

ADDITIVE MANUFACTURING PROCESS CLASSIFICATION AND CHALLENGES



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CONTENTS

- AM: A Long-term game changer.
- AM Classification.
- Why Metal AM?
- Current and future estimation of AM market size.
- Application of metal AM in different sectors.
- AM Challenges and opportunities.



LEARNING OBJECTIVES

- Understand the standard definition of additive manufacturing (AM) and seven standard classes of AM processes
- Gain basic knowledge of AM market size
- Gain basic knowledge of opportunities, threats, and trends in the AM industry
- Gain insight into applications of metal AM



ADDITIVE MANUFACTURING: A LONG-TERM GAME CHANGER

- Additive manufacturing (AM), often known as 3D printing, is a layer-by-layer fabrication technology
- AM is a platform that converts digital models to physical parts in a short chain of procedures, or "Art" to "Part" in a fancy analogy.
- Industrialized countries are researching AM to recover manufacturing leadership through innovation
- The world economy is nearing "Industry 4.0," the fourth industrial revolution.
- This new production method has gained international attention. AM innovations are reported every week. → *material, manufacturing, quality*
- the worldwide economic impact will be \$550 billion per year by 2030



ADDITIVE MANUFACTURING: A LONG-TERM GAME CHANGER

- As interest in AM grows, several sectors are incorporating it into their products and services. Aerospace, medical, automotive, tooling, energy, natural resources, consumer, and defense have embraced AM methods.
- The 2020 pandemic revealed that digital files and affordable 3D printers can fill medical supply gaps. Internet accounts indicate that people printed face shield parts during the pandemic supply chain disruption.
- This feature encourages the industry to focus on localized manufacturing to handle on-demand manufacturing with little foreign dependence.



ADDITIVE MANUFACTURING: A LONG-TERM GAME CHANGER

- When the skill gap is a key barrier to the adoption of AM in industry, AM-based courses are being added to the school, college, and university curricula to educate AM to youth
- This paradigm shift requires knowledge of AM principles, technology, and software, and efforts are underway to integrate these into educational platforms.



