Responding to COVID-19 with Additive Manufacturing

In response to COVID-19, many companies are working to create the equipment needed to treat patients and protect healthcare workers. Medical device companies are quickly scaling manufacturing operations, while other manufacturing companies are adapting their operations to assist. Some companies are experiencing difficulty in getting parts and tooling necessary for their operations, as suppliers and transportation networks adapt to containment measures for COVID-19.

Introducing additive manufacturing into the supply chain will help organizations overcome some of these challenges.

Managing Uncertainty with Additive Manufacturing
- Flexibility to increase short-term production capacity with shorter changeover and no additional capital expenses
- Shorten production ramp for conventional manufacturing with AM tool
- Manufacture parts closer to point of use, reducing impact of disruptions to transportation
- Additive Manufacturing capacity can be added without new capital expenses by identifying conventional suppliers with AM capabilities or adding AM-exclusive service bureaus to your supply chain
- Enable supply chain disintermediation by reducing components when you follow Design for Additive Manufacturing (DfAM) guidelines to take advantage of unique AM features

COVID-19 Applications
- Personal protective equipment (PPE)
  - Face shield
  - Face mask
  - Respirator
- Ventilator components
  - Air exchanger
  - Filter adapter
  - In-line filter housing
  - Pneumotachometer
  - Ventilator splitter
  - Flow restriction device
- Rapid tooling
  - Shorten production ramp for conventional manufacturing

Additive Manufacturing Technologies

Note: the following terms/definitions are based on “ISO/ASTM 52900: Standard Terminology for Additive Manufacturing - General Principles - Terminology”

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>PART SIZE</th>
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<tbody>
<tr>
<td>Metals</td>
<td></td>
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<tr>
<td>Polymers</td>
<td>S M L</td>
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<tr>
<td>Ceramics</td>
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</tbody>
</table>

- **Material Extrusion**
  Material is selectively dispensed through a nozzle or orifice

- **Material Jetting**
  Droplets of build material are selectively deposited

- **Vat Photopolymerization**
  Liquid photopolymer in a vat is selectively cured by light-activated polymerization.

- **Directed Energy Deposition**
  Focused thermal energy is used to fuse materials by melting as they are being deposited.

- **Powder Bed Fusion**
  Thermal energy selectively fuses regions of a powder bed.

- **Binder Jetting**
  A liquid bonding agent is selectively deposited to join powder materials.

- **Sheet Lamination**
  Sheets of material are bonded to form a part.

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COVID-19 EMERGENCY RESPONSE

Design for Additive Manufacturing

In response to the COVID-19 emergency, many individuals/organizations are willing to help by sharing medical part designs. Designers working on products to be fabricated with Additive Manufacturing (AM) should be aware of the unique capabilities and limitations of these processes. This brief guide draws from AM standards to provide guidance for designers responding to the needs of healthcare workers and patients during COVID-19.

The ultimate objective is to increase the quality of designs submitted (to the America Makes portal and other potential channels) and shorten the design review/selection process.

Benefits of Design for Additive Manufacturing (DfAM)

- Reduce Costs
- Decrease Production Time
- Improve Part Performance
- Improve Material Performance
- Reduce Part Mass
- Reduce/Eliminate Post-Processing
- Reduce/Eliminate Assembly

Common Design Issues

Selected extracts from ISO/ASTM 52910:2018 (Clause 7. Warnings to designers)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DETAIL LOSS (POST-PROCESSING)</td>
<td>Design access to internal features to release trapped material.</td>
</tr>
<tr>
<td>ABRUPT THICKNESS TRANSITIONS</td>
<td>Reference AM standards for guidelines and recommendations.</td>
</tr>
<tr>
<td>CLEANLINESS</td>
<td>Design slots or holes for material removal. Ensure post-processing includes thorough part cleaning and plug any holes at this stage, if needed.</td>
</tr>
<tr>
<td>TRAPPED VOLUMES</td>
<td>Use the standardized .AMF part file which describes an object for AM processing in more detail than .STL ISO/ASTM 52915:2016(E).</td>
</tr>
<tr>
<td>DETAIL LOSS (PART FILE)</td>
<td>Communicate with the additive manufacturing engineer to orient the part in the build chamber to minimize the impact of these features.</td>
</tr>
<tr>
<td>UNITLESS PART FILES</td>
<td>Build or orientation of the part relative to the build plane influences the support structure, productivity, material usage, and part performance.</td>
</tr>
<tr>
<td>LAYERING/STAIR STEPS</td>
<td>The layer-based process often leaves small surface transitions along the part surfaces.</td>
</tr>
</tbody>
</table>

