SHIPSHAPE Project:
Net Shape Hot Isostatic Pressing (HIP) of advanced materials and structures

Robin Young

Applied Materials Technology Ltd

SHIPSHAPE PROJECT - SHAPED SHELLS FOR HOT ISOSTATIC PRESSING

£450K Collaborative Funded by InnovateUK: 2 year programme
Technology Inspired Collaborative R&D – Advanced Materials
Sustainability and Materials Security theme

SHIPSHAPE unlocks the commercial potential of the Powder-HIP process by producing a sacrificial metal canister filled with fine metallic powder for consolidation at high pressure and temperature, in a Hot Isostatic Pressure (HIP) vessel, to form a fully dense part.

Powder-HIP provides an effective method of producing complex, high performance metal parts, with little or no material waste, making it particularly attractive for processing high value, scarce materials (such as nickel superalloys and Ti64, hardmetals and Metal Matrix Composites)

APPLIED MATERIALS TECHNOLOGY

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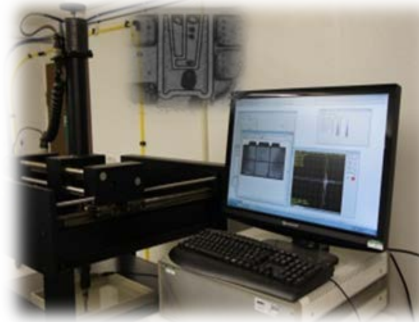
Electroplating

Electrolytic Processes

- Bright Nickel Rack and Barrel
- Suphamate Nickel – Rack only and Barrel
- Woods Nickel strike
- Brush plate Nickel
- Black Nickel
- Cyanide Copper (Cuprax) – for steel
- Bright Acid copper (High Build) – not for steel
- Silver Cyanide (99.99% purity)
- Silver Strike
- Silver Brush
- Bright tin
- Dull tin (acid)
- Dull tin (stanate, alkali)
- Brush tin
- Gold (cyanide) 99.99%
- Brush gold
- Immersion gold * on application
- Ruthenium 99.99% purity
- Black ruthenium
- Indium
- Lead – on application

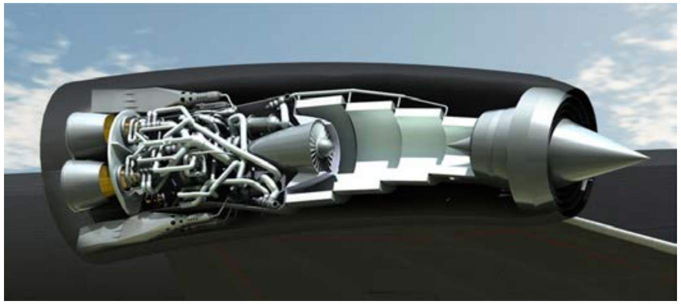
Electrolytics and Electrolytics Cu – Ni – Sn - 49s Gold Silver - Platinum Group - Ruthenium - Blacks – Indium - Lead Solder process for metallic foams - plastics/ composites - transient liquid phase

