IVS 2019 - Industrial Valve Summit Conference
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DESIGN AND QUALIFICATION OF 3D PRINTED PARTS: NEW CHALLENGES FOR CONTROL VALVES

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Introduction

- **The panorama of industrial valves is rapidly changing, with the transition to solutions able to manage variable operating conditions during extraction, transport and subsequent treatments**
- **Due to high corrosivity, the use of corrosion-resistant alloys is fundamental to grant system reliability and safety**
- **As valves are responsible for 60% of the so-called "Fugitive emissions“, and their production has to meet specific standards foreseen for chemical and petrochemical plants in order to prevent losses of Volatile Organic Compounds (VOC).**

Introduction

- **The design of control valves is rapidly moving to the production of compact and complex geometries, difficult to be produced by traditional processing technologies.**
- **Additive manufacturing is exploiting the market and even higher amounts of parts is now available in automotive and aerospace industries.**

Introduction

- **Qualification of the material, which plays a key role in the accreditation of the production technology itself (performance constraints, microstructural requirements, corrosion…)**

Standards
- Certification
- According to?

Materials qualification
- Mechanical, physical
- Corrosion

Guidelines

Guidance Notes for the Certification of Metallic Parts made by Additive Manufacturing

March 2017

Lloyd's Register

TWI

DNV·GL

CLASS GUIDELINE

DNVGL-CG-0197

Edition November 2017

Additive manufacturing – qualification and certification process for materials and components

Guidelines

Position in the value chain	Typical activity	Feasibility Study	Technology Qualification	Technology Assessment	Manufacturing Procedure Qualification	Approval of Manufacturer	Type Approval	Material/ Product certification
Designer	Design of products for end-use or functionality	•	•	•			•	
Manufacturer	Raw material producer (powder/wire etc.)	•		•	•	•		•
	Print 3D products using own printing facility	•		•	•	•		•
	Manufacturing support such as HT etc.	•		•	•	•		•
	Product manufacturer	•		•	•	•	•	•

Magazines…2018…

With additive manufacturing in oil and gas, the future starts now

May 21, 2018

By John Bolto, Specialist Advisor, Advisian, A WorleyParsons Group company

How should Oil and Gas Industry get into additive manufacturing?

News from the 3D printing industry | 5 April 2018

Nowadays


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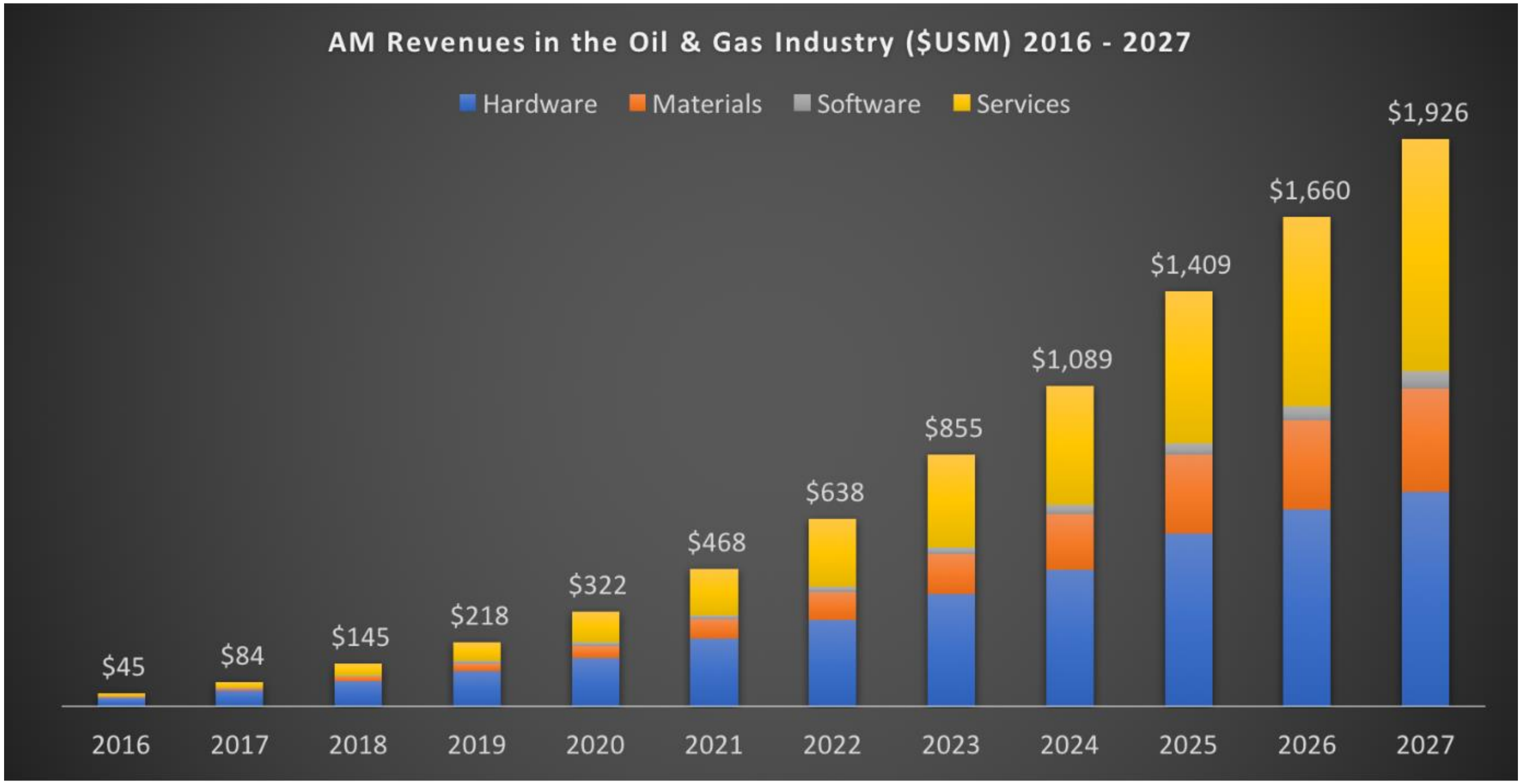
3D Printing in the Oil and Gas Industry
Just as additive manufacturing (AM) is increasingly utilized in the healthcare and aerospace industries, so too is it gaining acceptance in the oil and gas industry. A SmarTech report projects that AM oil and gas revenue will reach $450 million by 2021. Furthermore, analysts predict that such revenue in oil and gas will triple over the next few years, surging to $1.5 billion by 2025.

Nowadays



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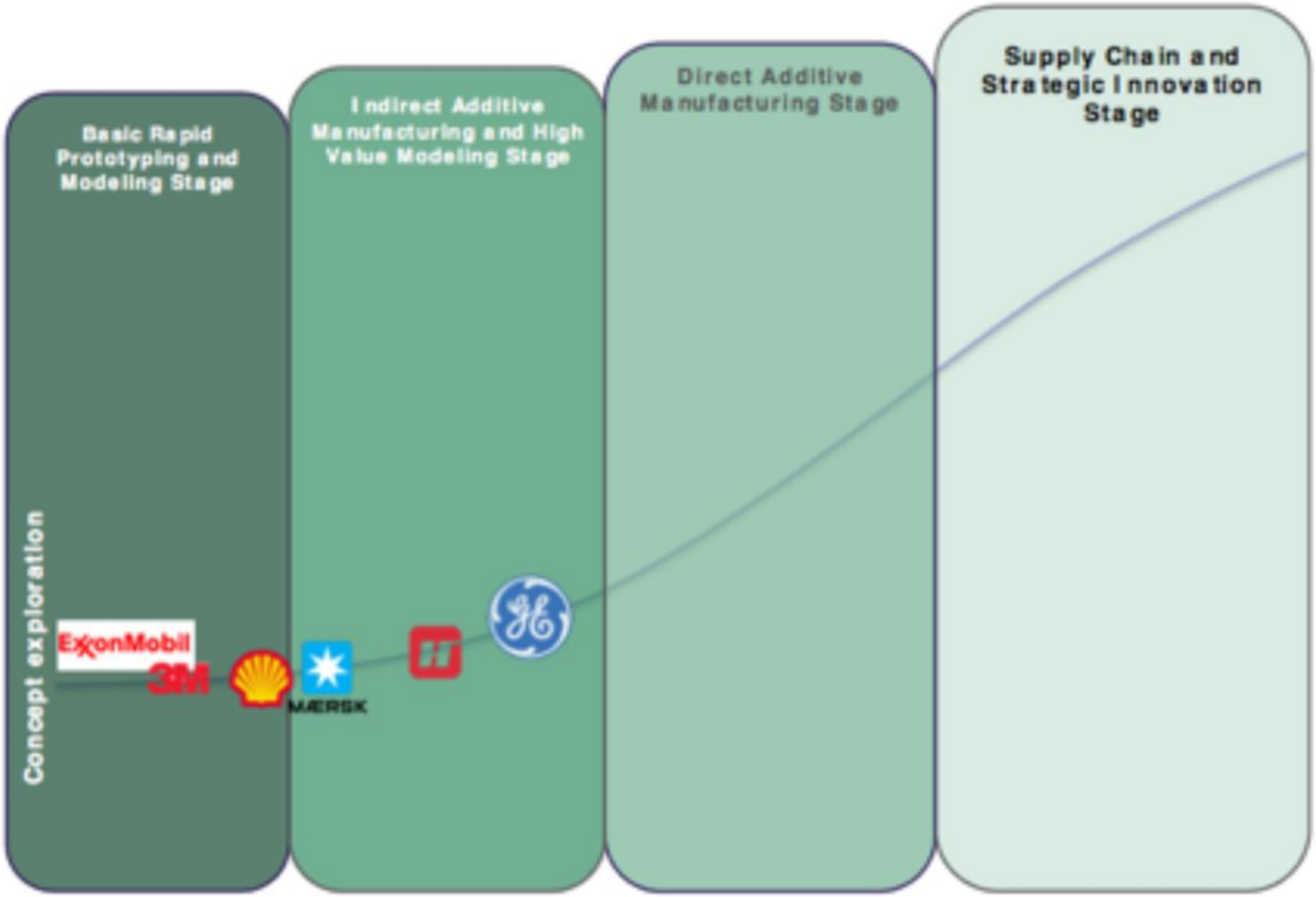

