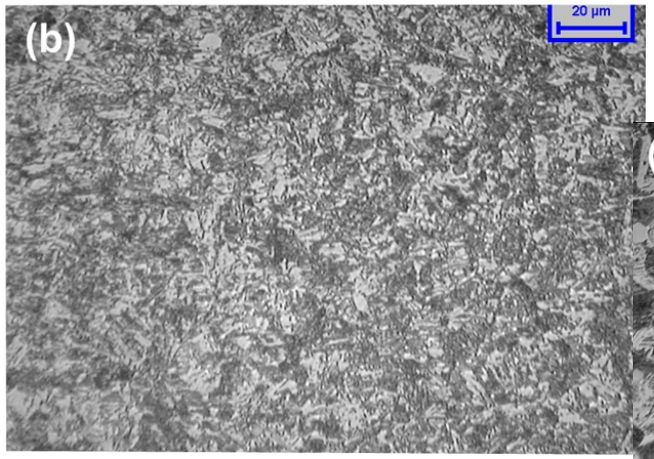
EBM implants on the market

Bodycote

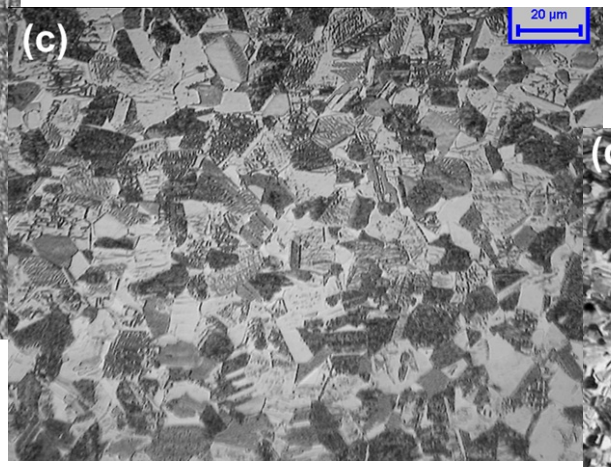
Production case for aerospace
- Turbine blades in γ-TiAl

- Prototype turbine blades in γ-TiAl
- Weight reduction
- Challanging to cast
- 325 mm build heigh / tolerance: ±0.1 mm
- Turnaround time: 7,5 h / blade

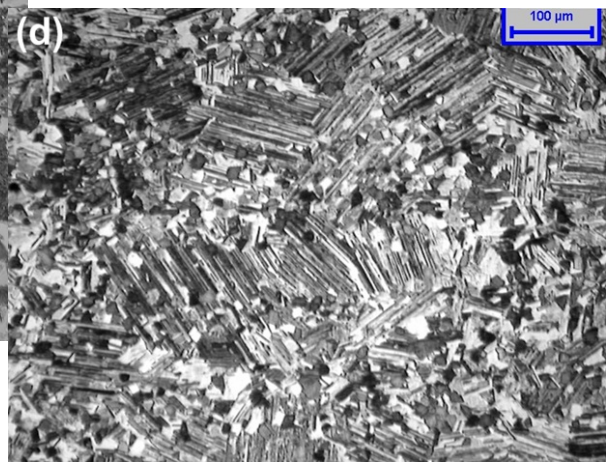
Success Factor
- Material Quality in par with industry standards



As-built by EBM



HIP 1260 °C, 1700 bar, 4h
Equiaxed γ
Grain size <20 µm



Heat Treatment
Duplex
Lamellar colonies ~100 µm
Equiaxed grains ~15 µm
Lamellar fraction ~ 40%

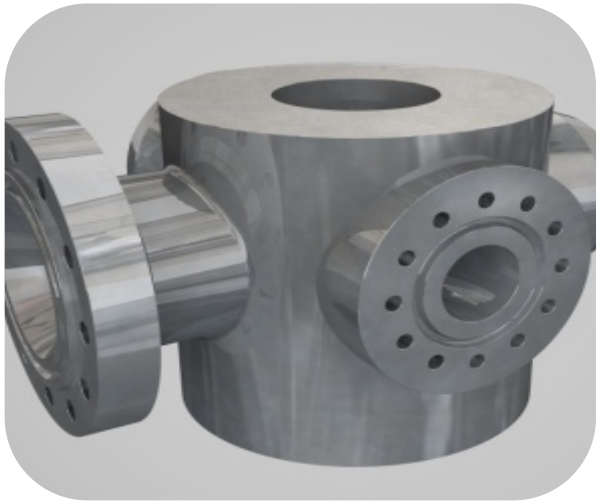
EBM® γ-TiAl: microstructures

Hot Isostatic Pressing - Two Business Units

HIP

HIP Services
Casting Densification

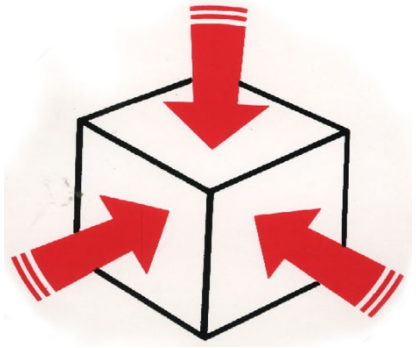
Product Fabrication



What is HIP

Simultaneous application of **High Pressure** (15000 – 30000psi) and **High Temperature** (up to 2000°C) under **Isostatic conditions** in an inert atmosphere **(Ar gas).**

Under these conditions of heat and pressure, internal pores or defects in castings collapse, and encapsulated powders shrink and diffusion occurs to produce a fully dense component.

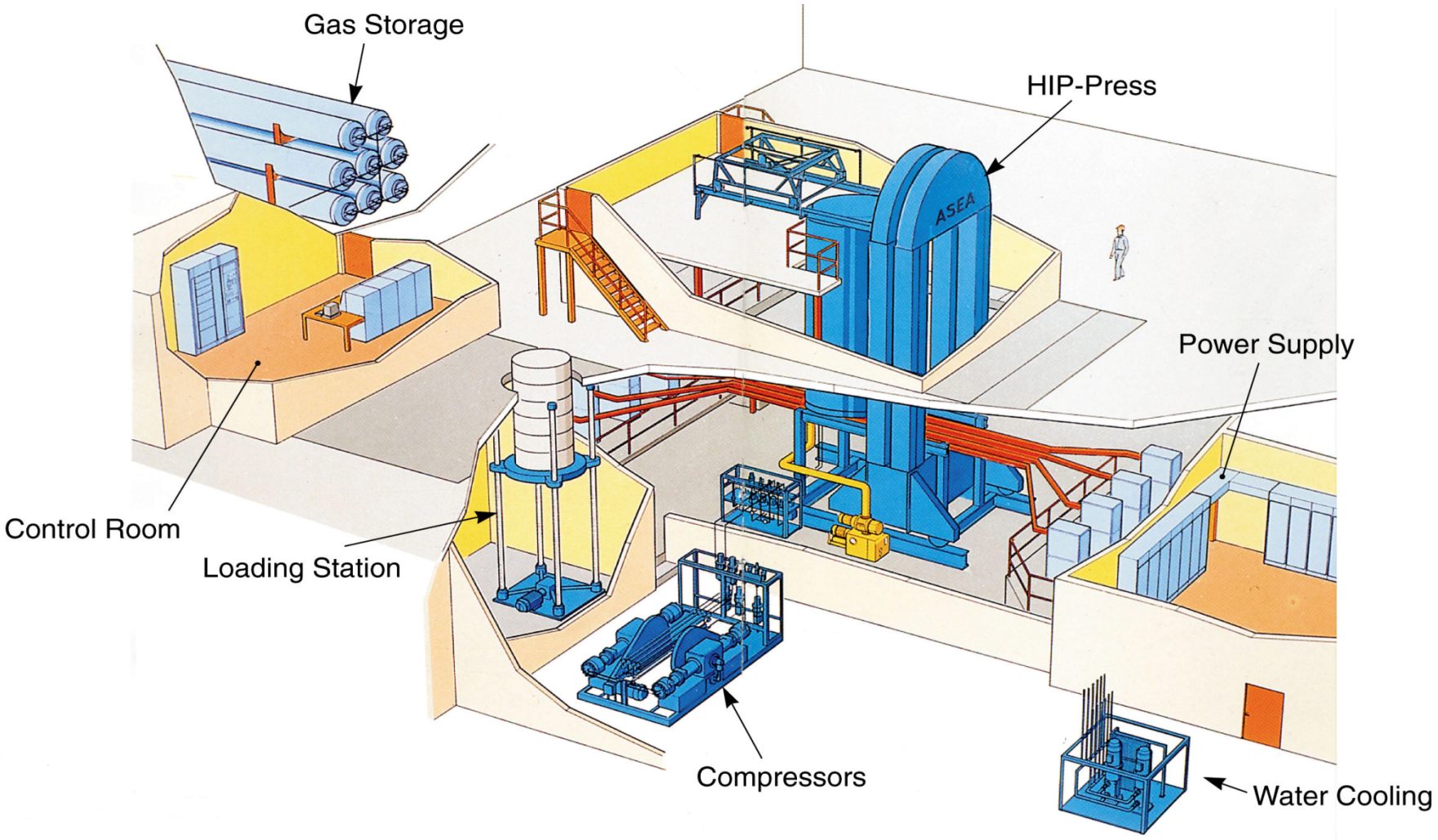


FIELDS OF APPLICATION:

