Additive manufacturing of composites

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- 3D print with fibre reinforced polymer
- 3D printed spare parts and repair on demand

Agenda

- Introduction
- 3D printing of composite parts
- Maritime composite 3D-printing
- Maritime Repairs/Maintenance
  - Possibilities
  - Obstacles
- Conclusion

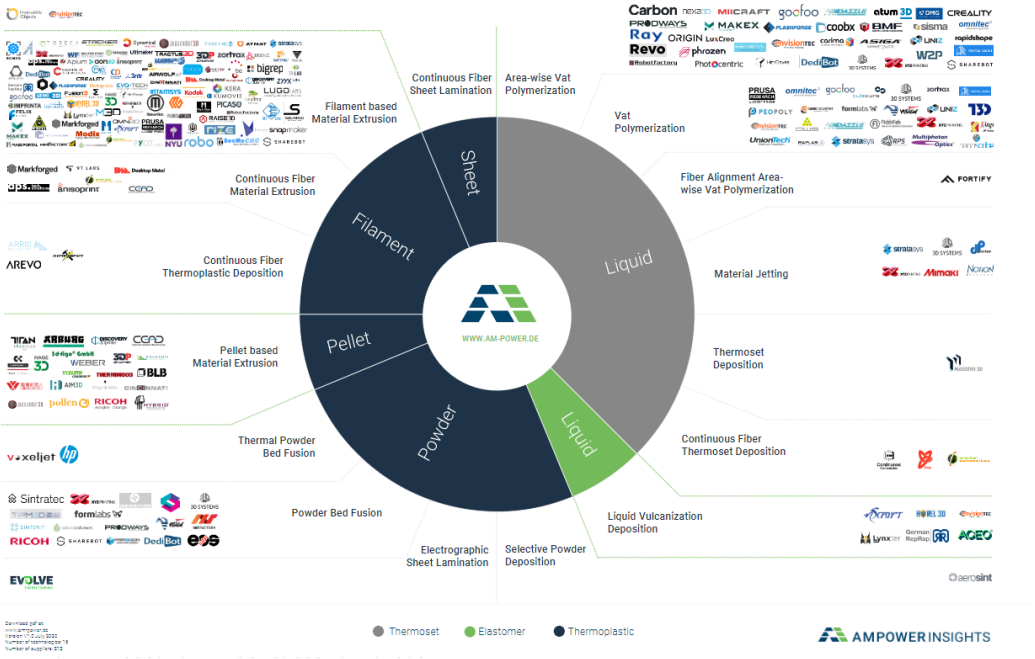
3D-printing composite parts – Why?

3D printing of composite parts

- Composite 3D-printing is new technology
- Highly specialized area
- Great potential