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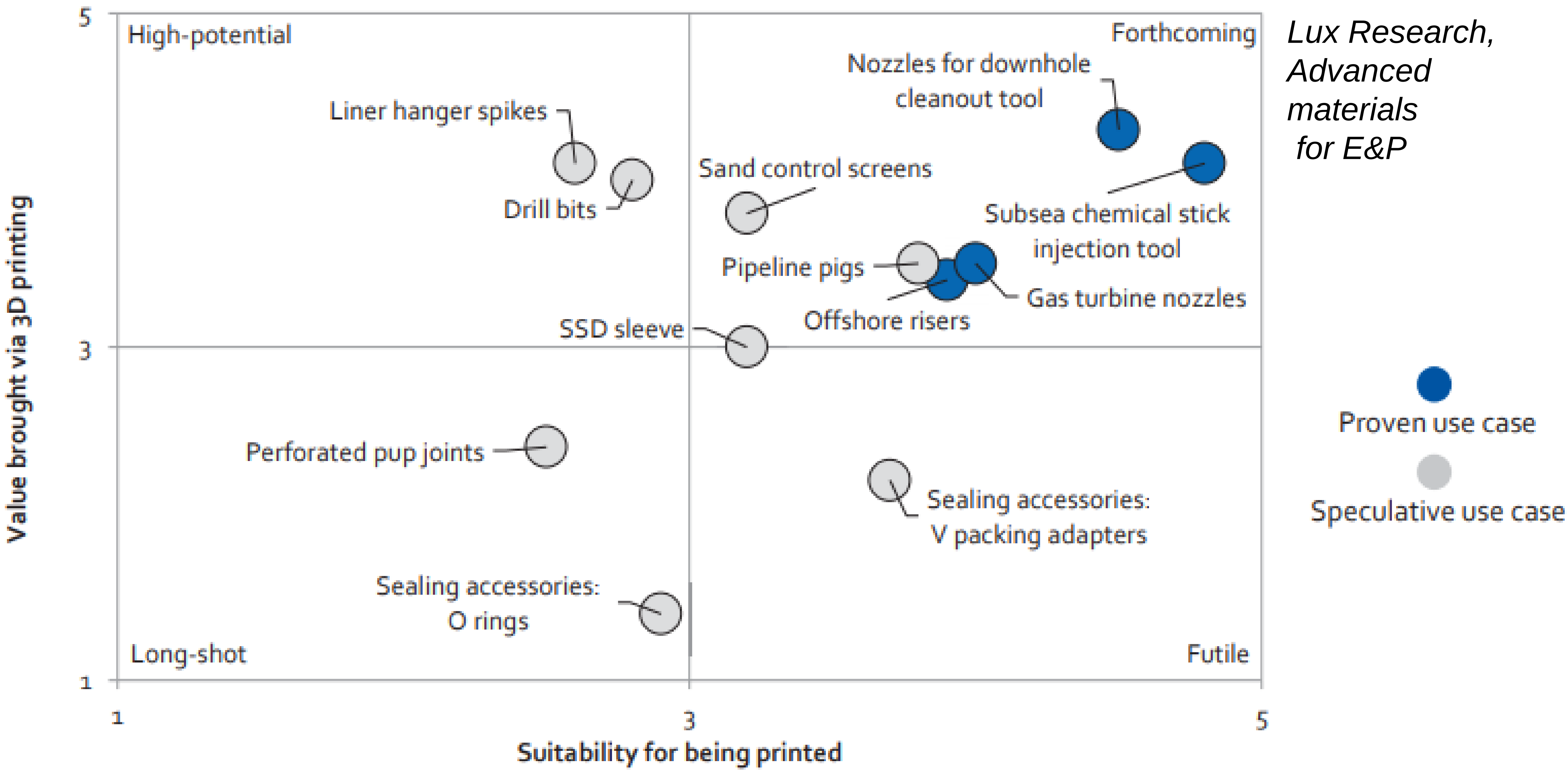
Nowadays



Lux Research, Advanced materials for E&P

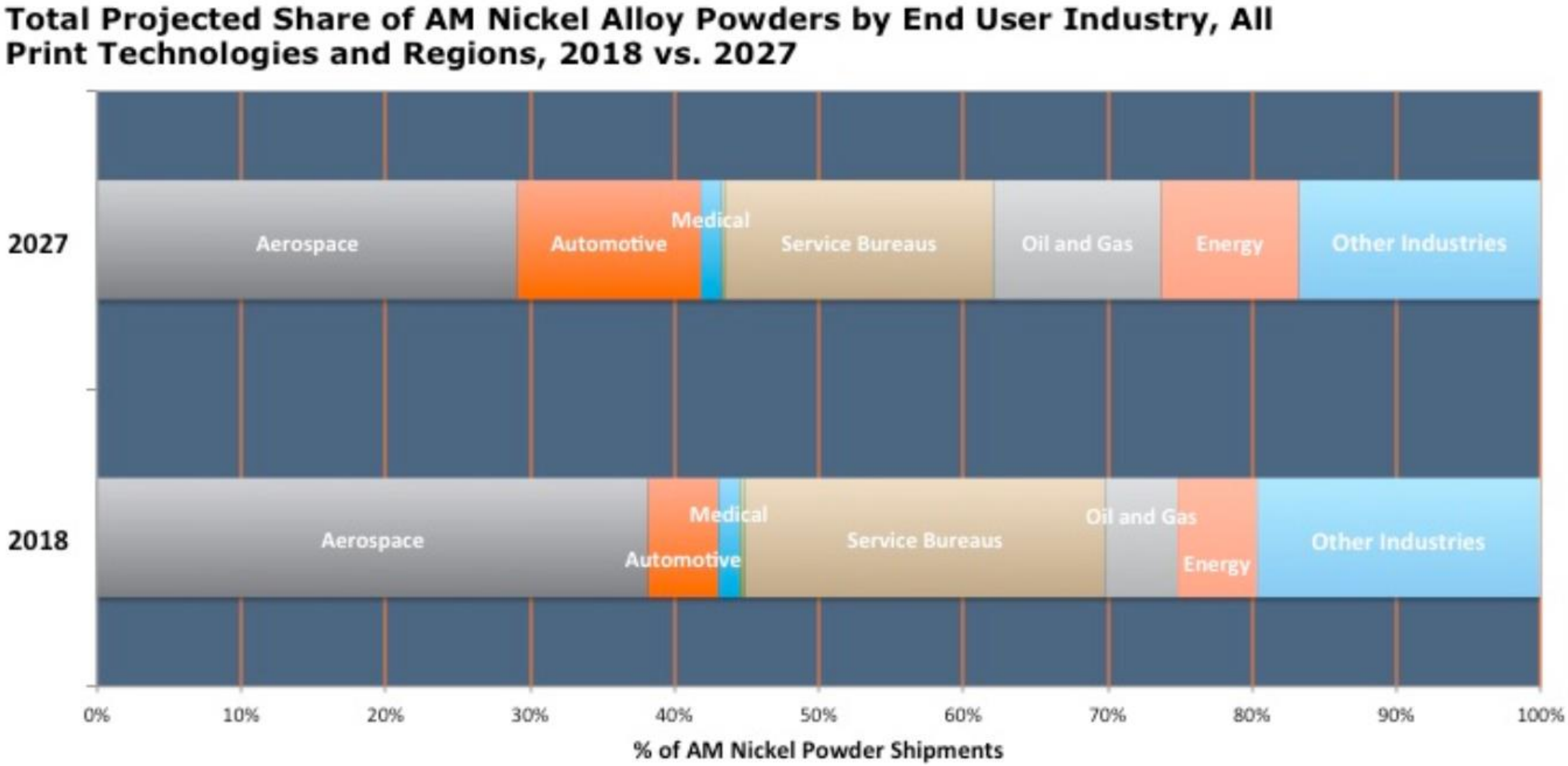
Aims

- **Study of the mechanical and corrosion behaviour of 3D printed nickel alloy (Alloy 625) produced by laser powder bed fusion (SLM – Selective Laser Melting).**

- **Define role of microstructure and post processing heat treatments in order to achieve both mechanical and corrosion resistances, suitable for Oil&Gas applications**

- **Evaluate the corrosion and stress corrosion cracking behaviors of 3D alloy compared to hot worked alloy**

Why Ni-Alloys?