ADDITIVE MANUFACTURING

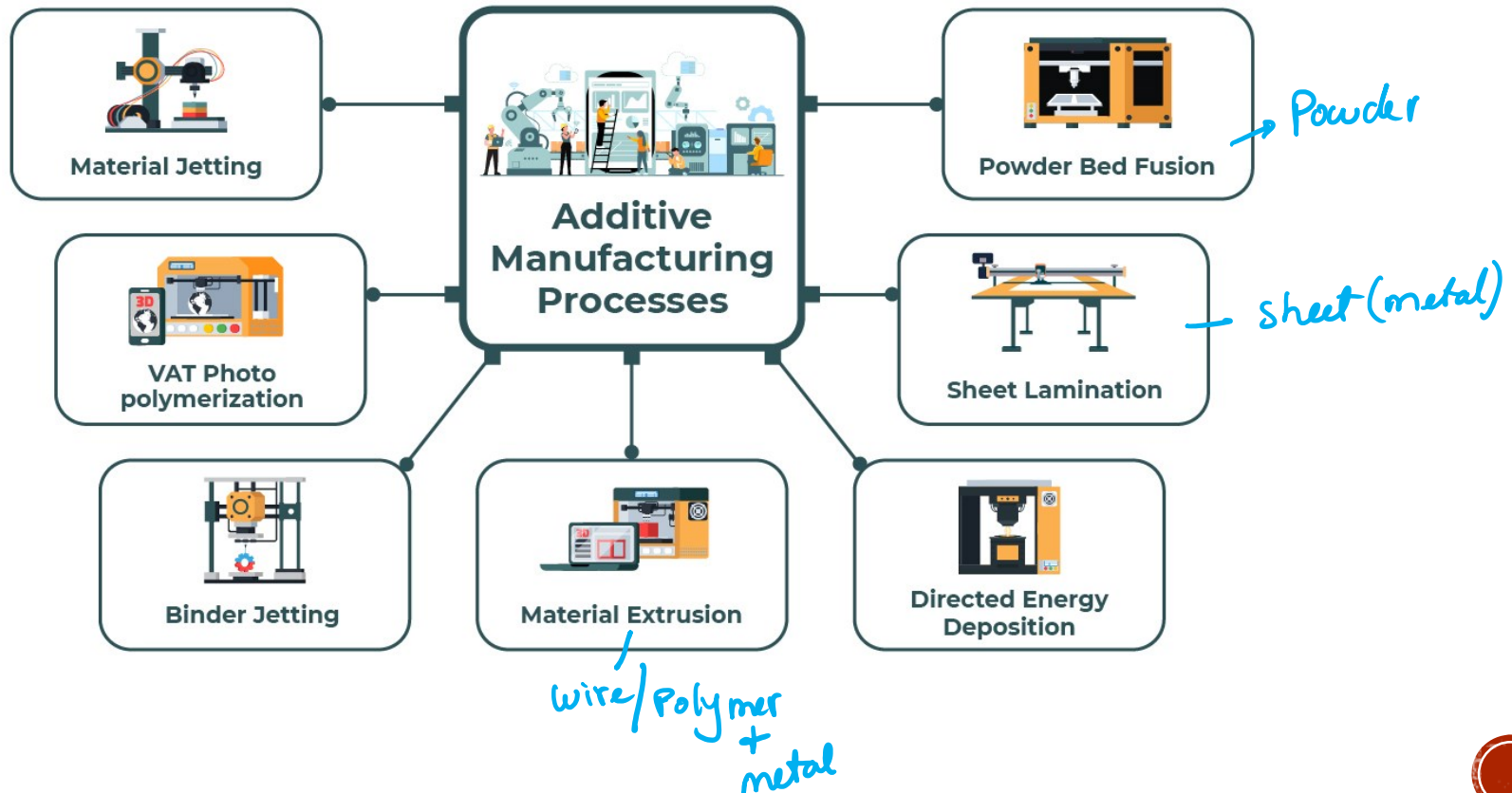
ITS CLASSIFICATION

- “Additive manufacturing (AM) is process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies.”
- Standard categories of AM
 1. Binder Jetting
 - ② Directed Energy Deposition → *metals*
 - ③ Material Extrusion
 - ④ Material Jetting
 - ⑤ Powder Bed Fusion — *metals/ceramics*
 - ⑥ Sheet Lamination
 7. VAT Photopolymerization

Polymer + metal



ADDITIVE MANUFACTURING PROCESS



ADDITIVE MANUFACTURING PROCESSES



1. **Binder jetting** uses a liquid bonding agent to combine powder materials. Polymer
Ceramic
2. **Directed energy deposition**, an additive manufacturing technology that melts materials as they're deposited.
3. **Material Extrusion:** Material is extruded through a nozzle or aperture in additive manufacturing. material Powder
↓
wire.
4. **Material jetting** is a droplet-based additive manufacturing technology. Photopolymer and wax are examples.
5. In **Powder bed fusion**, thermal energy selectively fuses powder bed regions. Cer
Pol metal
6. **Sheet lamination** is an additive manufacturing process that bonds sheets to make an object.
7. **Vat photopolymerization** selectively cures liquid photopolymer in a vat using light



WHY METAL ADDITIVE MANUFACTURING?

1. On-demand low-cost rapid prototyping
2. Simpler supply chain for effective low-volume production
- ✓ 3. Geometric complexity may be free
- ✓ 4. Light weighting
- ✓ 5. Parts consolidation (300:1)
- ✓ 6. Functionally graded materials (FGMs) and structures (FGSs)
- ✓ 7. Parts with conformal cooling channels for increased productivity
- ✓ 8. Parts repair and refurbishment → metal



WHY METAL ADDITIVE MANUFACTURING?