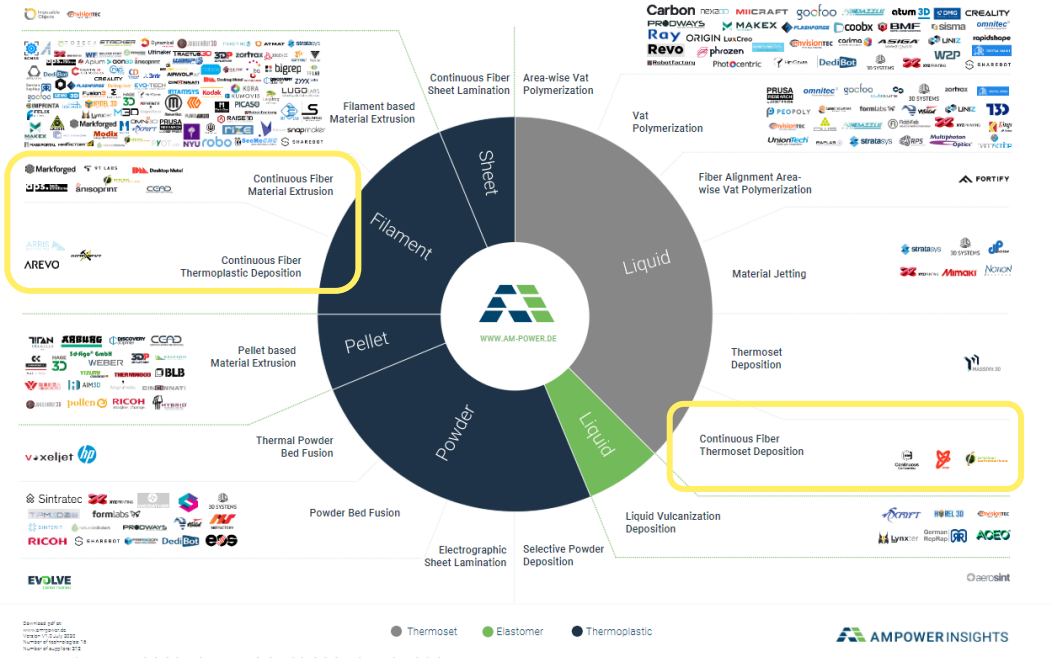
3D printing of composite parts

Polymer Additive Manufacturing technology landscape



3D printing of composite parts

Polymer Additive Manufacturing technology landscape



Origin 1 : Pure polymer 3D printers

Origin 2 : Industrially mature automation technologies such as AFP/ATL

Photo : Mtorres, AFP

Photo : Mtorres, ATL

Composite 3D-printers, desktop models

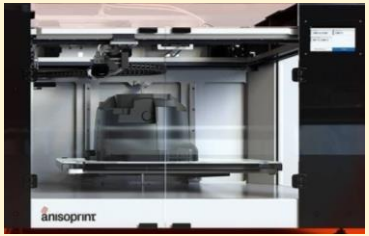


Photo : Anisoprint

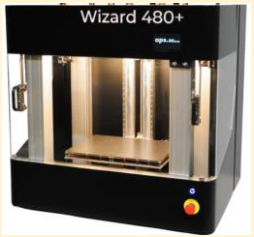


Photo : APS tech

Photo : Desktop metal

Photo : markforged

Composite 3D-printers, Non-desktop models

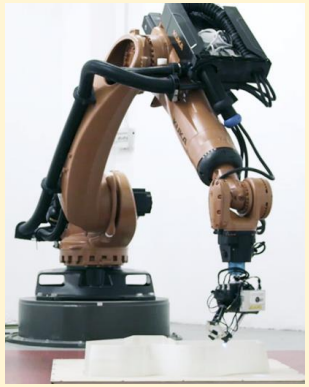


Photo : Moi composites

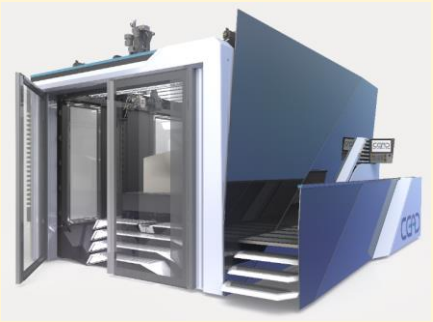


Photo : CEAD

Photo : Aervo

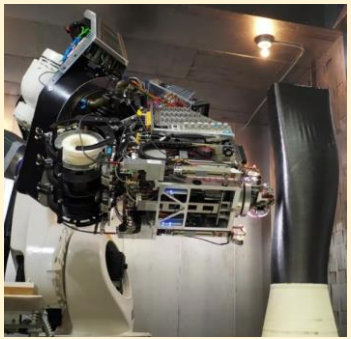


Photo : Electroimpact

Composite "3D-printers"

Post-processing (consolidation, reductive processes, special tooling)

Photo : Mtorres, AFP

Photo : Mtorres, ATL

Photo : Impossible objects

Photo : 9T Labs

Properties?

Maker	Material	Tensile modulus (Gpa)	Tensile strength (Mpa)	Strain %
	ABS polymer	2,3	39	24
	Aluminium 6061	70	310	17
	Steel 4140	200	655	25
Desktop metal	PEEK+Carbon µAFP	145	2400	0,8
Desktop metal	PEEK+Carbon (chopped, FFF)	8,1	105	3
Markforged	Carbon reinforcement	60	800	1,5
Markforged	HSHT FG reinforcement	21	600	3,9

Properties?