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Project activities

- **Functional prototype manufacturing**
- **Microstructure analysis (porosity, intermetallics and second phases) of material produced by different building strategy and heat treatments**
- **Mechanical and thermo-physical behaviours**
- **General and localized corrosion behaviours compared to forgings**
- **Fracture toughness and stress corrosion cracking evaluation**

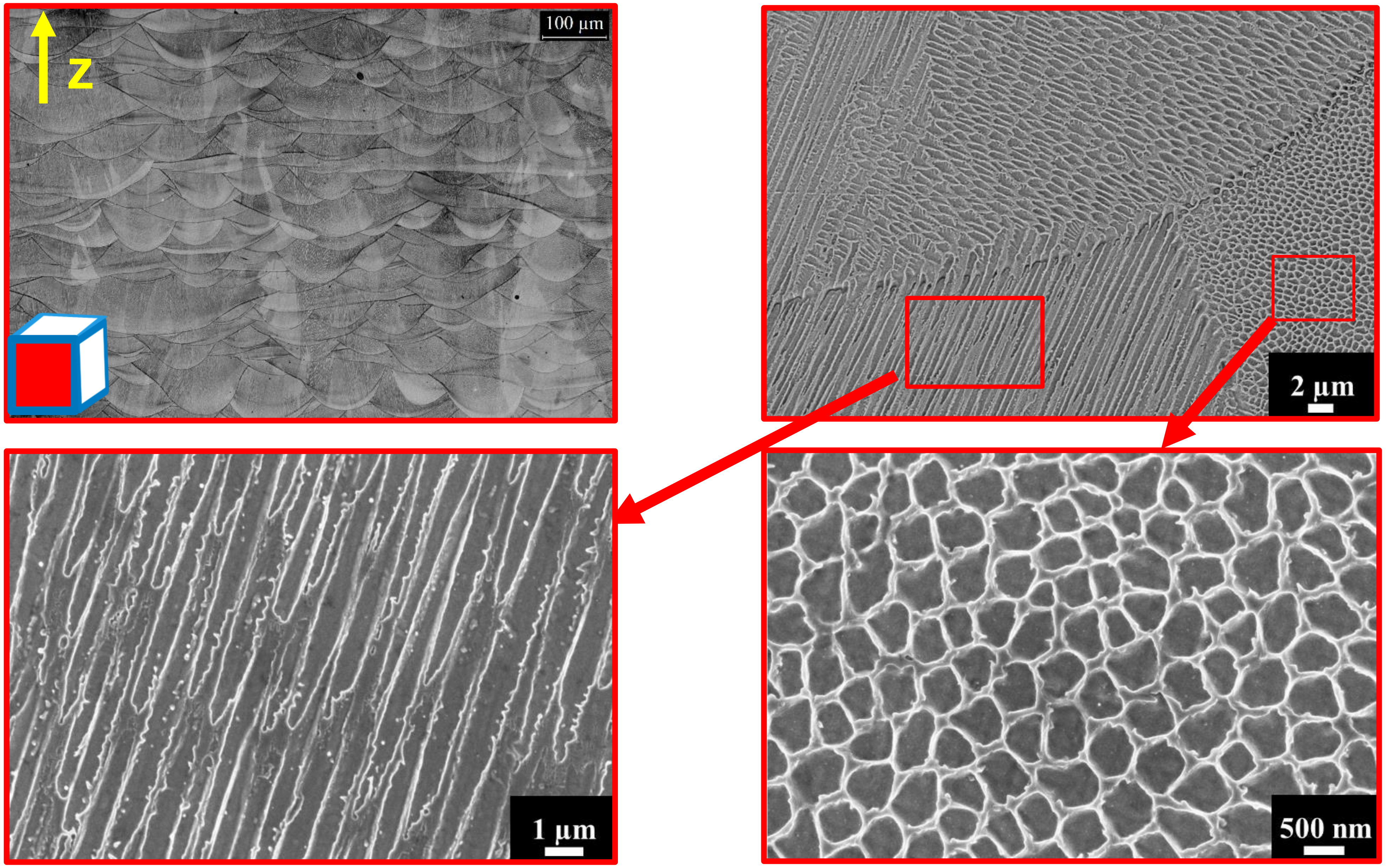
Prototype

	C	Si	Mn	P	S	Cr	Mo	Ni	Nb	Ti	Al	Co	Ta	Fe	Nb+Ta	Cu
Hot worked	0.036	0.25	0.19	0.007		21.6	8.26	61.92	3.660	0.243	0.199			3.11	3.67	-
Powder (AM)	≤0.1	≤0.50	≤0.50	≤0.015	≤0.015	20-23	8-10	≥58	3.15-4.15	≤0.4	≤0.4	≤1	≤0.05	≤5	-	-
Composition of Alloy 625 2.4856 / NiCr22Mo9Nb EN 10095	0.03-0.10	≤0.50	≤0.50	≤0.020	≤0.015	20.00-23.00	8.00-10.00	≥58.00	-	≤0.60	≤0.40	≤1.00		≤5.00	3.15-4.15	≤0.50
UNS N06625 NACE MR 0175 ISO15156-3:2009+Cir.1:2011	≤0.1	≤0.50	≤0.50	≤0.015	≤0.015	20.0-23.0	8.0-10.0	resto	3.15-4.15	≤0.4	≤0.40	-	-	≤5	-	-
ASME SB 564	≤0.10	≤0.50	≤0.50	≤0.015	≤0.015	20.0-23.0	8.0-10.0	≥58.0		≤0.40	≤0.40	≤1.0	-	≤5.0	3.15-4.15	-

Prototype

Material	Area Fraction Porosity (%)
Alloy 625: Block 1	0.16
Alloy 625: Block 2	0.12

Microstructure analisys – As built Alloy 625



Heat treatments

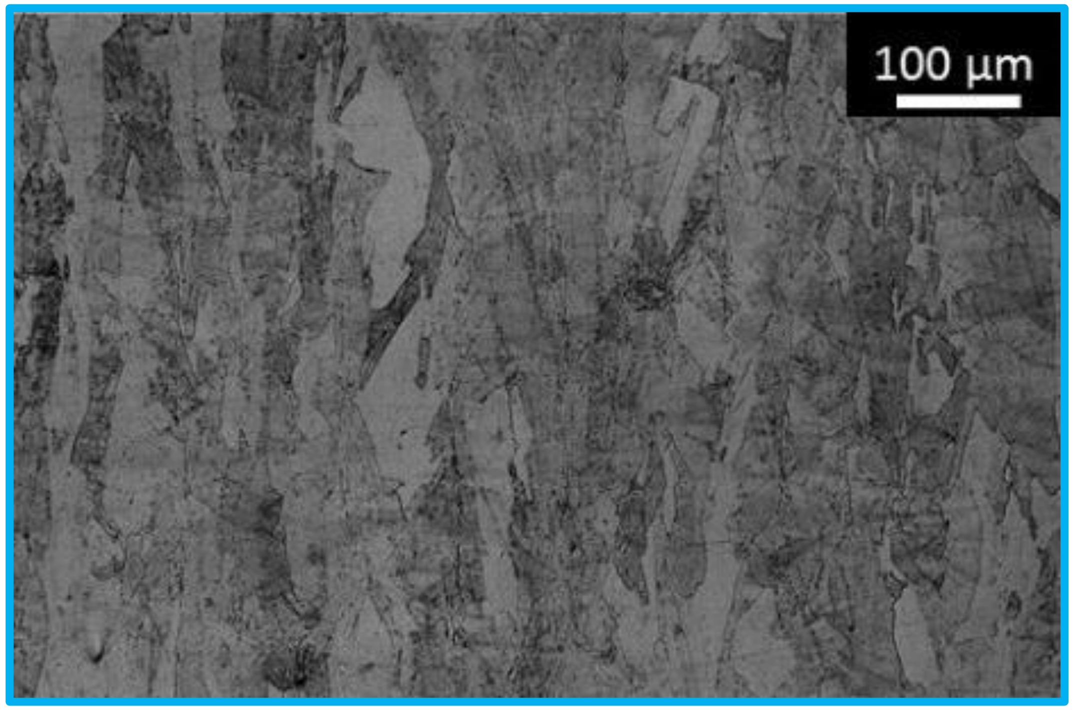
B 443 – 00 (2005)