- Consolidation of Powder of Metallic and Non-Metallic Materials
- Densification of castings & pre-sintered components.
- Interfacial Bonding (Solid/Solid, Powder/Solid)

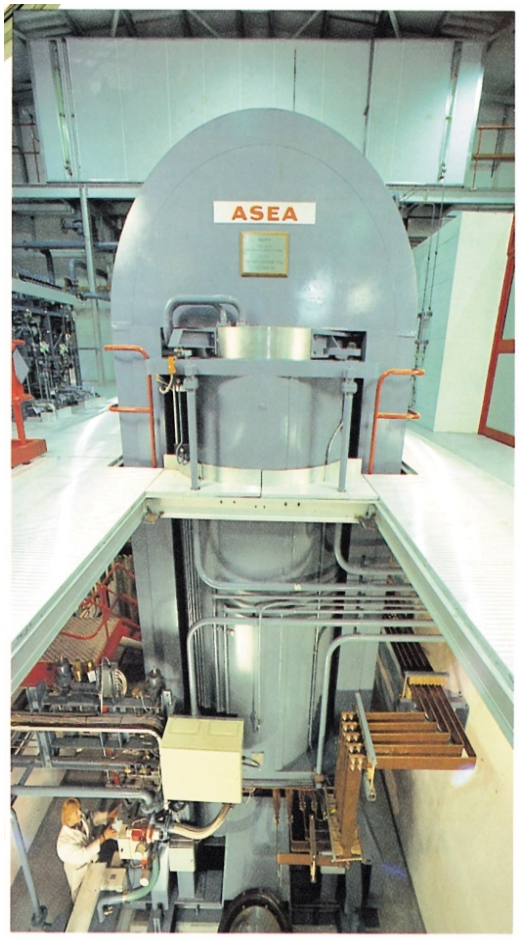
Typical HIP Plant Layout – Standard Mega-HIP

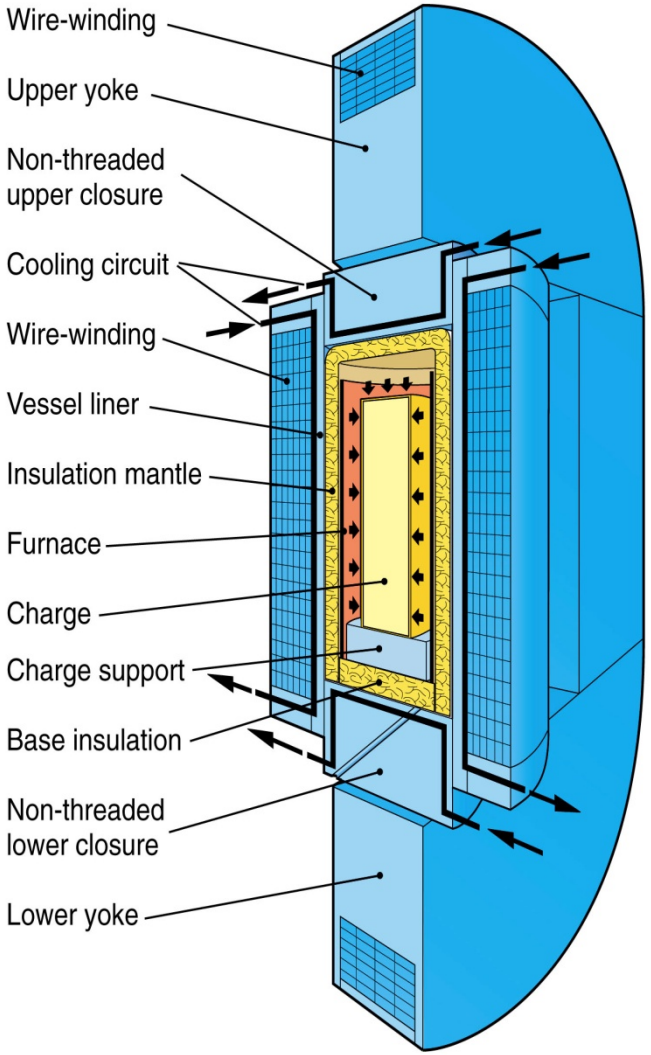
Bodycote



HIP Equipment

Bodycote



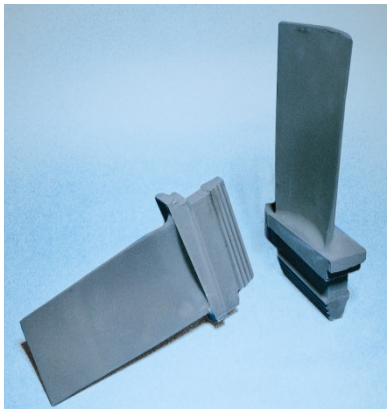


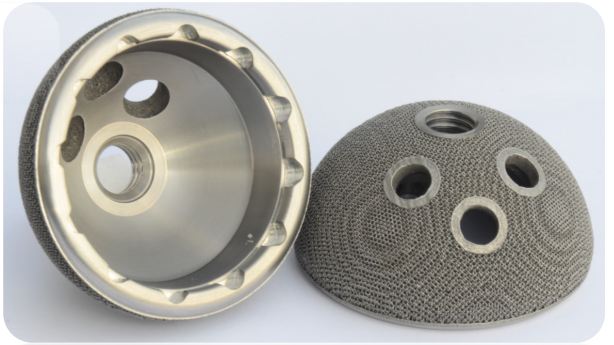
Mega HIP Unit and Furnace at Bodycote Chesterfield

(Courtesy Avure Technologies)

