Additive Manufacturing Fundamentals and Stratasys Systems

This briefing document synthesizes the main themes and important ideas from the provided sources, covering fundamental AM concepts, Stratasys technologies, materials, software, and post-processing techniques.

Additive Manufacturing Fundamentals and Terminology:

1. SME CAM-F: The acronym "SME CAM-F" stands for "Society of Manufacturing Engineers, Certified Additive Manufacturing - Fundamentals."
2. Additive vs. Subtractive Manufacturing: Additive manufacturing is defined by building up material, and subtractive manufacturing is removing material.
3. Manufacturing Eras: The Neolithic era is characterized by the "Transition from hunting/gathering to agriculture."
4. Topology Optimization: This design technique in AM removes excess material while retaining strength.
5. Design for Additive Manufacturing (DfAM): Key considerations in DfAM include minimizing unsupported angles when dealing with overhangs and reducing the amount of support needed.
6. ASTM Categories: Material Extrusion (e.g., FDM/FFF), Vat Photopolymerization (e.g., SLA, DLP), Powder Bed Fusion (e.g., SLS, SLM, EBM), Binder Jetting, Material Jetting, Sheet Lamination, Directed Energy Deposition (DED)
7. In-situ Monitoring (ISM): This refers to "Real-time quality assurance of 3D printers."
8. Thermoplastics: Polymers that become pliable or moldable when heated and solidify upon cooling, without undergoing any significant chemical change. This allows them to be recycled many times.
9. Thermosets: Polymers that undergo an irreversible chemical reaction, known as curing, during processing. This reaction forms a highly cross-linked, three-dimensional network of covalent bonds between polymer chains. This means they cannot be recycled.

Stratasys Technologies (FDM and PolyJet):

1. FDM (Fused Deposition Modeling):
    a. Known for producing strong and durable parts while offering economic sparse fill and providing accessibility with many different types of materials
    b. Key components include: the gantry (positions print heads in the XY plane), extruder assemblies (model and support)
    c. Uses both Soluble Support (SR) materials and Breakaway Support Structures (BASS).
    d. Heated build chamber (Airflow within the build chamber is important for uniform temperature distribution and layer-to-layer bonding.)

2. PolyJet:
    a. Offers different material types and colors (Clear, tough, elastic)
    b. Can print multiple materials and near-infinite colors.
    c. Digital Materials are created by combining primary and secondary rigid or flexible materials.
    d. PolyJet is best suited for small parts with accuracy, detail, and excellent surface finish
    e. Can achieve extremely high resolution prints
3. FDM Material Categories:
    a. Standard (PLA, ABS-PLUS, ABS-M30, ABSi, ABS M30I, ABS-ESD7, ASA)
    b. Engineering (NYLON 12, NYLON 6, PC-ABS, PC-ISO, PC, NYLON CF)
    c. High Performance (ULTEM® 9085, ULTEM® 1010, ANTERO)
4. PolyJet Material Categories:
    a. Rigid Opaque
    b. Rigid Transparent (Veros)
    c. Simulated Polypropylene (Rigur, Durus)
    d. Flexible Rubber-like (Tango, Agilus)
    e. Digital Materials (Composites, Digital ABS)

Material Testing:

1. Thermal Resistance: measure of a material's resistance to distortion under a given load at elevated temperatures
2. Tensile (Stretching): force needed to stretch a sample to break it
3. Flexural (Bending): stress needed to bend a sample until it breaks
4. Izod Impact: material's resistance to impact
5. Coefficient of Thermal Expansion: measure of how samples expand or contract under temperature difference
6. Electrical Properties: Static Dissipative, Static Resistance, and Volume Resistance
7. Water Absorption: amount of water absorbed under specified conditions (submerged or exposed to humid atmosphere)
8. Shore Hardness: resistance of a material to indentation

Software (GrabCAD Print and Insight (legacy version of GrabCAD)):

1. GrabCAD Print:
    a. Can read native CAD files
    b. Connect to Stratasys (only) printers
    c. Provides print management and remote monitoring
    d. Used for model setup, orienting parts, slicing, generating toolpaths, creating supports, and sending jobs to the printer
2. Insight:
    a. Legacy version of GrabCAD
    b. Did most of the same features, but had an outdated UI

Post-Processing:

1. Support Removal: Soluble support is removed in a cleaning station with heated water and a cleaning agent. Key considerations include tank agitation, temperature, manually removing some support, keeping parts submerged, and using enclosures for fragile or small parts. Sparse parts may absorb water and require drainage holes.
2. Bonding/Gluing: Used for models larger than the tray size, or when printing parts individually is more practical. Requires separating the model in CAD or STL software and adding clearance for the glue. Hot Air Welding is the strongest FDM bonding method, while Epoxy is the weakest.
3. Plating: Requires adjusting the CAD file for plating thickness, sanding surfaces to remove layer lines, sealing surfaces (Finishing Station, Solvent Dipping, Epoxy coating), curing, and re-sanding. Coating thickness and temperature of the plating process impact design and material selection for plating, while wall thickness and coating color do not.
4. Mass Finishing: Uses abrasive media to smooth and polish parts. Centrifugal Barrel Machines are best for fine details and a quick, aggressive finish, while Vibratory Tubs are ideal for more fragile parts with complex geometries requiring a gentler finish. Media shapes and sizes affect cutting action and smoothing. Design modifications may be needed for thin features, narrow channels, or holes.
5. Vapor Smoothing: Smooths (removes layer lines and can seal it) FDM parts with acetone, limited to certain materials.

Safety Considerations:

1. Metal Powders: Safety risks include inhalation of fine particles, fire or explosion hazards, and skin contact hazards. UV radiation exposure is NOT typically associated with handling metal powders in AM. Could also cause damage due to the weight of the metals.
2. Post-Processing: Safety is the most important consideration when using tools and machines for post-processing.
3. Safety Data Sheets (SDS): Provide information about the properties and safety of materials.

Economic Impact of AM:

AM is contributing to the development of new business models and supply chains, including decentralized manufacturing. It changes the economics of production, particularly impacting economies of scope (producing a wider variety of products more efficiently) and economies of scale (reducing cost per unit with increased volume). While conventional manufacturing typically benefits from economies of scale, 3D printing can be more cost-effective for lower volumes and more variants.