1. On-demand low-cost rapid prototyping

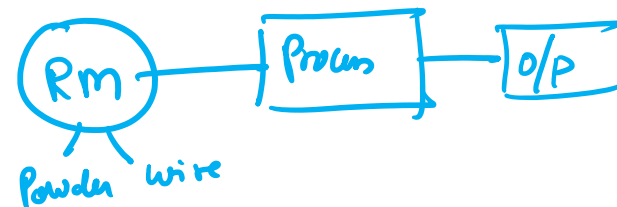
- Functional prototypes are made with AM.
- Such prototyping costs a fraction of standard procedures and is fast.
- This quick turnaround speeds up design (design, test, revision, and redesign).
- AM can develop moulds that would take 4–6 months in 2–3 months. → 50%



WHY METAL ADDITIVE MANUFACTURING?

2. Simpler supply chain for effective low-volume production

- Low-volume specialty production costs more. Due to this challenge, conventional manufacturers avoid low-volume production. AM firms can fill this gap.
- Metal AM can replace time-consuming and expensive low-volume manufacturing processes. AM lags behind casting and forging for bulk production.
- AM usually requires a simpler supply chain with fewer stakeholders. As AM's supply chain develops, low-volume production should increase.



WHY METAL ADDITIVE MANUFACTURING?

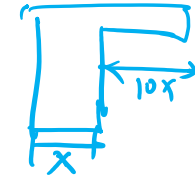
2. Simpler supply chain for effective low-volume production

- When AM develops into series manufacturing, lower material prices will boost low-volume adoption.
- AM has cheaper initial costs than conventional processes since fewer tools and jigs/fixtures are needed.
- To offset tooling costs, the quantity of items should be high. AM doesn't require specialist tools, thus there are no upfront costs (called fixed costs too). This allows you to reach breakeven sooner and make profits with lesser volumes.



WHY METAL ADDITIVE MANUFACTURING?

Design for $\underline{\underline{X}}$



3. Geometric complexity may be free

- AM can make complicated shapes that other technologies couldn't
- AM's additive nature allows geometric complexity to be cost-effective.
- AM allows "design for use" instead of "design for manufacture"
- Complex or organic parts designed for performance may cost less, but not all are AM-manufacturable.
- Overhanging features may produce residual stresses and flaws in metal AM, therefore complexity may not equal freedom.



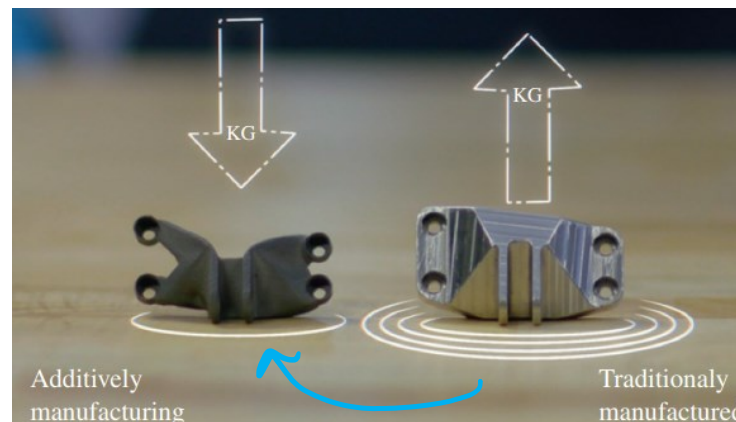
Complex parts made by AM.



WHY METAL ADDITIVE MANUFACTURING?

4. Light weighting

- Manufacturers make greener and cheaper products.
- Lightweight components reduce energy utilization and raw material use.
- Lightweight components reduce costs, resources, and the environment for both reasons.



*optimisation of shape
size
strength
Roughness.*

Lightweight structure made by AM



WHY METAL ADDITIVE MANUFACTURING?