HIP Densification Applications

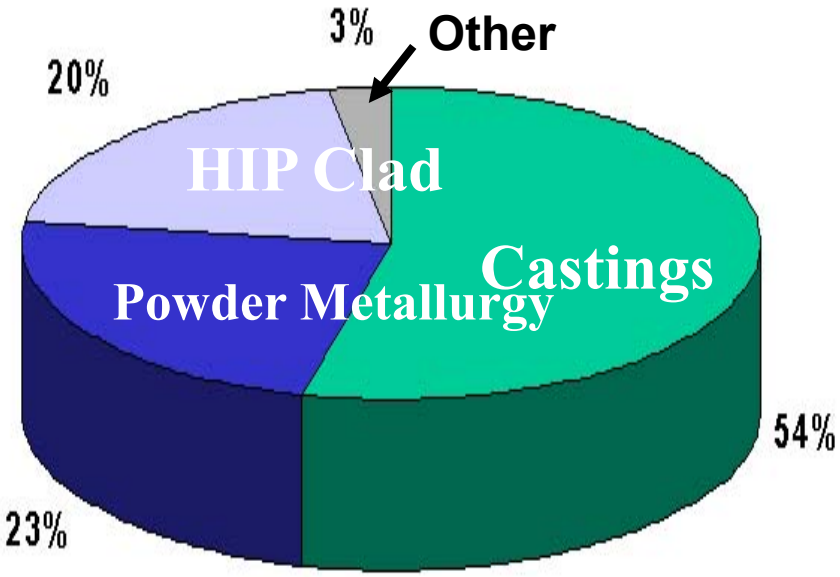
Bodycote

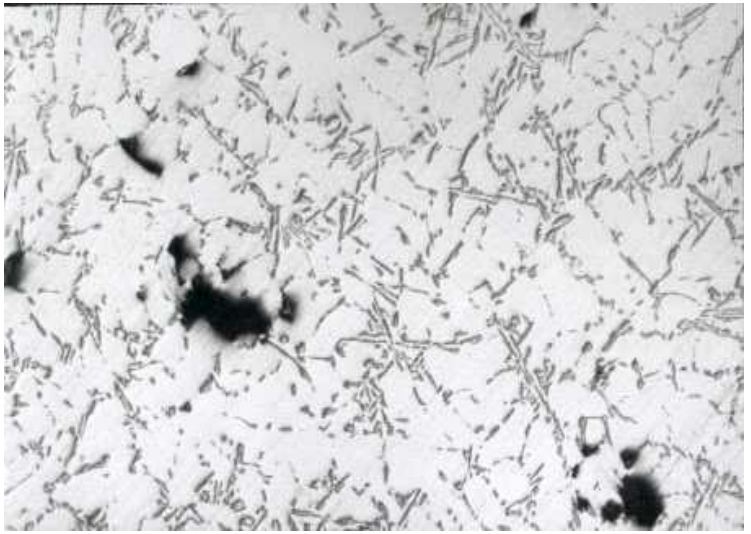


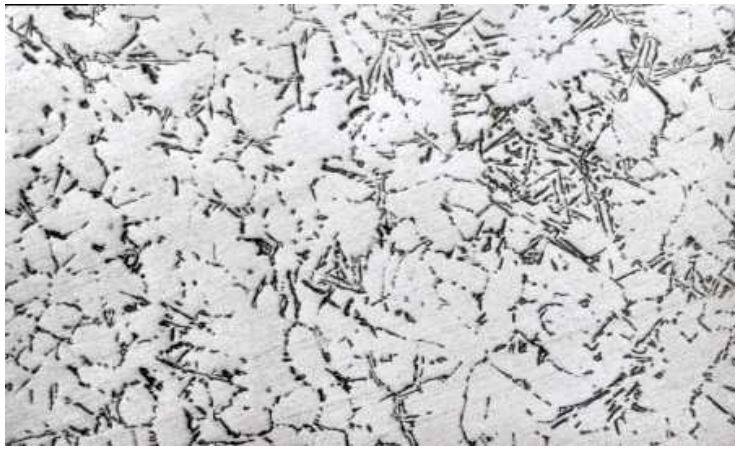


HIP Market Applications

Bodycote





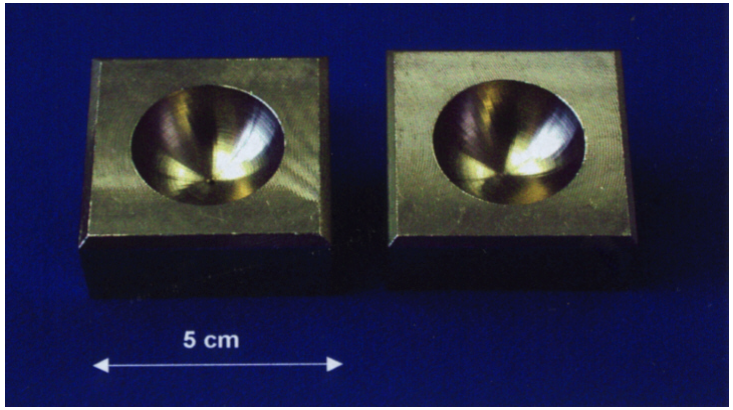


The largest commercial use of HIP is the densification of castings

Processing of castings represents ~ 50% of HIP world wide facilities

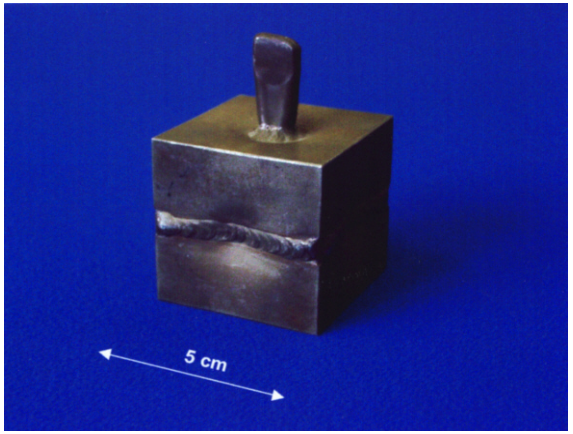
Demonstration – Removal of Pore by HIP

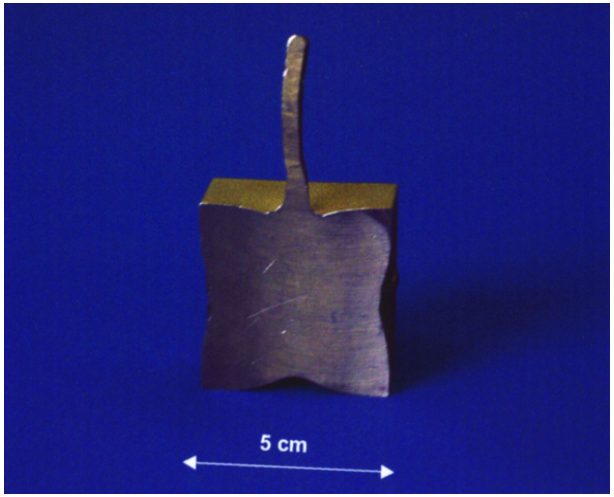
Bodycote



Two alloyed steel block halves, each with a half sphere of about 30mm diameter…

… welded together around the block edges to simulate an internal pore …

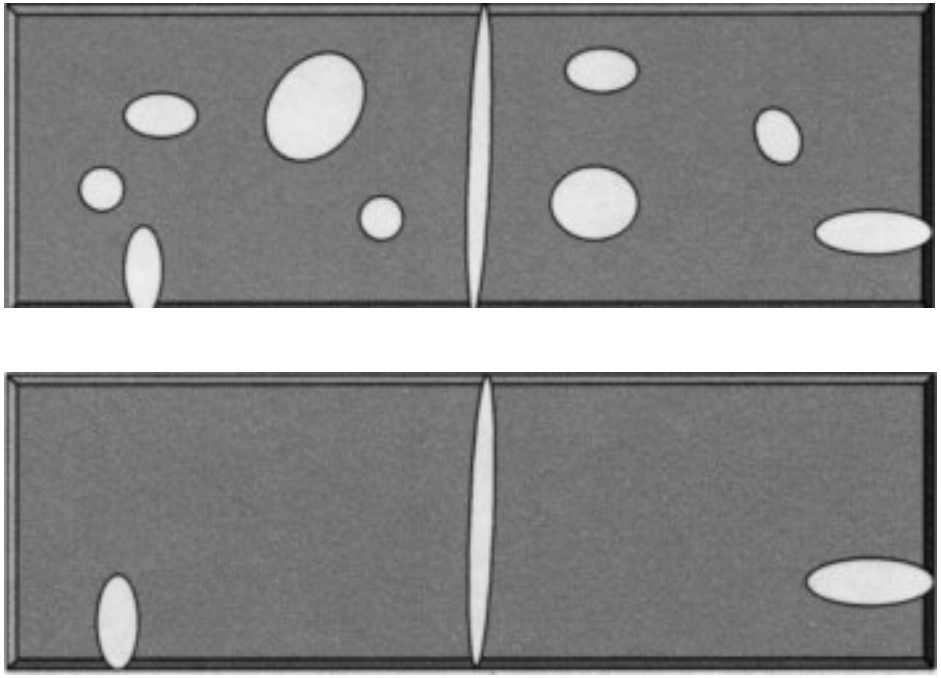




… after HIP cut in half to reveal full dense material.