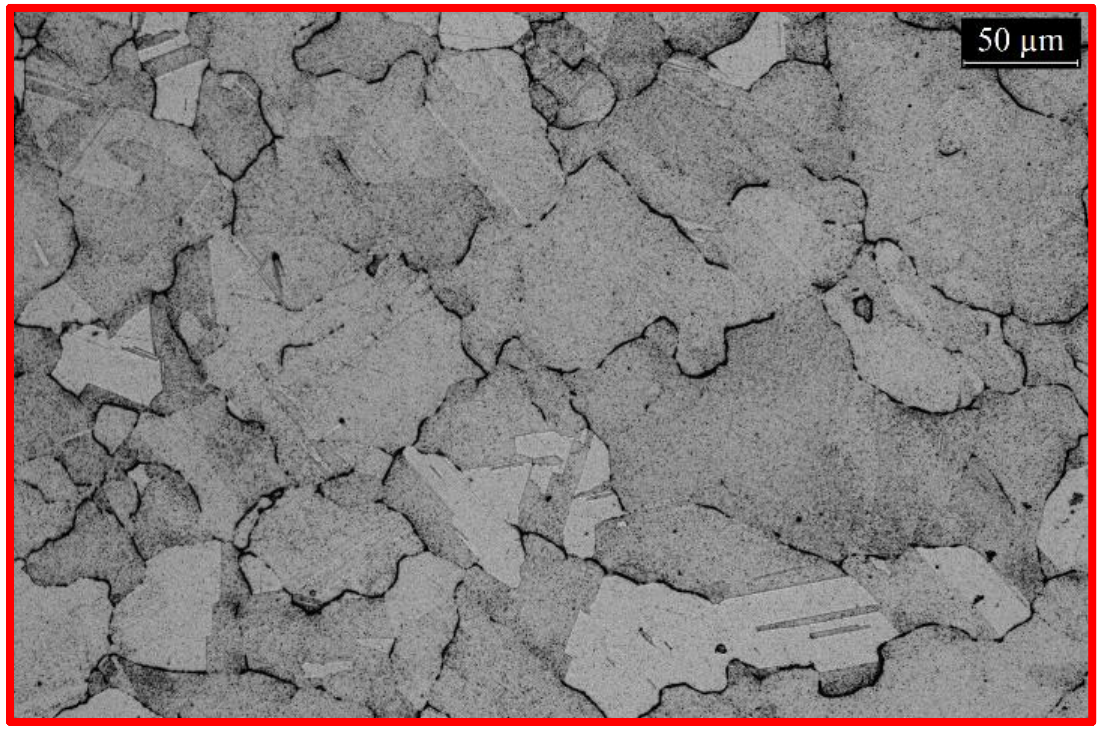
TABLE 3 Room Temperature Tensile Properties and Heat Treatment
(All Thicknesses and Sizes Unless Otherwise Indicated)

Product	Tensile Strength, min, ksi (MPa)	Yield Strength[A] (0.2 % Offset), min, ksi (MPa)	Elongation in 2 in. or 50 mm (or 4*D*), min, %[B]
Grade 1 UNS N06625 (Annealed)[C]			
Cold-rolled sheet and strip	120 (827)	60 (414)	30
Hot-rolled sheet and hot-rolled plate up to 2.75 in. (70 mm), incl	110 (758)	55 (379)	30
Cold-rolled plate up to 0.375 in. (9.5 mm), incl	110 (758)	55 (379)	30
Grade 2 UNS N06625 (Solution Annealed)[D]			
Cold-rolled sheet and strip, hot-rolled sheet, cold-rolled plate, and hot-rolled plate	100 (690)	40 (276)	30
All UNS N06219 (Solution Annealed)			
All plate, sheet, and strip	96 (660)	39 (270)	50

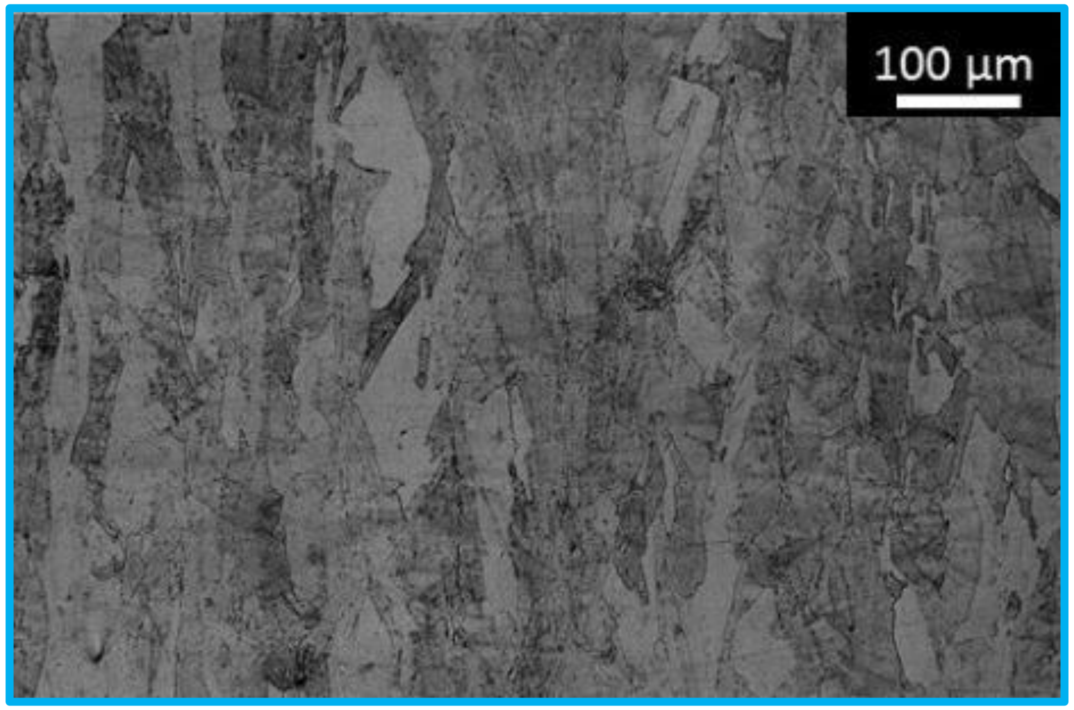
[A] Yield strength requirements do not apply to material under 0.020 in. (0.508 mm) in thickness.
[B] Elongation requirements do not apply to material under 0.010 in. (0.254 mm) in thickness.
[C] Annealed at 1600°F (871°C) minimum.
[D] Solution annealed at 2000°F (1093°C) minimum, with or without subsequent stabilization anneal at 1800°F (982°C) minimum to increase resistance to sensitization.

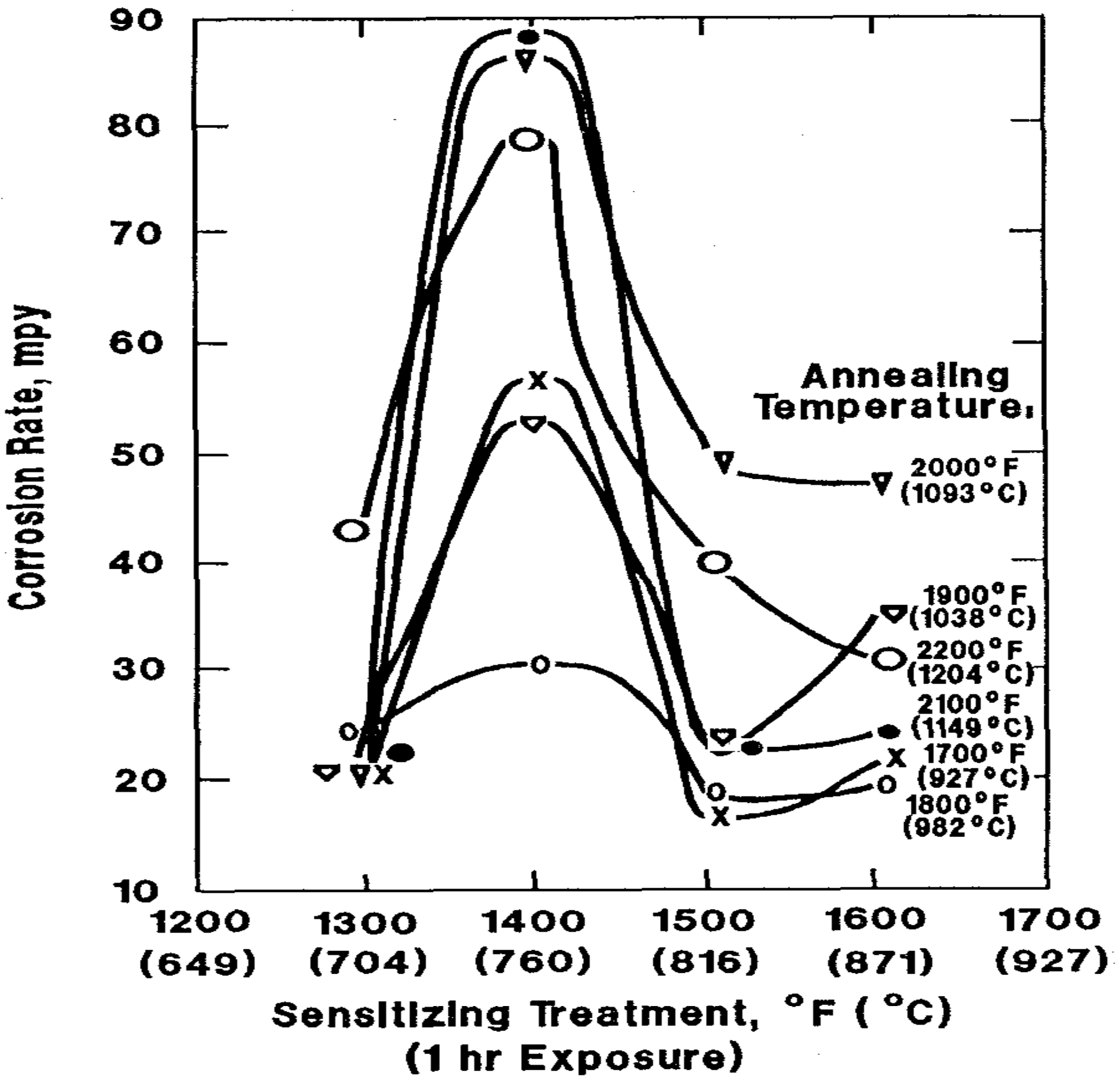
Microstructure analisys – Heat treatments