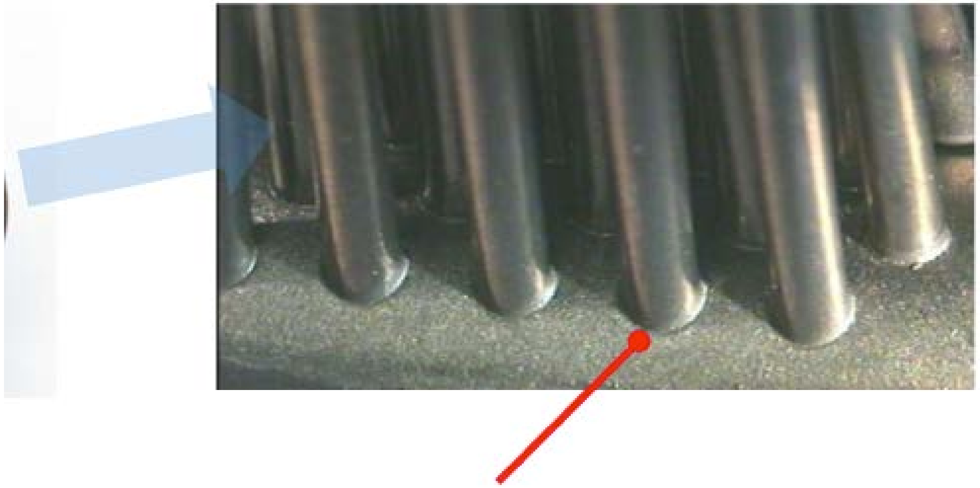
APPLIED
MATERIALS
TECHNOLOGY

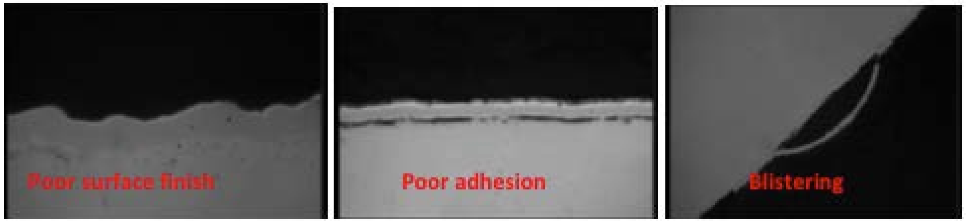


APPLIED MATERIALS TECHNOLOGY

Aerospace Example







Development of a process for well adhered and precision thickness plating to facilitate hermetic liquid phase bonding in heat exchanger

CRYOVAC ENGINEERING LIMITED

APPLIED MATERIALS TECHNOLOGY

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Cryo Pumps

Cryogenic & vacuum engineering specialise in repairs, maintenance for Brooks (C.T.I), Oxford Instruments, Oerlikon Leybold.

Compressors

All compressors will be appraised and a concise report compiled to enable you to make the right commercial decision.

Roots Pump

Whether you're looking for a strip and service or a fully diagnostic analysis, we'll be sure to offer a bespoke and professional service for you.

On Site Service

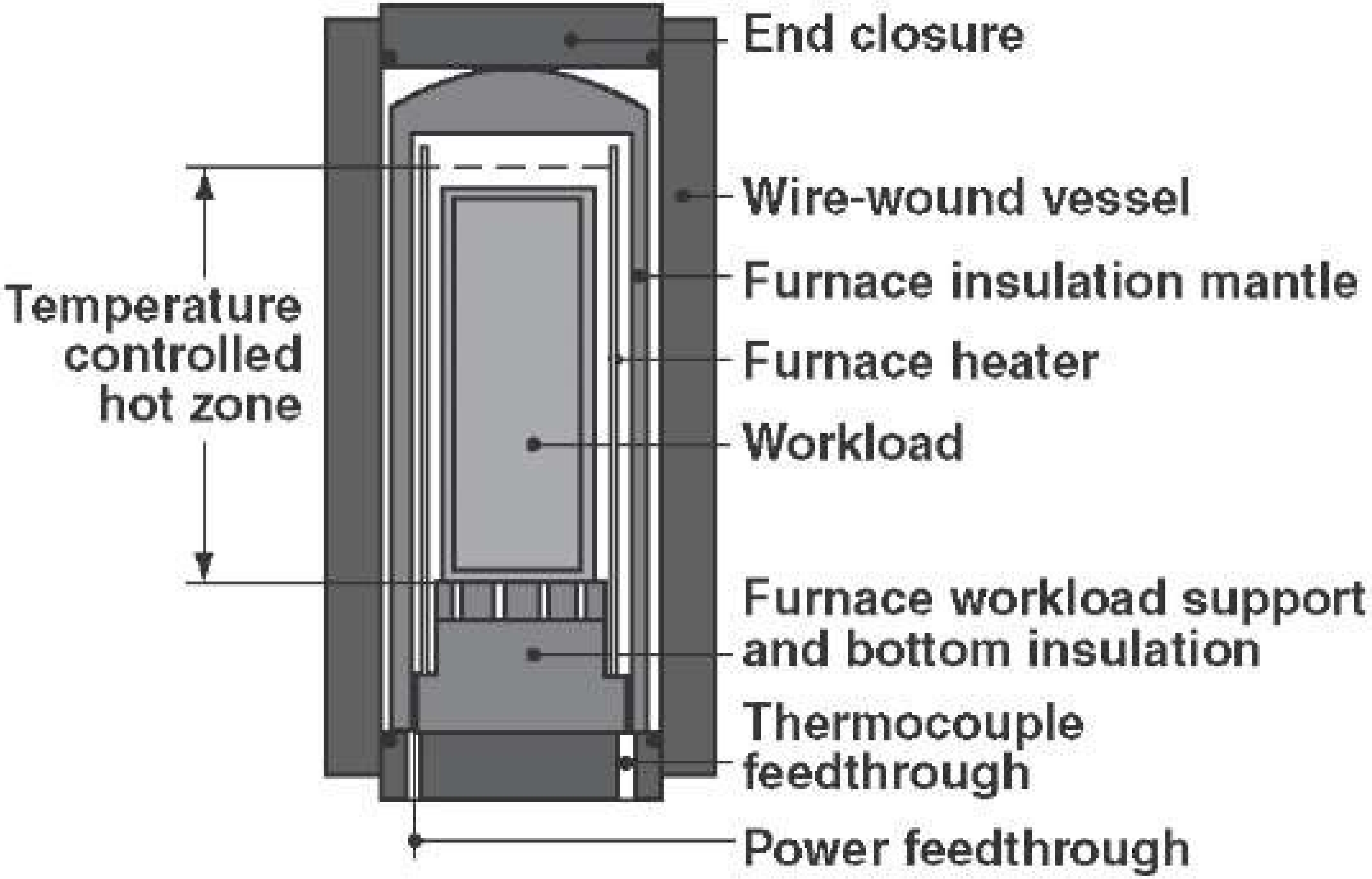
You can be assured that all onsite services are tailor made to suit your needs.