Porosity Removal by HIP

Bodycote



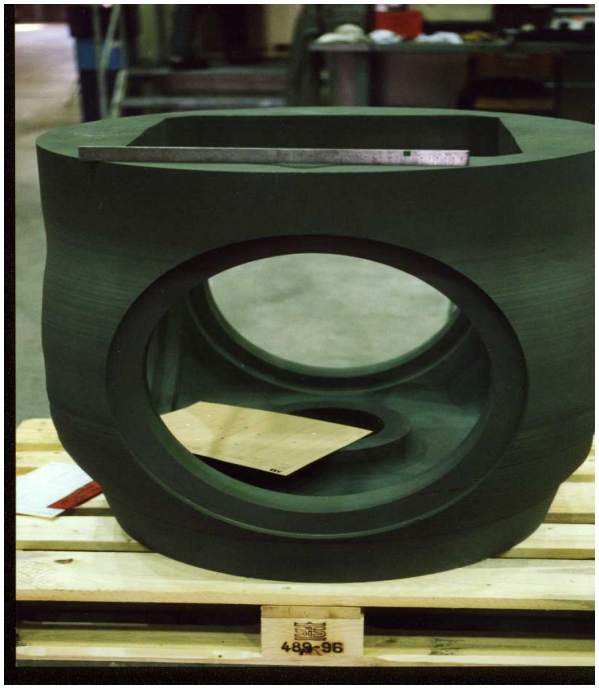
Before HIP

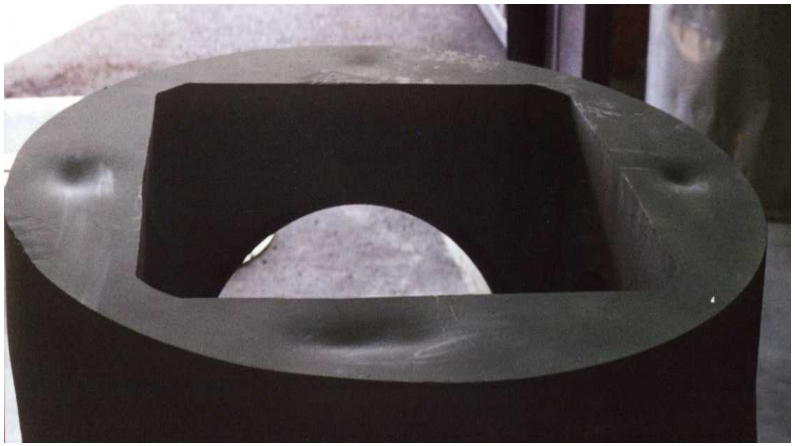
After HIP

HIP closes all internal porosity
but cannot close
surface connected pores

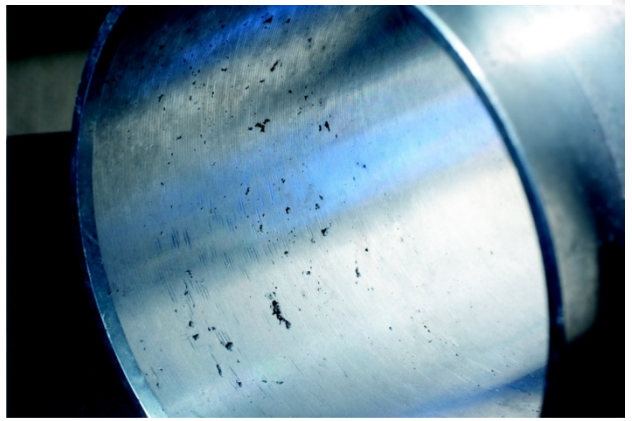
Evidence of Porosity Closure during HIP

Bodycote

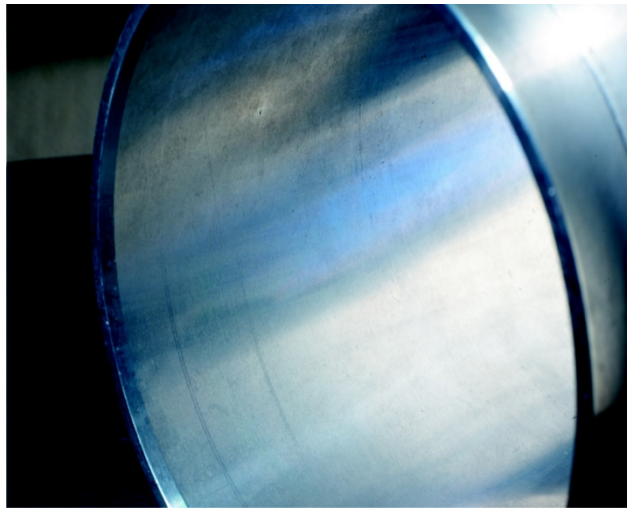




Machined before HIP (Pores)



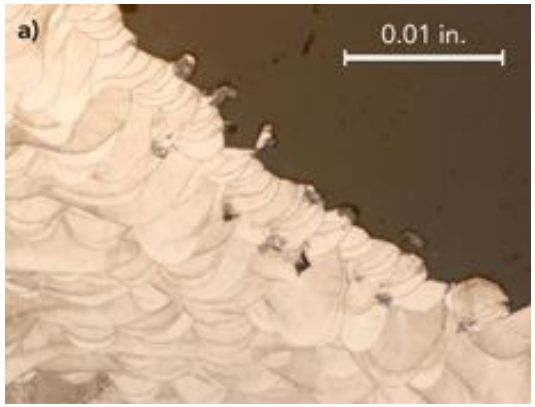
Machined Post HIP (No Pores)



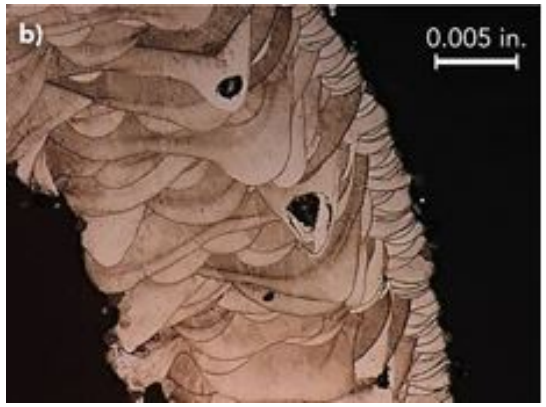
HIP of Additive Manufactured Components
Laser or Electron Beam AM?

Bodycote

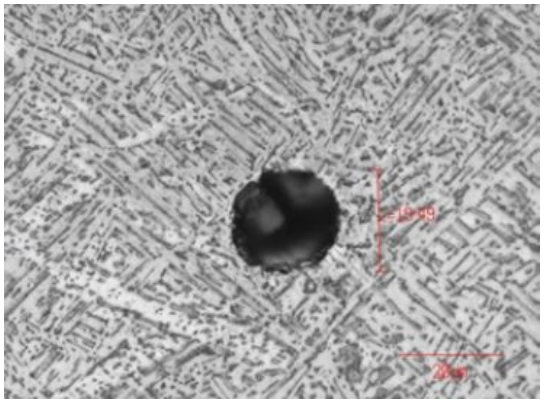
- Laser & Electron Beam AM parts typically contain a small amount of porosity
  - Scanning calibration mismatch (a)
  - Key-hole beam-weld interaction (b)
  - Gas (can be internal to individual powder particles) (c)
  - Shrinkage as previous layers solidify
  - Micro-cracks due to as-built residual stresses



(a)



(b)



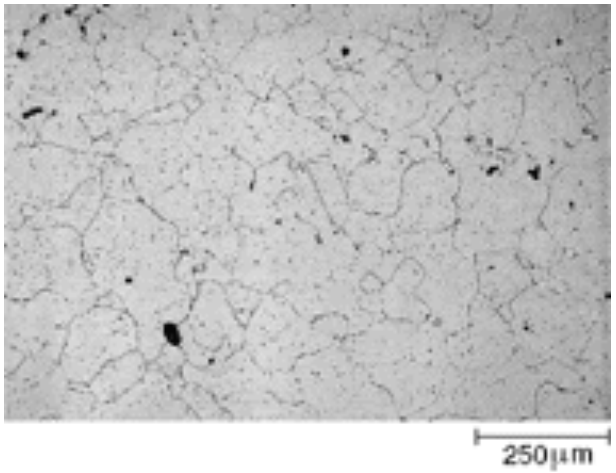
(c)