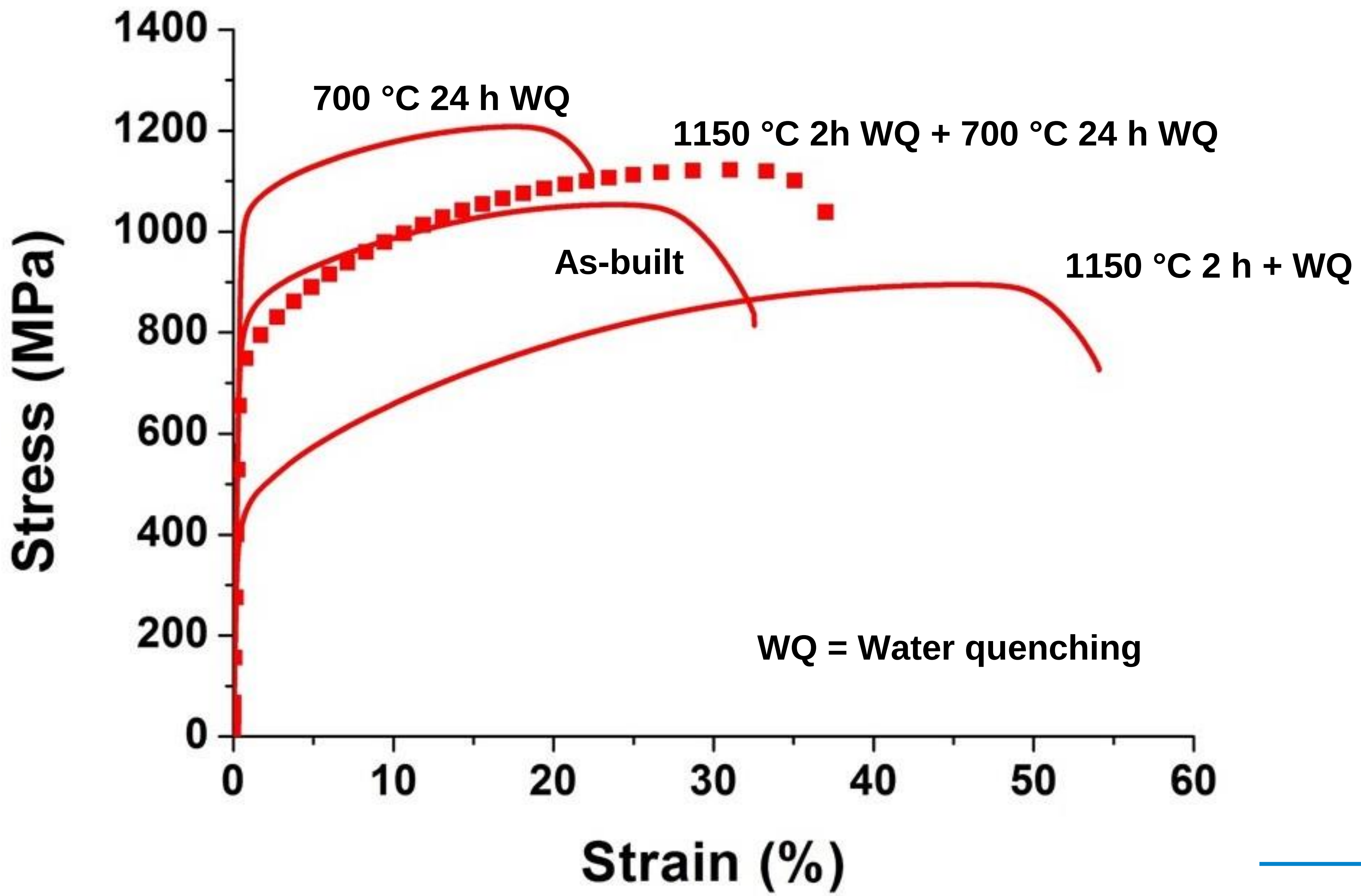


Microstructure analisys – Heat treatments

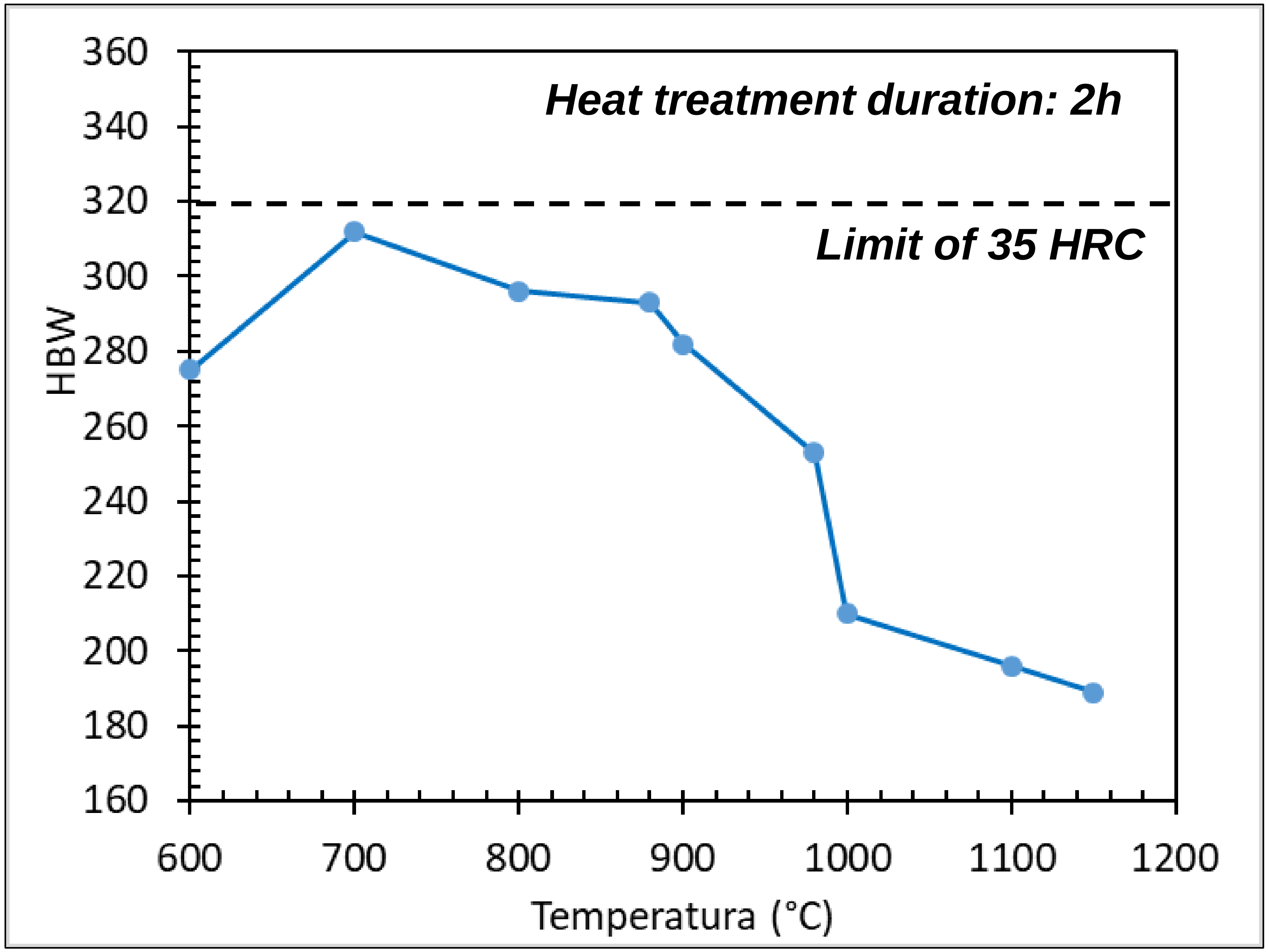




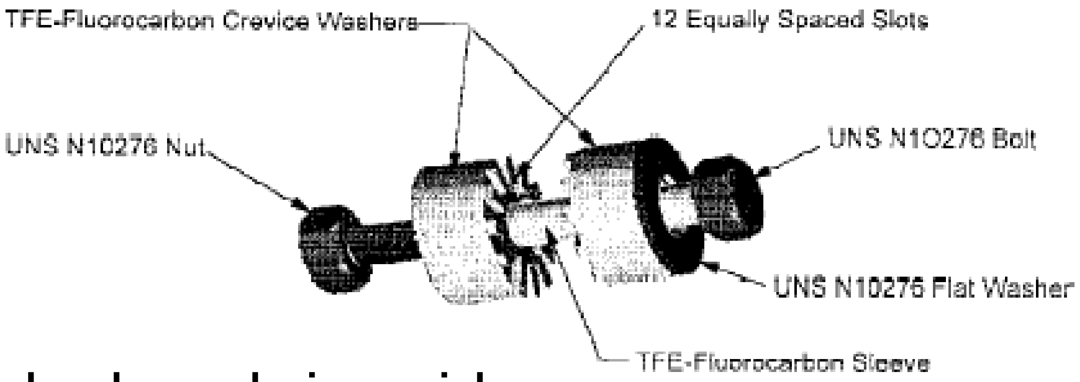
Tensile tests



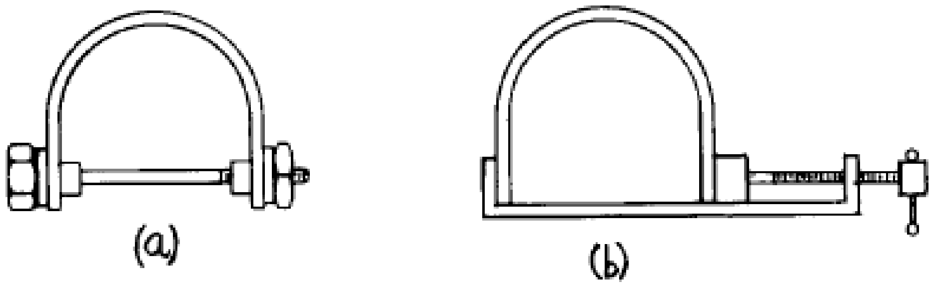
Hardness tests



Corrosion tests



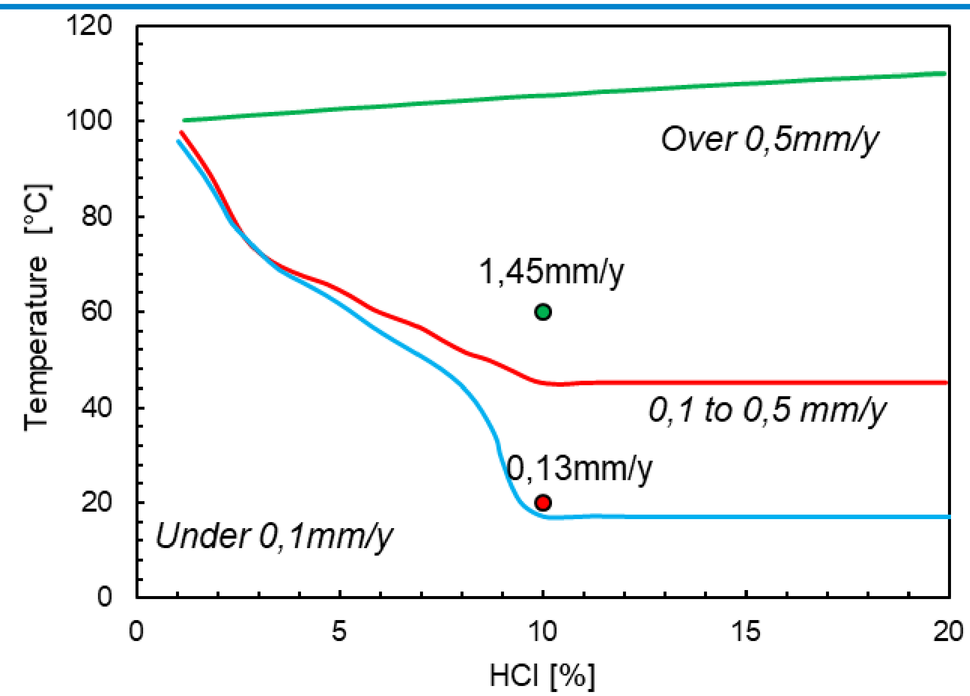
- **Weight loss**
  - ASTM G31: Hydrochloric acid, sulphuric acid, phosphric acid up to 20% at 20,40 e 60 °C
- **Pitting potential**