4. Light weighting

- AM is coupled with topology optimization, allowing it to design and manufacture high-strength, lightweight structures.
- Topology optimization and lattice structure design work with AM to create lightweight structures.
- Aerospace uses several lightweight, high-strength parts. Any weight decrease saves money on parts and fuel.



WHY METAL ADDITIVE MANUFACTURING?

5. Parts consolidation

- Industrial products have mechanical assembly. In sophisticated mechanical machinery, components are welded, bolted, or press-fit together.
- Parts consolidation reduces the number of individual parts that must be designed, manufactured, and assembled.
- Part consolidation has many advantages.
 - i. design simplification;
 - ii. reduced overall project costs;
 - iii. reduced material loss;
 - iv. reduced weight;
 - v. reduced overall risk as the number of suppliers of individual parts drops;
 - vi. improved overall performance as it enables desirable geometries not possible with conventional manufacturing.

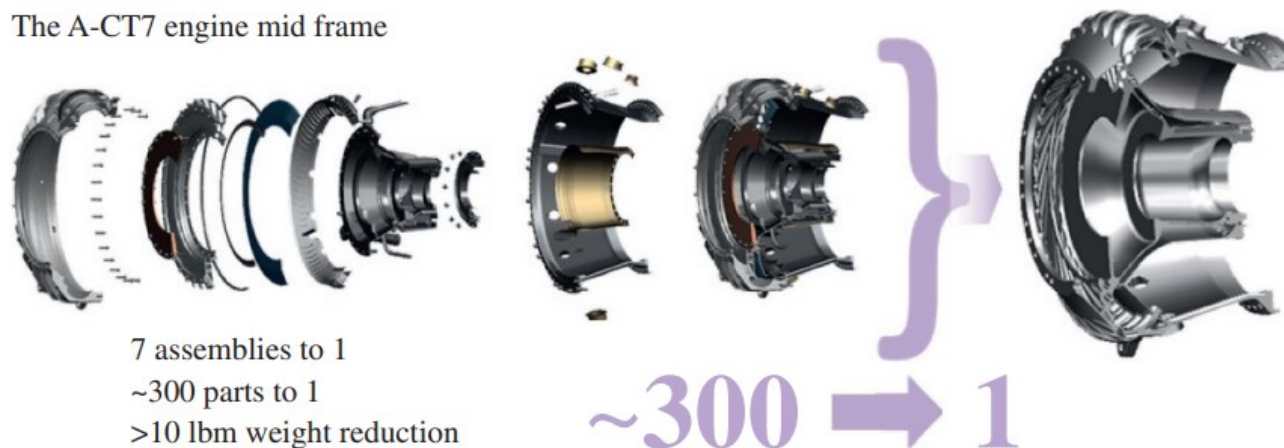


WHY METAL ADDITIVE MANUFACTURING?

6. Parts consolidation

- AM facilitates parts consolidation, sometimes eliminating assembly.
- AM can improve product performance by lightweighting/consolidation without losing high strength by optimizing heat sinks, fluid flow, and energy absorption.
- Figure demonstrates GE Additive's work. The A-CT7 engine frame combines about 300 pieces. This consolidation cut 10 pounds from seven assemblies

The A-CT7 engine mid frame



WHY METAL ADDITIVE MANUFACTURING?