(a), (b) GE Aviation; (c) Arcam

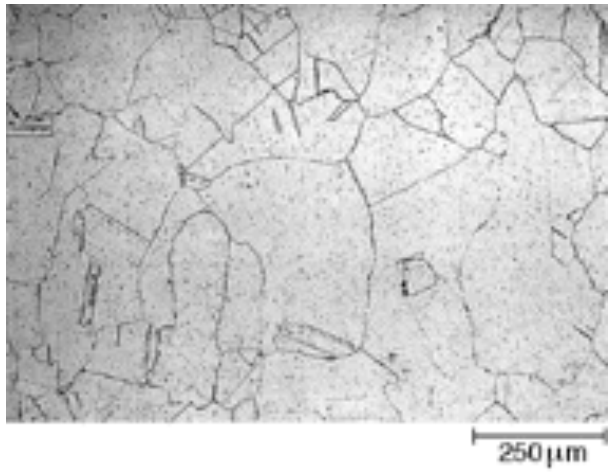
Effect of HIPing AM Components

Bodycote

- The HIP cycle can provide stress relief
- The HIP process can affect microstructure
  - Recrystallization
  - Homogenization
  - Grain growth (eg. laser-sintered IN625 below)



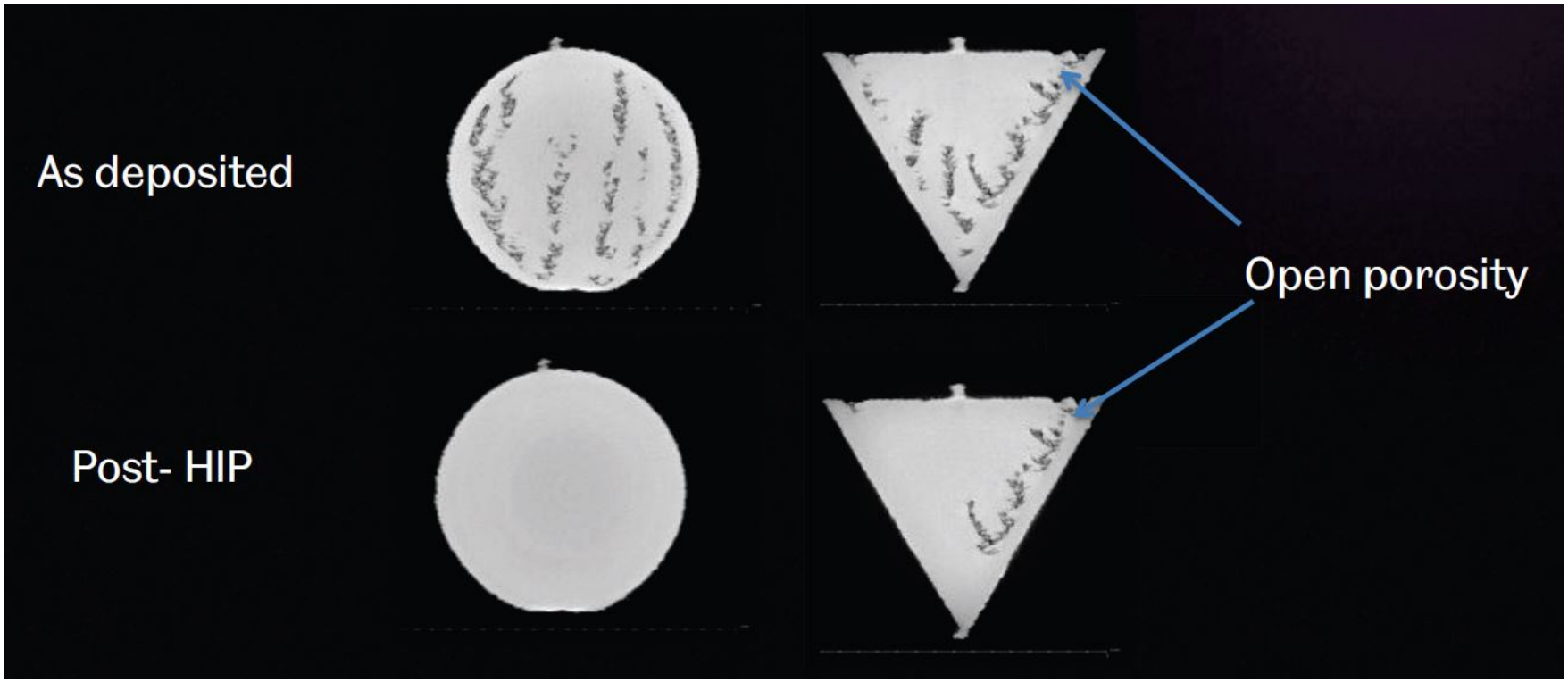
As built, 98.5% density



Post HIP, 99.5% density

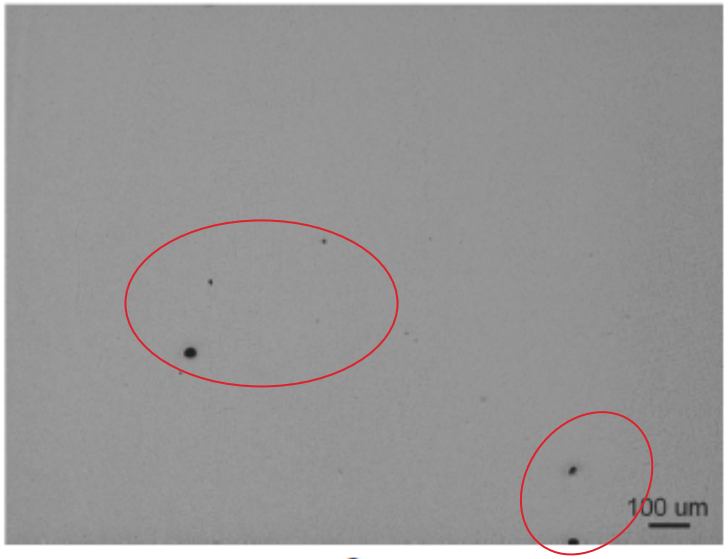
photomicrographs courtesy of Das et al.

Effect of HIP on Pore Closure in AM Parts

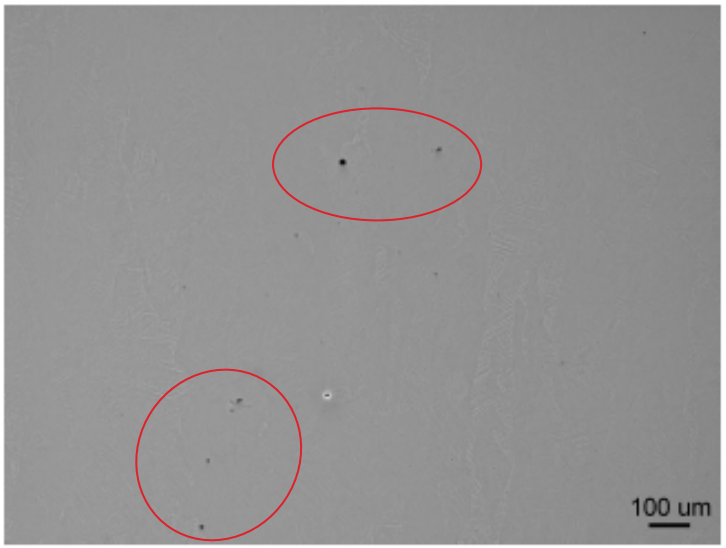


courtesy of Mercury Centre, University of Sheffield

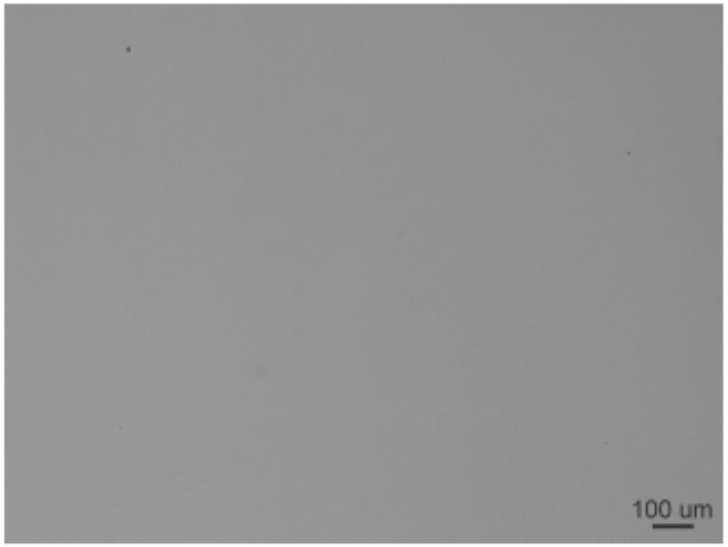
Elimination of porosity by HIP - titanium