Prototype Electroformed Tools for Composites (PERFORM)

Robin Young, Applied Materials Technology
Lee Marston, FiberStone Products
Rob Hewitt, AIM-Altitude
Tim Swait, AMRC with Boeing

Aerospace Growth Partnership

SHIPSHAPE PROJECT – HOT ISOSTATIC PRESSING



SHIPSHAPE PROJECT - SHAPED SHELLS FOR HOT ISOSTATIC PRESSING

Key characteristics	Fabricated	Forged / machined	Cast	Powder-HIP
Microstructure in 3 dimensions	Poor	Poor	Good	Excellent
Homogeneity	Poor	Poor	Good	Excellent
Absence of segregation	Poor	Good	Medium	Excellent
Strength properties level	Low	Medium	Low	High
Strength in 3 directions	Poor	Poor	Good	Excellent
Material waste	Low	High	Low	Low

A1: Comparison of different manufacturing technologies for high performance metal parts (Source epma)

Trade off with ALM

Cost: Advantages with scale
Performance: Material integrity/uniformity
Design complexity: Similar to investment casting *

SHIPSHAPE PROJECT - SHAPED SHELLS FOR HOT ISOSTATIC PRESSING

Step	Description of process	
1	**Pattern (mandrel) manufacture:** Using techniques developed for the precision investment casting industry (wax or resin patterns) or FDM modelling .	
2	**Electroforming:** Thin metallic canister (typically 0.5-1mm thick) of nickel, copper or iron	
3	**Mandrel removal:** Remove small wax patterns by melting Polymer pattern can be produced using weak alkali solution.	
4	**Powder filling:** Once cleaned and leak tested the canister is filled with metal powder, baked (~200°C to drive off moisture/organic volatiles), evacuated and sealed to maintain the vacuum inside the canister.	
5	**HIP densification:** By exposure to programmed cycles involving slow heating.	
6	**Stripping of canister:** Thin shells can be removed mechanically or etched away.	

A6: Steps in the Powder HIP process

SHIPSHAPE PROJECT - SHAPED SHELLS FOR HOT ISOSTATIC PRESSING

Production method		Cost	Net shape capability
Fabricated		Low	Poor
Machined tooling		High (~£25K for tooling for aeroengine casting)	Moderate
Electroformed shell		Low	High
Subtractive Manufacturing	 	High	Moderate

A3: Current canister manufacturing methods for Powder-HIP

Shell Options

Shell Material	Ease of electroforming	PM material systems compatible	Relative cost
Nickel	Medium – low stress variant available	Ni, Cu, Al, Steels, Co Chrome	6
Copper	Good – high build rate and good throw	Al , Mg, Cu	3
A5: Electroformed shell attributes			


Division of Project

- POWDER SUPPLY: LPW / Total Carbides / Materion
- Mandrel and Electroform Development AMT
- Leak testing: AMT/CVE
- Project management MTC
- HIP processing and assessment: Materion
- Geometry evolution (GOM scanning) MTC
- Cost Modelling MTC

Technical Challenges and Issues

Group 1

- **Hermetic can - thickness – structure – pin holes**
- **Stress in plating - process trade offs**
- **Metallurgical compatibility**

Group 2:

- **Mandrel technology**
- **Stripping mandrel**
- **Stripping can**

Group 3:

- **Process consistency at fill stage**
- **Shape stability through process (can stress, thickness, geometry)**

Further work: Core technologies and shape modelling

CAPACITY LIMITS

Development tanks at AMT now: small 500 * 500 * 1000 mm

Useable: 70% of volume

Large: 1500 * 800 * 800 mm (scalable but critical)

HIP: Not a problem…

Courtesy Quintus Technology)

MANDRELS

Different processes to suit different volumes:

- o Low volume - additive manufacture ideal. Some compatibility issues. FDM used for basic work.