7. Functionally graded materials (FGMs) and structures (FGSs)

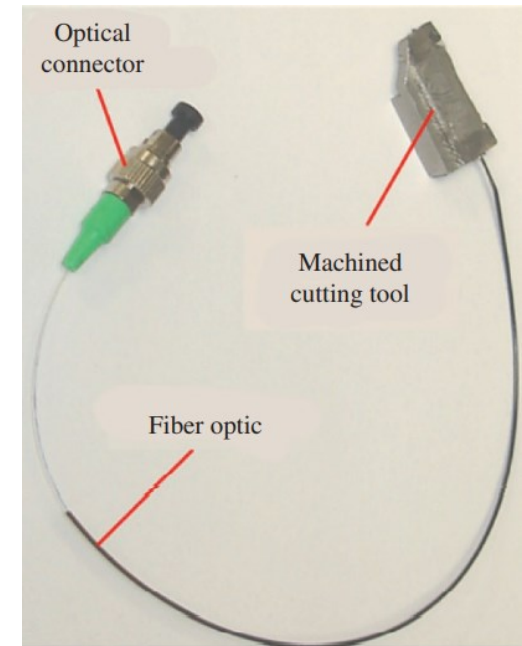
- Multiple advanced materials in one component are a fast-growing AM field.
- AM may generate multiphase materials with progressive composition changes.
- AM processes adjust material composition layer-by-layer to achieve the desired functionality.



WHY METAL ADDITIVE MANUFACTURING?

7. Functionally graded materials (FGMs) and structures (FGSs)

- AM also permits FGSs with a single-phase material, where the density is gradually modified by adding cellular/lattice structures and embedding things (e.g. sensors) within structures.
- DED is the most promising AM technique for developing such structures because it can switch powders in-situ to generate appropriate composition and alloys

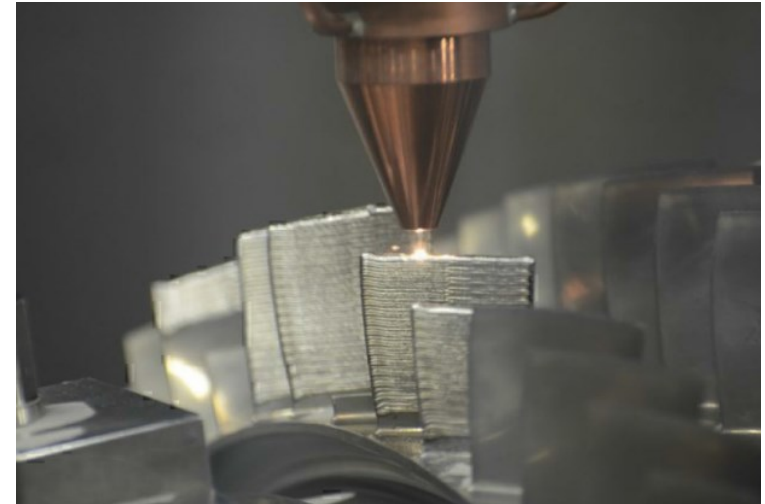


A cutting tool with an embedded fiber optic, developed by an AM-based process



WHY METAL ADDITIVE MANUFACTURING?

- **Parts repair and refurbishment**
 - Machining faults or last-minute technical revisions might delay tools supply and product launch.
 - AM, especially DED techniques, can safely repair tools, especially contacting surfaces.
 - AM can save a high-value tool that would otherwise be replaced



LDED used to rebuild turbine blades



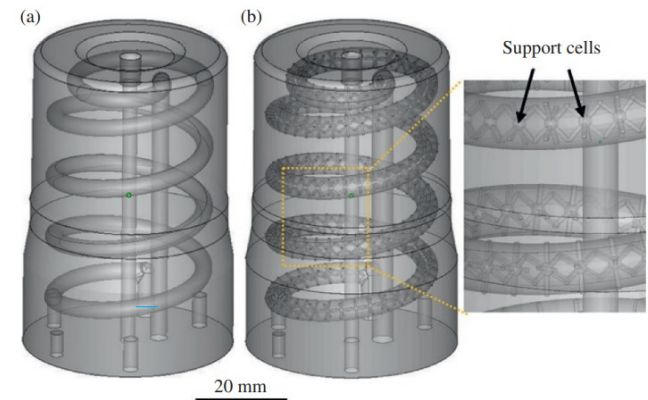
WHY METAL ADDITIVE MANUFACTURING?