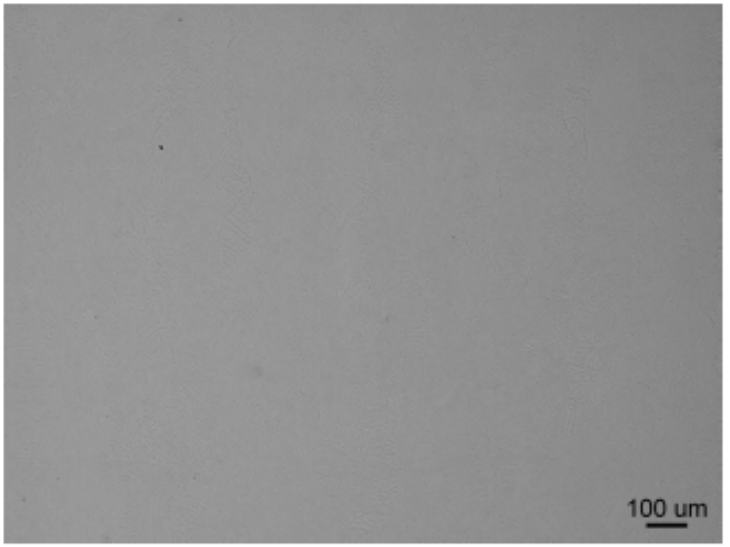
(a) EBM® (as-built)



(b) DMLS (as-built + stress relief)



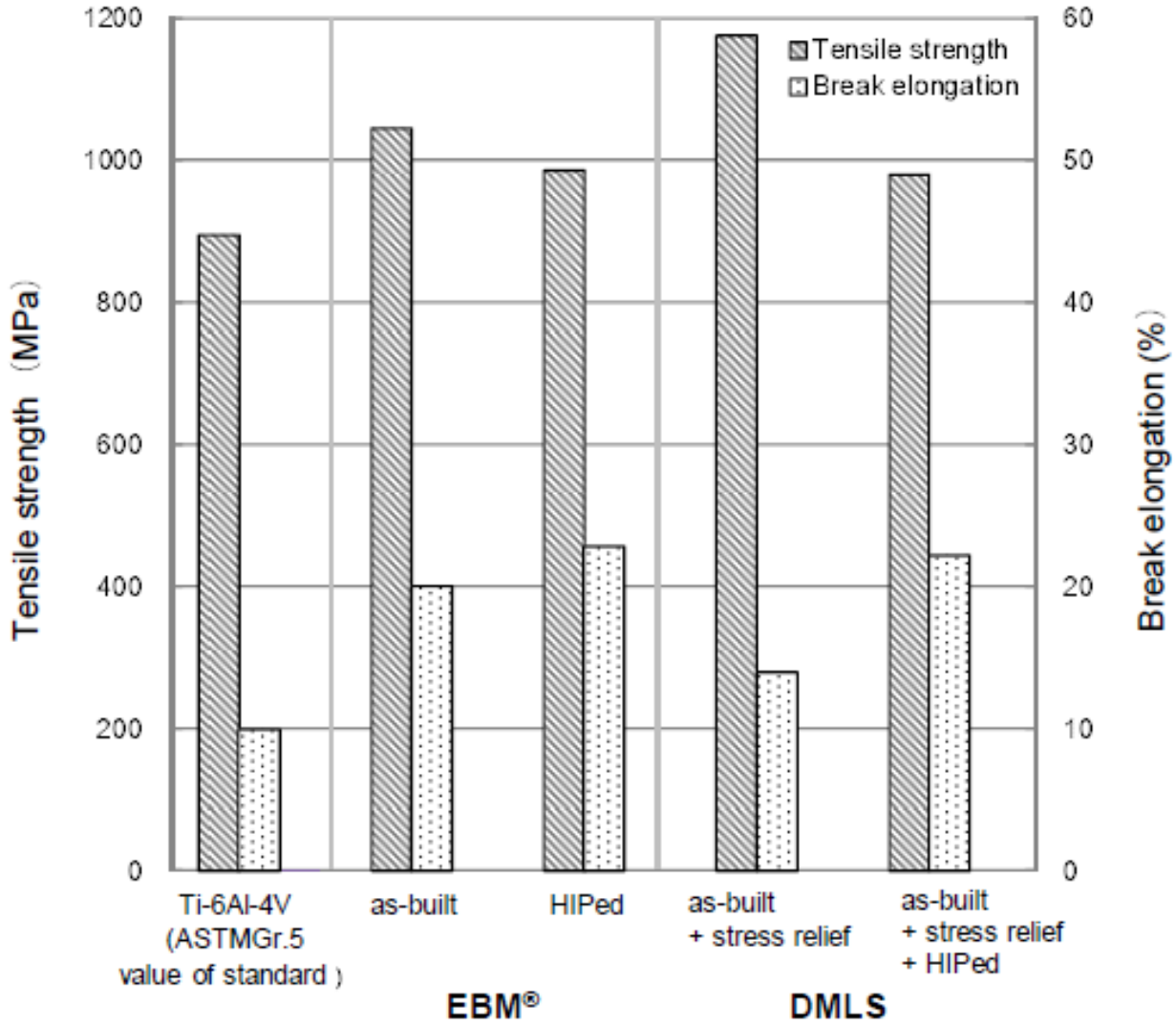
(c) EBM® (HIPed)



(d) DMLS (as-built + stress relief + HIPed)

Courtesy of MOROKOSHI, et al.

Tensile strength comparison 6Al-4V



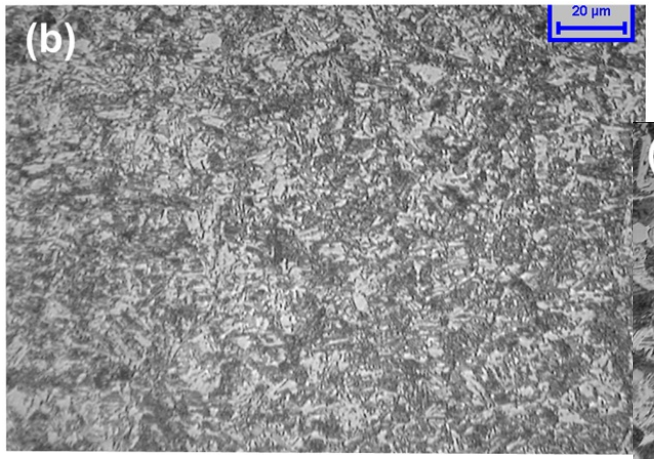
Tensile and yield strengths tend to reduce slightly with HIP.

The benefit: increased ductility without significant strength decrease

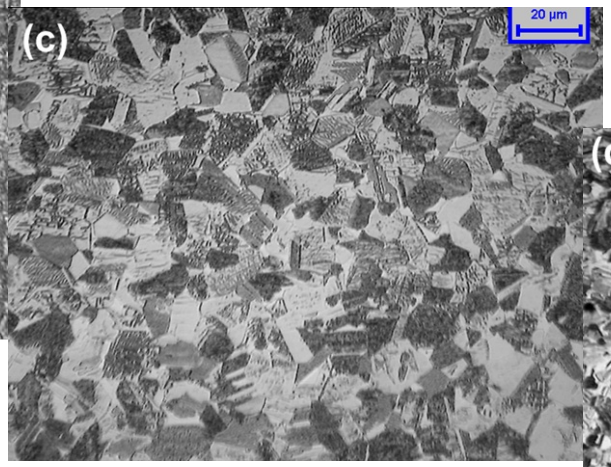
Courtesy of MOROKOSHI, et al.