  - ASTM G5: 40°C in 35 g/l deaerated NaCl solution
- **Critical crevice temperature**
  - ASTM G48: seawater, initial temperature: 30°C
- **Crevice**
- ASTM G78
- **Intergranular corrosion**
  - ASTM G28: Boiling sulphuric acid and ferric sulphate for 120 h
- **SCC**
  - ASTM G30-36: Boiling magnesium chloride solution (45%) (155 °C)

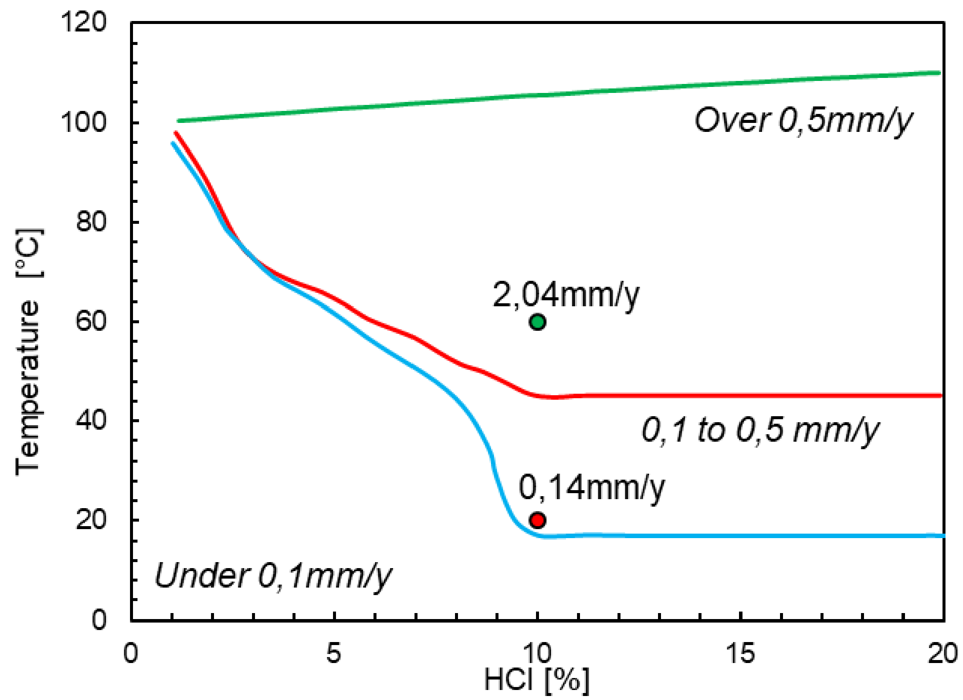


General corrosion

Corrosion rates in HCl (Haynes Int.)