Maker	Material	Tensile modulus (Gpa)	Tensile strength (Mpa)	Strain %	Density (g/cm^3)
	ABS polymer	2,3	39	24	1,06
	Aluminium 6061	70	310	17	2,7
	Steel 4140	200	655	25	7,85
Desktop metal	PEEK+Carbon µAFP	145	2400	0,8	1,73
Desktop metal	PEEK+Carbon (chopped, FFF)	8,1	105	3	1,39
Markforged	Carbon reinforcement	60	800	1,5	1,4
Markforged	HSHT FG reinforcement	21	600	3,9	1,5

3D-printing of composite parts

- Short-fiber reinforced polymer where complicated geometry is beneficial
- Continous fibre where mechanical loads are more demanding
- Composite printers are versatile!
  - Polymer parts (with or without fillers)
    - High performance PEI….
    - Engineering plastics ABS, PP, PA, PC….
  - Metal parts

3D-printing of composite parts

Development work is underway on several parts of the process.

- Larger scale
- Better mechanical properties
- Hybrid solutions
- Faster process

3D printing in maritime maintenance and repair applications

US Navy – onboard Markforged metal X desktop printers

RAMLAB – Rotterdam AM lab for metal spare parts

Wilhelmsen group - 3D printed marine spare parts

Greenship of the future/**create it REAL** – 3D printing polymer onboard

Shipparts.com

3D printing in maritime maintenance and repair applications

Example or the risks involved….

3D printer onboard (metal, polymer, composite)

Design (reverse engineered, original part)

Printed part quality

Assembled part breakdown (Door handle, part of machinery)

Responsible?

3D printing in maritime maintenance and repair applications

On-site repair of composite parts/ships

- Probably not feasible at the moment and in the forseeable future

Repair and retrofit parts

- Small parts on-board
- Small to medium sized parts at printing hubs

3D printing in maritime maintenance and repair applications

- Maintenance workshop on-board
- Ships with much equipment of varying kind on-board
- Older vessels – hard-to-get spare parts
- Passenger ships
  - Inventory parts, many similar parts

Factors to consider when deciding if 3D-printing is viable compared to current MRO solutions