Success Factor

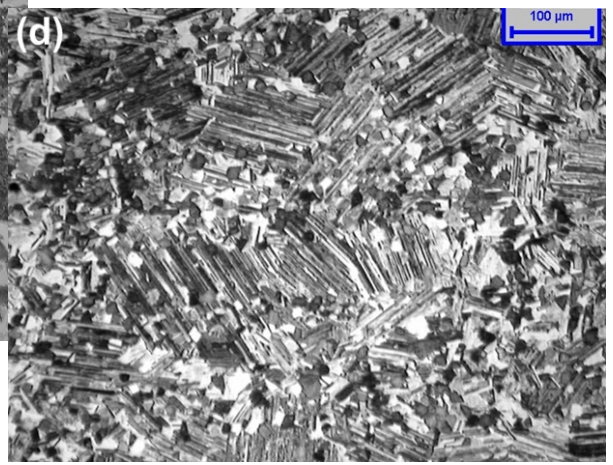
- Material Quality in par with industry standards



As-built by EBM



HIP 1260 °C, 1700 bar, 4h
Equiaxed γ
Grain size <20 µm



Heat Treatment
Duplex
Lamellar colonies ~100 µm
Equiaxed grains ~15 µm
Lamellar fraction ~ 40%

EBM® γ-TiAl: microstructures

EBM TiAl Blades – HT cycle

Heat treatment according to the following parameters:

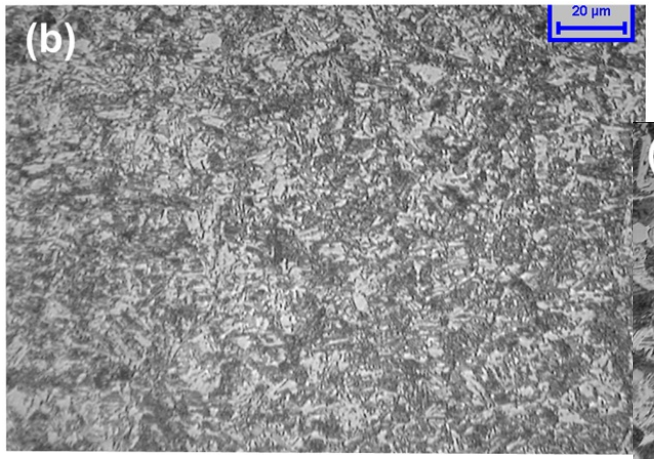
- Vacuum heat treatment (<10-4 mbar) to a temperature of 1335±8°C holding for 3 hour ±15minutes
- Cool at a rate between 80-100°C/min to a temperature of 1000°C or below.
- Cool from 1000°C to room temperature at any rate.

Heat Treatment

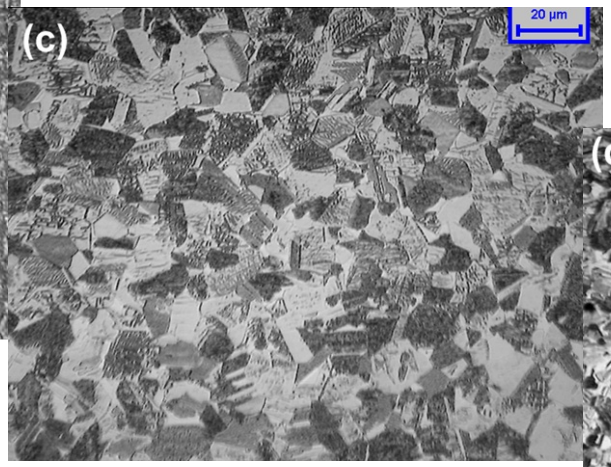
- Vacuum heat treatment

Success Factor

- Material Quality in par with industry standards



As-built by EBM



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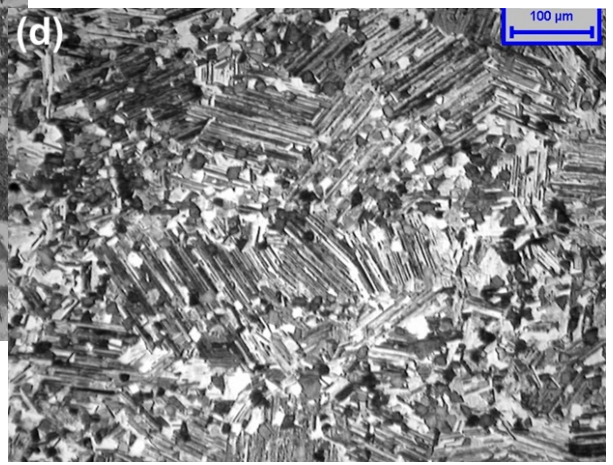

Heat Treatment
Duplex
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EBM® γ-TiAl: microstructures

What does Bodycote do?

World's largest supplier of HIP and heat treating services

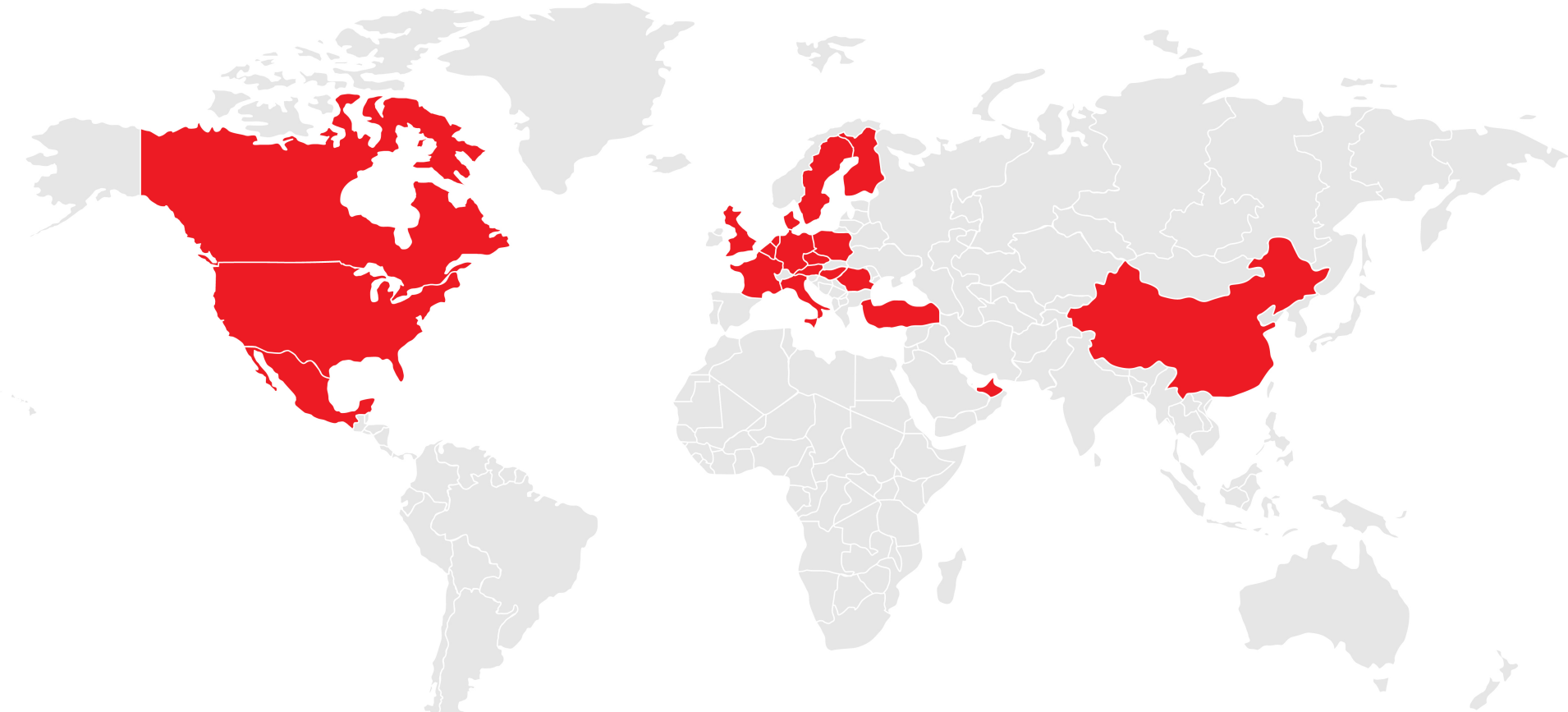
Classical Heat Treatment

Bodycote's Classical Heat Treatments describe a group of mature processes and treatments such as nitriding, carburizing, annealing, tempering and many more. Working to very exacting quality specifications, heat treatment uses precisely controlled furnaces to process a huge variety of metals and alloys, improving their mechanical properties.