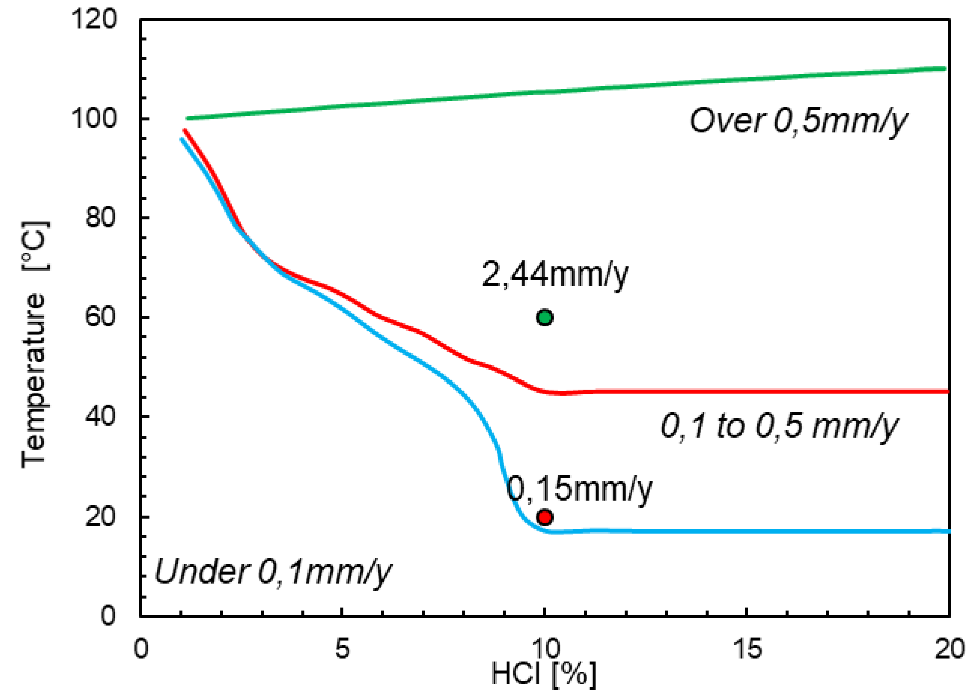
LPBF – As-built



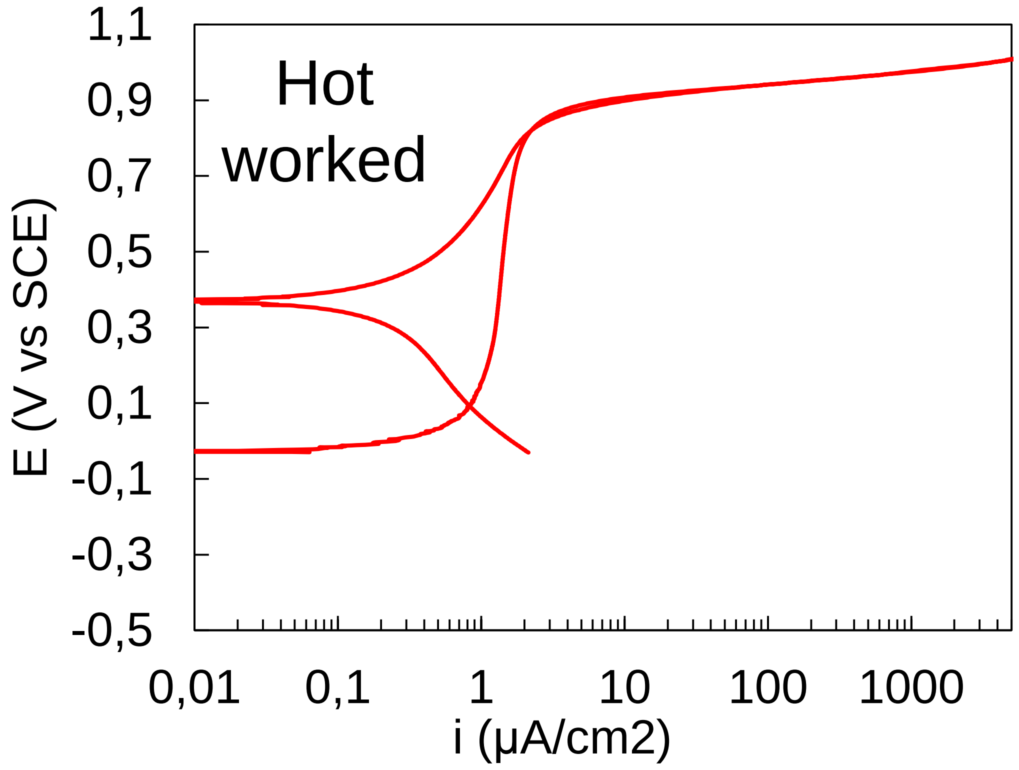


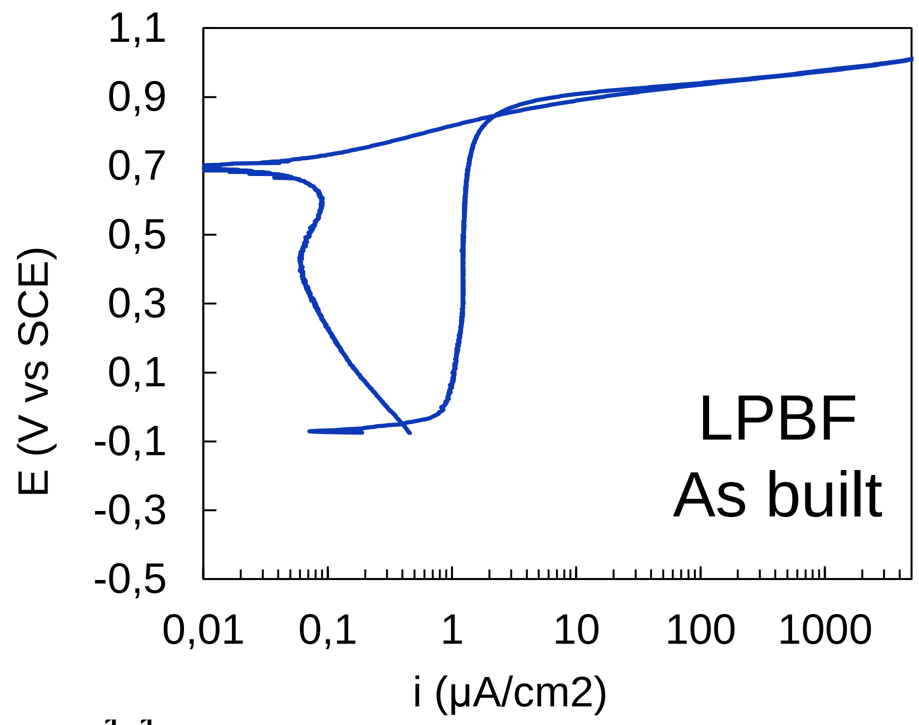
LPBF – HT

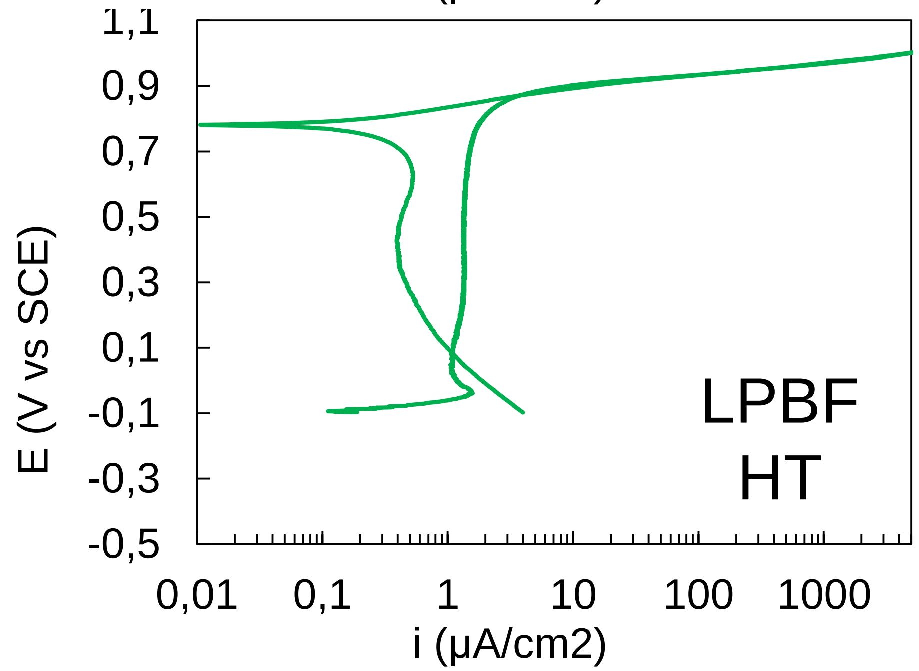
Hot worked



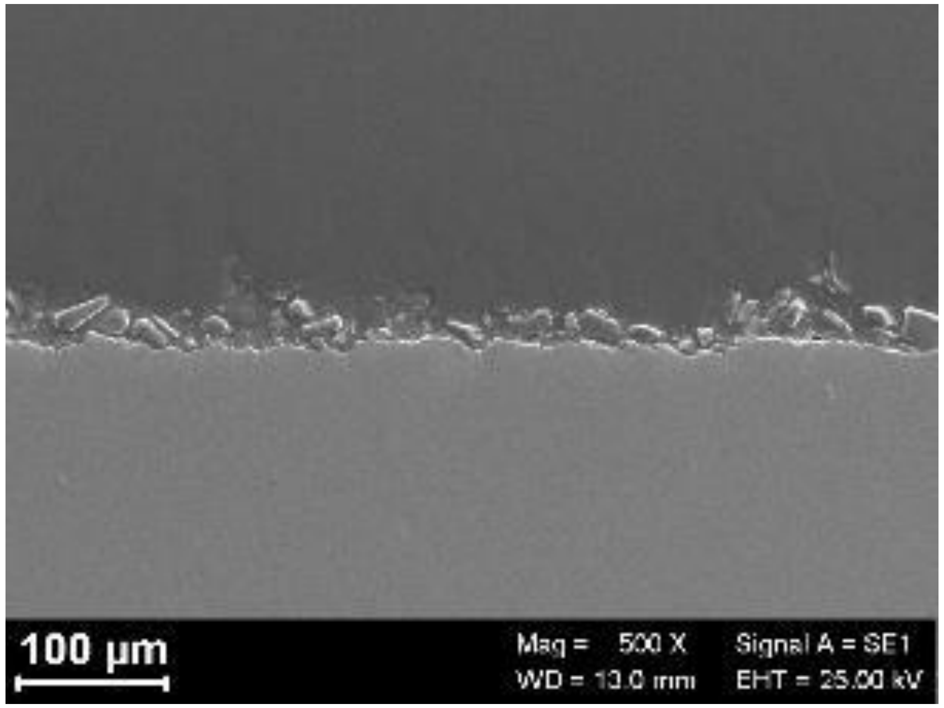
Localised corrosion – ASTM G5 (1N H_2SO_4)