Following DfAM guidelines and communicating with AM process specialists is critical to the success of the final parts. Published AM standards can provide more detailed guidance and additional considerations not covered here, such as:

1. Process limitations
   - minimum feature sizes, surface finish
2. Materials
   - safety, permeability, recycling
3. Thermal effects
   - shrinkage, distortion, residual stress
4. Productivity
   - nesting, process optimization

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Additive Manufacturing Community Response to COVID-19

America Makes is maintaining a portal to submit your organization’s AM capabilities, AM designs, or health care PPE needs to help match manufacturing capabilities with needs.

LEARN MORE
www.americamakes.us/statement-on-covid-19/

ASTM International publishes voluntary consensus standards for a wide range of materials, products, systems, and services including additive manufacturing, medical devices, and personal protective equipment. These standards provide requirements, guidelines, and recommendations that can accelerate the design review and validation.

ASTM International is providing no-cost public access to important ASTM standards used in the production and testing of personal protective equipment - including face masks, medical gowns, gloves, and hand sanitizers - to support manufacturers, test labs, health care professionals, and the general public as they respond to the global COVID-19 public health emergency.

LEARN MORE
www.astm.org/COVID-19

- F42: Additive Manufacturing Technologies
- F04: Medical and Surgical Materials and Devices
- F23: Personal Protective Clothing and Equipment
- D11: Rubber and Rubber-like Materials
- E35: Pesticides, Antimicrobials, and Alternative Control Agents

ASTM Additive Manufacturing Center of Excellence (AM CoE) brings together industry, government, and academia to optimize the AM R&D and standards development processes. By tightly coupling these processes, standards get into the hands of those who need them faster, drastically reducing AM time to market and increasing widespread adoption.

- Establish standards, certification, and qualification for repeatable, consistent parts and processes
- Prevent gaps and duplication of work in a dynamic, fast-paced technology space
- Identify challenges that can be solved with technological improvement

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ASTM Standards and COVID-19

ASTM International is providing NO-COST PUBLIC ACCESS to important ASTM standards used in the production and testing of personal protective equipment - including face masks, medical gowns, gloves, and hand sanitizers - to support manufacturers, test labs, health care professionals, and the general public as they respond to the global COVID-19 public health emergency.

Visit www.astm.org/COVID-19 to access these standards through the ASTM Reading Room.

**Masks**
- ASTM F2299/F2299M-03(2017) — Standard Test Method for Determining the Initial Efficiency of Materials Used in Medical Face Masks to Penetration by Particulates Using Latex Spheres
- ASTM F2101-19 — Standard Test Method for Evaluating the Bacterial Filtration Efficiency (BFE) of Medical Face Mask Materials, Using a Biological Aerosol of Staphylococcus aureus
- ASTM F2100-19 — Standard Specification for Performance of Materials Used in Medical Face Masks
- ASTM F1862/F1862M-17 — Standard Test Method for Resistance of Medical Face Masks to Penetration by Synthetic Blood (Horizontal Projection of Fixed Volume at a Known Velocity)
- ASTM F1494-14 Standard Terminology Relating to Protective Clothing

**Medical Gowns**
- ASTM D751 - 19 — Standard Test Methods for Coated Fabrics
- ASTM D5034-09(2017) — Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
- ASTM F1494-14 — Standard Terminology Relating to Protective Clothing

**Gloves**
- ASTM D3578-19 — Standard Specification for Rubber Examination Gloves
- ASTM D6977-19 — Standard Specification for Polychloroprene Examination Gloves for Medical Application

**Hand Sanitizers**
- ASTM E3058-16 — Standard Test Method for Determining the Residual Kill Activity of Hand Antiseptic Formulations

**Respirators**
- ASTM F3387-19 Standard Practice for Respiratory Protection

www.astm.org/COVID-19