ALM and SLA offer some benefits (more expensive)

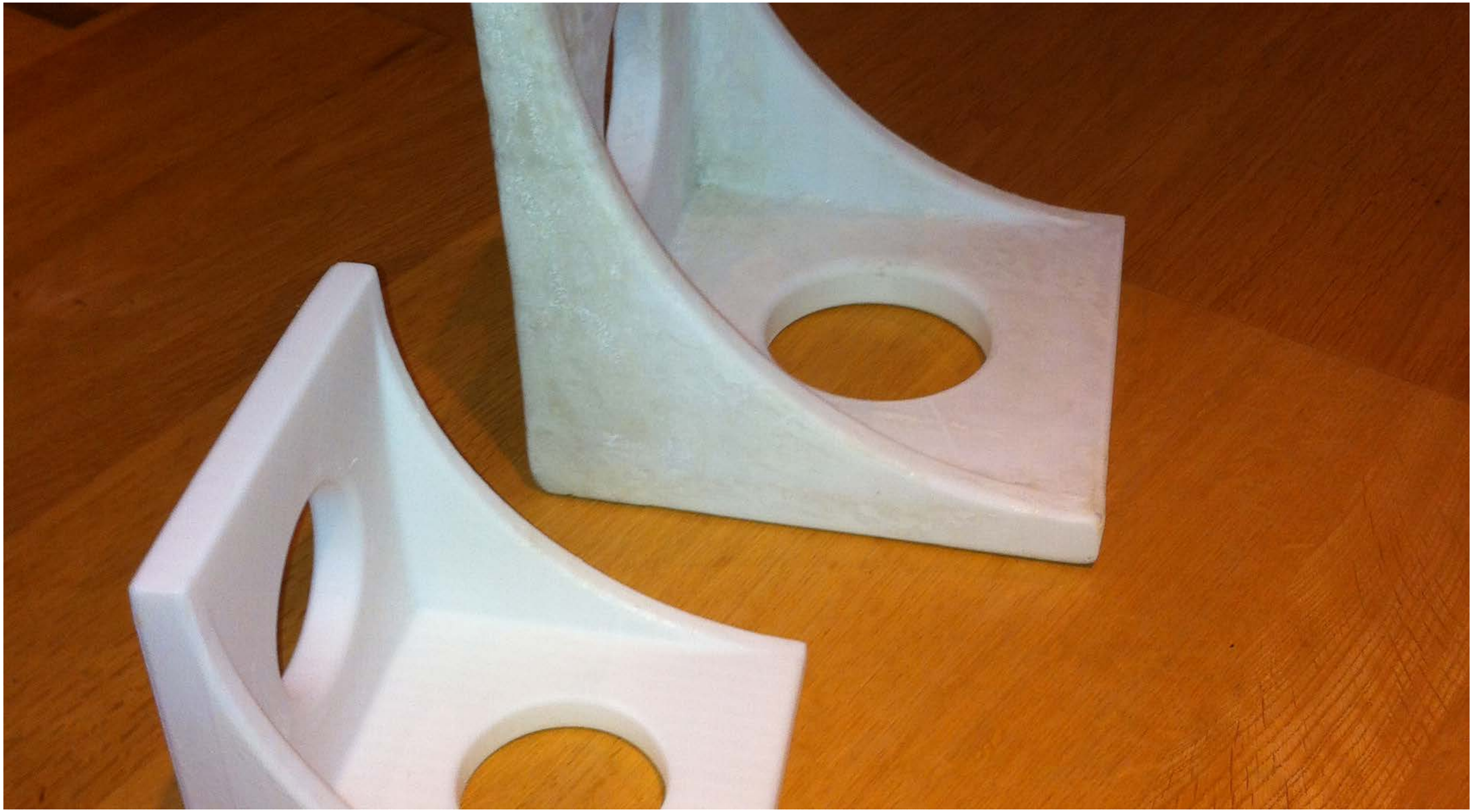
Thermajet printing of waxes; machining of waxes

- o Medium volumes: Wax injection using soft tooling
- o High volumes: Injection moulding with hard tooling

WAXES PREFERRED – Good supply chain for investment casting; strip with autoclave; recyclel disadvantage is thermal expansion and softening at plating temperatures

Examples of shells on wax and plastic

Demonsator brackets



Nickel shells with feed/crimp tubes welded

After HIP Processing

Densified part left and shell (right)

Linear shrinkage in line with expected shrinkage from consolidation of tap density powder

COST MODELLING - in process

- Comparison with fabricated cans
- Trade off with shell thickness leakage rate (technology sensitive
- Not likely to be advantageous for simple geometries
- Large impellers are a natural application area
- Combustors, Ni base alloys, Ti structures

SUMMARY

- Demonstrated with Nickel 713, Stainless Steel, Ti 6-4, Stellite (other alloy systems underway)
- Comparison with fabricated cans - not likely to be advantageous for simple geometries
- Large impellers or blades are a natural application area
- Combustors, Ni base alloys, Ti structures
- R&D focus on improving hermetic performance and demonstration of parts with higher complexity

Thank you!

robin.young@appmat.co.uk

Unit 6-7 Lyndon Business Park

Farrier Rd

Lincoln LN6 3RU