- **Parts with conformal cooling channels for increased productivity**
 - Many parts' productivity and performance depend on their cooling systems.
 - In injection moulding, cooling accounts for almost 40% of cycle time. Productivity increases considerably if this period is shortened by removing mould heat.
 - In an active antenna, constructing conformal channels is crucial so that heat may be drained from the zone without affecting antenna performance.



WHY METAL ADDITIVE MANUFACTURING?

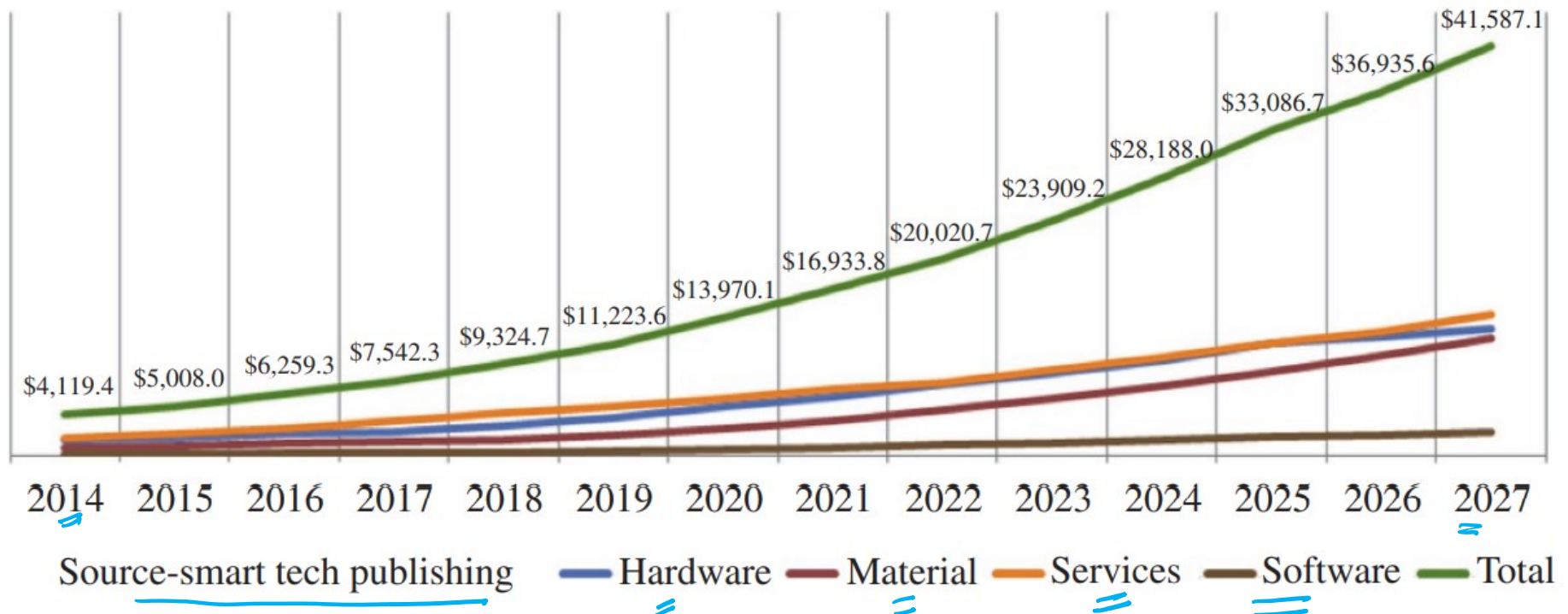
- **Parts with conformal cooling channels for increased productivity**
 - With AM, designers can incorporate conformal cooling channels that promote uniform cooling over the entire surface.
 - Optimization can incorporate sub-conformal channels.
 - The concept uses support cells to increase heat transmission in a conformal cooling channel.



A mold insert with (a) conformal cooling channels, and (b) conformal and lattice structures to improve heat dissipation.



MARKET SIZE: CURRENT AND FUTURE ESTIMATION



THANK YOU