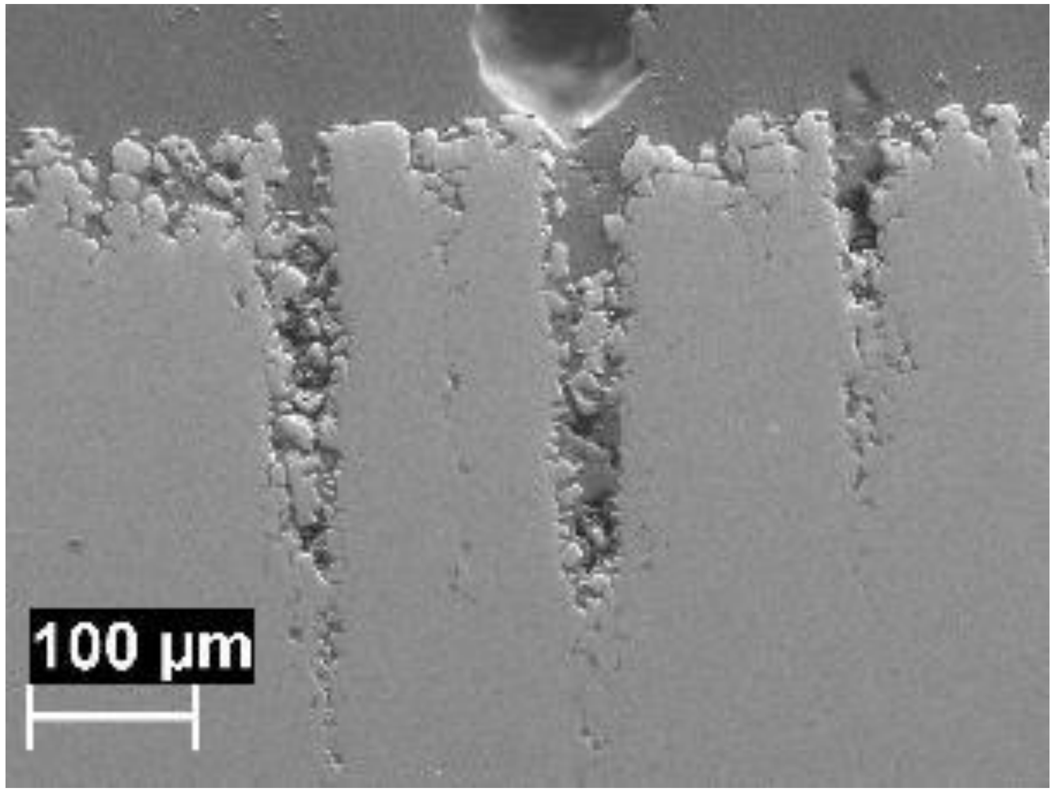




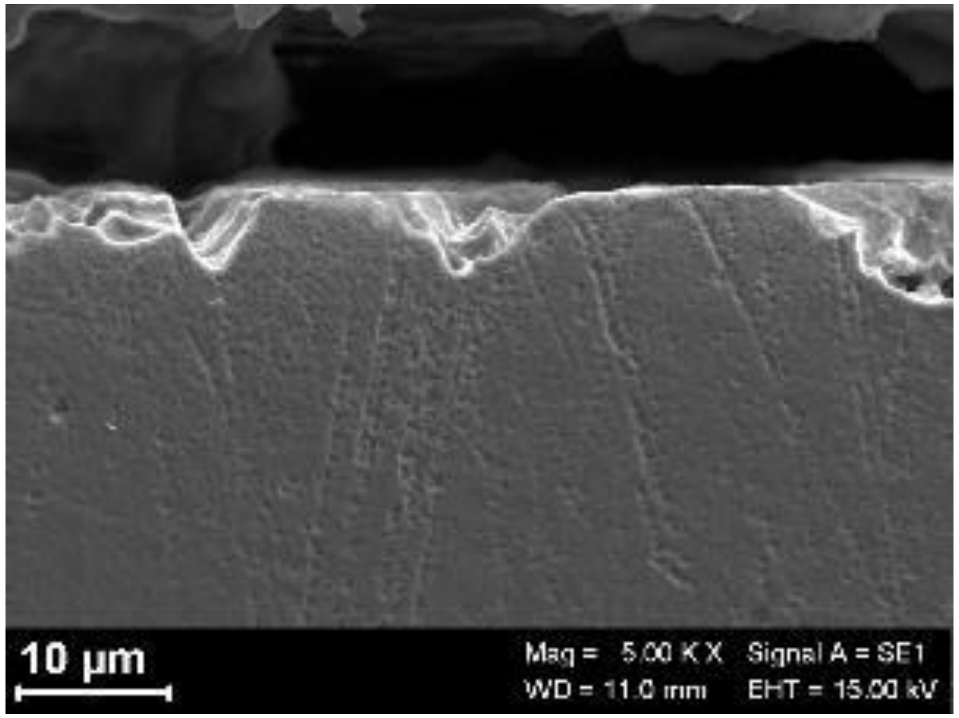


Intergranular corrosion – ASTM G28

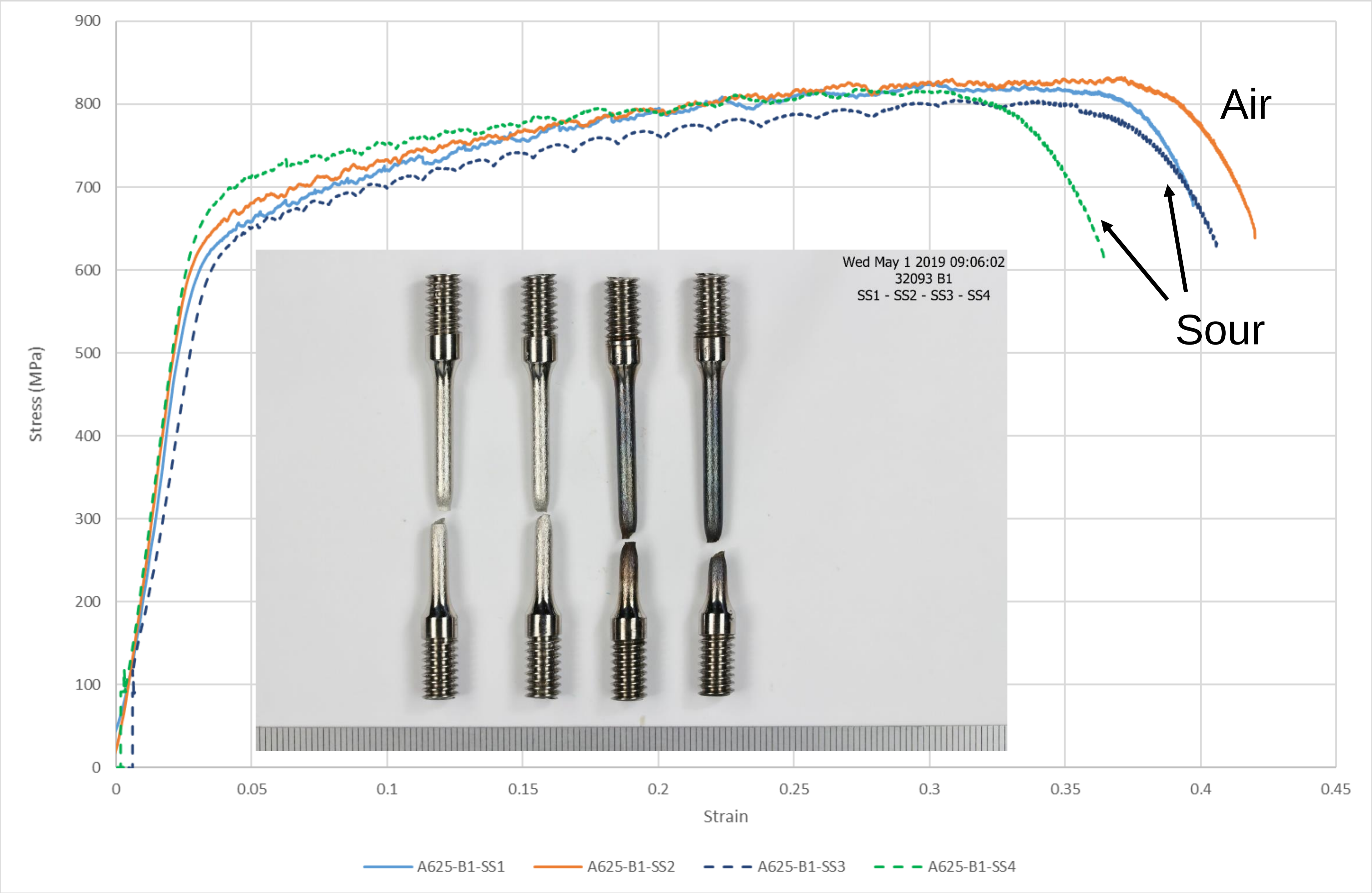




HOT WORKED



Sour tests – As built alloy *(ISO 15156-3:2015)*



Concluding remarks

The results show:

- **the mechanical and corrosion behaviour of 3D printed alloy 625 produced by laser powder bed fusion.**
- **the role of microstructure optimisation during the manufacturing process and post heat treatments to achieve both mechanical and corrosion resistance suitable for Oil&Gas.**
- **the corrosion and stress corrosion cracking behavior of AD alloy according to the main standards, compared with hot worked alloy.**

Concluding remarks

- **The correlation between unique microstructure of 3D printed alloys and corrosion morphologies is addressed.**
- **The performances comparison between 3D printed and traditional alloys evidences the need of accurate material qualification procedures to grant both performances and safety.**

Thank you!

Do you have questions?

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