Specialist Technologies: HIP Services, HIP Product Fabrication and Surface Treatments

Bodycote's Specialist Technologies refer to a group of processes which require specialist expertise and technologies. In some cases, they are proprietary technologies which have undergone extensive development and offer unique solutions for a variety of critical applications.

A global presence



Bodycote is experienced in all major market sectors and is able to combine the capability and expertise of a network of over 170 worldwide locations to deliver global, or local, services to customers.

Europe

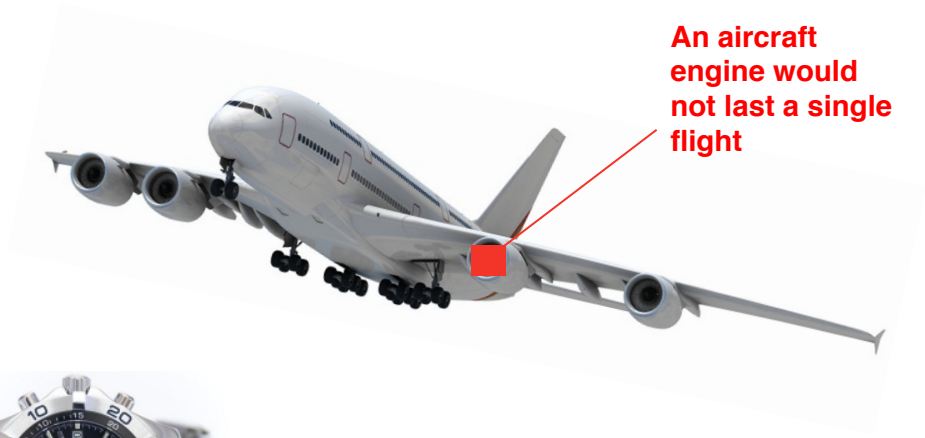

NORWAY
FINLAND
ESTONIA
LATVIA
LITHUANIA
KALININGRAD
BELARUS
North Sea
DENMARK
REP. OF IRELAND
UK
NETHERLANDS
BELGIUM
LUX
GERMANY
POLAND
CZECH REP.
SLOVAKIA
UKRAINE
AUSTRIA
HUNGARY
MOLDOVA
SWITZ.
FRANCE
SLOVENIA
CROATIA
ROMANIA
B & H
SERBIA & M.
ITALY
BULGARIA
Black Sea

Why do we need Bodycote's services?

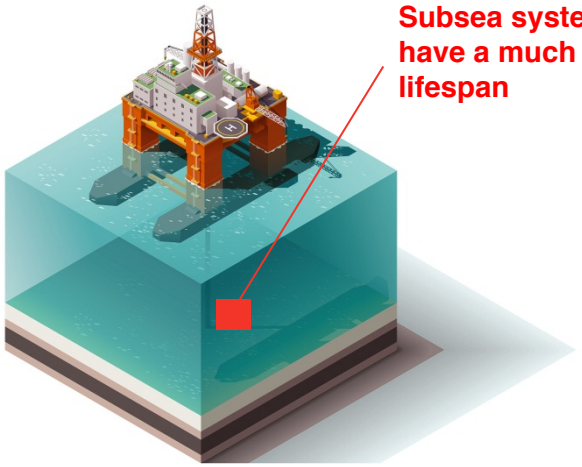
Virtually every type of metal component, whatever its application, has received some form of treatment to enable it to perform to the required standard and last longer once it's put into service.

In a world without Bodycote's vital services….

An automotive gearbox might last only a week



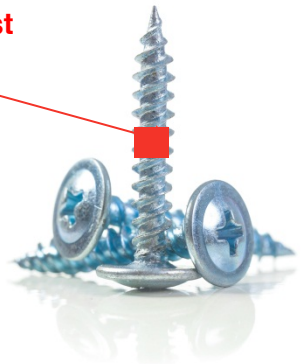
An aircraft engine would not last a single flight



Subsea systems would have a much shorter lifespan

The finish on this watch would quickly become scratched

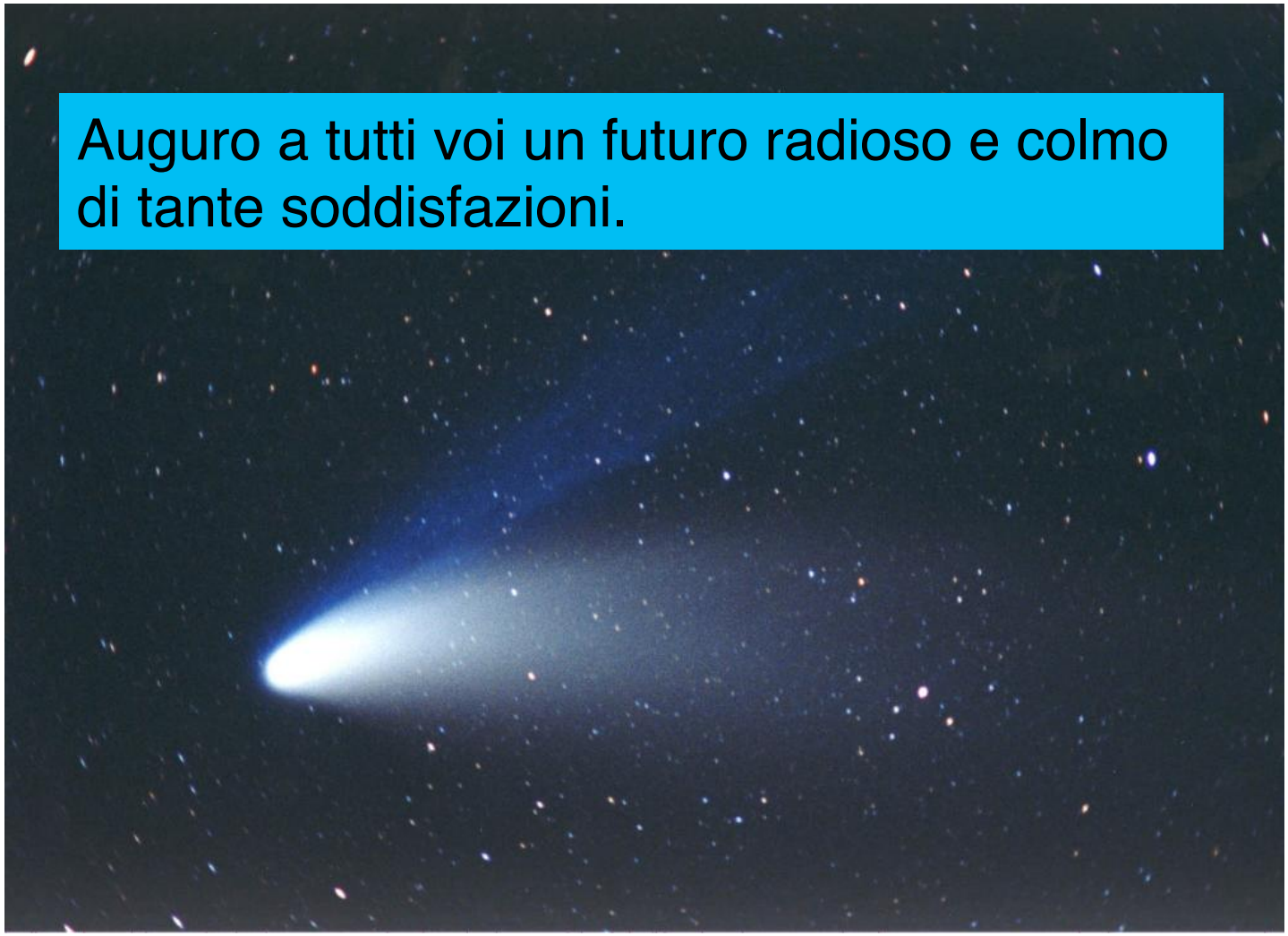
Fasteners would rust more quickly



The vital link

Bodycote is the world's largest and most respected provider of thermal processing services. These services are a vital part of any manufacturing process and include:

- Classical Heat Treatments & Metal Joining
- Specialist Technologies


Auguro a tutti voi un futuro radioso e colmo di tante soddisfazioni.

Q&A