Value of part

Repair/replacement frequency

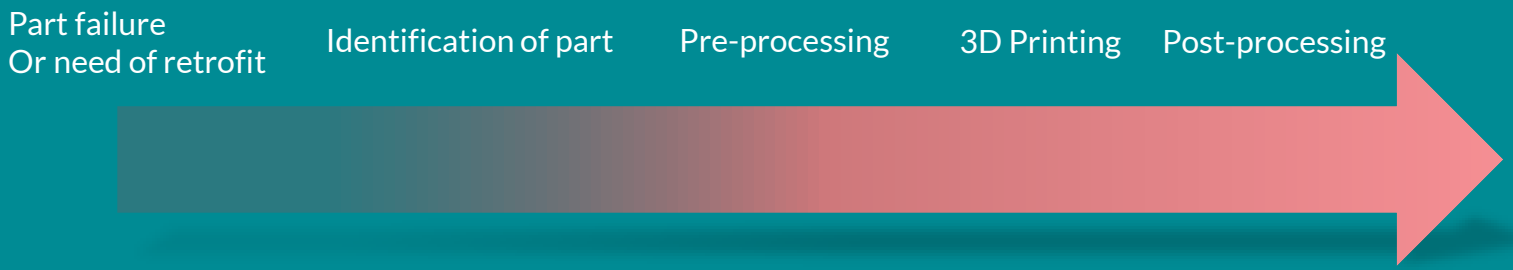
Inventory cost

Re-design value

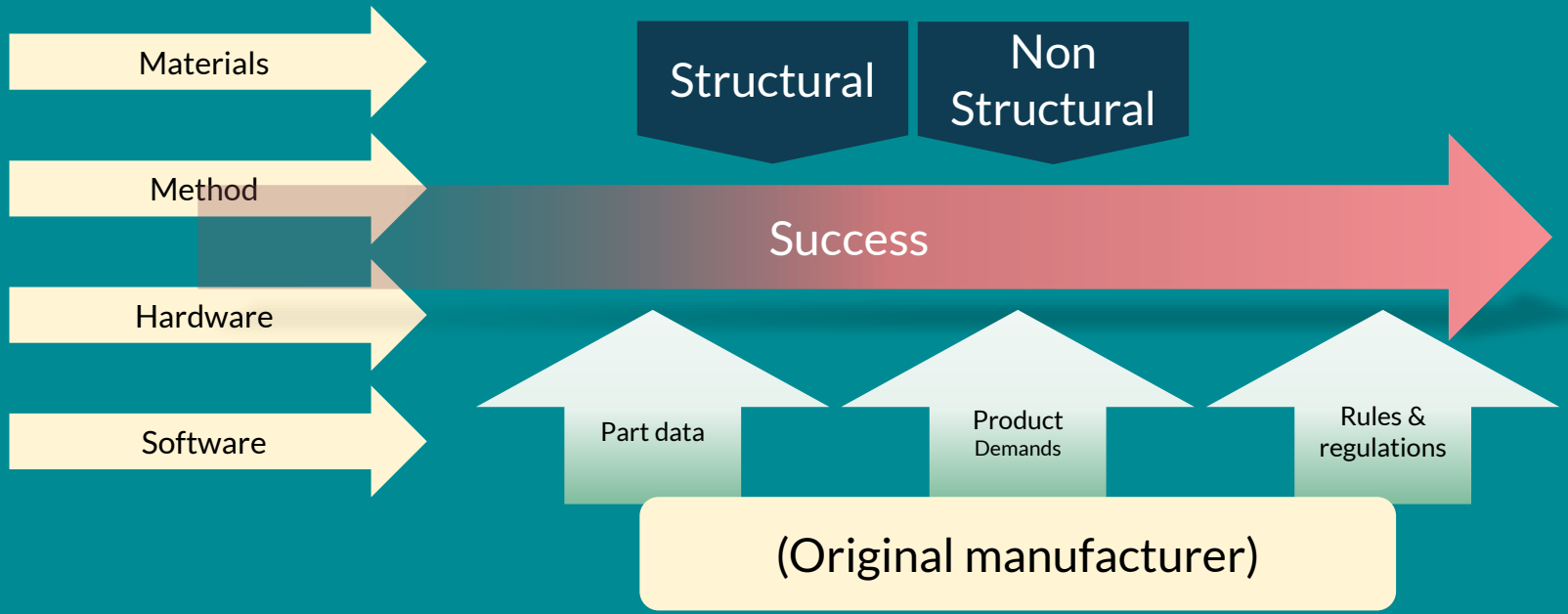
Part performance evaluation

AM readiness for part

Part replacement - process description



Part replacement



Part examples

Credit: Hans Fredrik Asbjørnsen

Photo : Markforged

Conclusion on 3D-printing for maritime MRO

Original part manufacturer

- Involved
- Business model
- Updates (retrofit)
- Qualification

Part database

- Upon request, updated part data should be found in databases
- Print files for each printer type/brand, material
- Data on how to post-process and quality check part

Preparation of instructions on-shore

Conclusion on offshore 3D-printing

To be succesfully used for spare/retrofit parts on-board several parts of the process must be in place

1. Load material – Choose part – Start printing – Quality control – Part ready
2. Load material – Printer operated remotely by onshore personel – Quality control – Part ready

- Part database
- Internet connection
- Quality control onboard
- Simple maintenance and handling of the 3D-printer onboard
    - Spare parts
    - Material

Conclusion on onshore 3D-printing

3D printing hubs at several places around the globe could be acting suppliers of spare parts and retrofit parts.

Need – Contact spare part center - contact 3D hub – next time in port, delivery of part

3D hub

- Replacement/Updated parts
- Printing
- Quality control
- Classified parts
- Business model

Questions?

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