Additive Manufacturing Gaining Traction at Fleet Readiness Center East

Potential Safety & Environmental Impacts Addressed

TO SUPPORT THE Fleet-wide push toward additive manufacturing, personnel from the Fleet Readiness Center East (FRCE) in Cherry Point, North Carolina have identified the potential environmental impacts and workplace safety measures associated with this advanced technology.

AM can be a more cost-efficient method of manufacturing parts. Energy costs are lowered because there is no casting process and fewer production steps, inventory is reduced because items can be made one at a time, and flexibility is greatly enhanced, allowing for precise, intricate designs. Small-scale produce thermoplastic tooling and parts using Fused Deposition Modeling (FDM) technology. A computer-aided manufacturing software package within the Fortus system controls the process. A coiled thermoplastic filament is supplied to a five-centimeter-long extrusion nozzle head which heats the material to the proper temperature, then ejects the molten plastic which hardens immediately to produce a product. Depending on part geometry and orientation, some down-facing surfaces will require supports as the part is being formed. This support material is extruded through a second nozzle during operation.

AM reduces adverse environmental impact and health risk by minimizing high temperature foundry operation and hazardous materials usage, such as metal working fluids, lubricants, and biocide.

> Additive manufacturing reduces adverse environmental impact and health risk by minimizing high temperature foundry operation and hazardous materials usage.

Additive Manufacturing

The terms additive manufacturing (AM) and three-dimensional (3D) printing are often used synonymously in mainstream media. However, 3D printing is technically a subset of additive manufacturing processes that refer to material buildup through a nozzle or other printing technology. Traditional subtractive manufacturing entails the removal of material (often by lathing, cutting, chipping or grinding) to create a final product. In contrast, AM uses an additive process, creating objects layer by layer through the use of a nozzle.

AM processes may even be used onboard a ship, potentially allowing for on-the-spot repairs.

In general, AM processes involves three basic steps, once design of the AM part or assembly is complete:

1. AM part building
2. Removal of support material
3. Final surface finishing

Step 1: Additive Manufacturing Part Building

FRCE uses two Fortus systems (manufactured by Stratasys Ltd.) to

Air emissions appear to be a non-issue as well. Although some fumes and ultra-fine particles are released when plastics are heated to the softening point during extrusion, Stratasys Ltd. has analyzed air samples taken at the operator control panel located at the edge of the door opening and opposite the exhaust fan vents. Among chemicals collected were styrene, acrylonitrile, methyl methacrylate, butadiene, and hydrogen cyanide. Samples representative of an 8-hour exposure were compared with the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL). Results found that the toxic chemical emissions released from the Fortus systems were all below the OSHA PEL. Personnel from FRCE's Industrial Hygiene Division will conduct their own survey in the near future to confirm that emissions are as reported.

An example of the cost and time savings made possible by AM is the stretch forming of sheet metal to make aircraft skins. The conventional manufacturing process, using foundry processes followed by hand forming the surface, takes approximately three months to complete. Changing to AM and "printing" the part reduces the process time to two weeks—minimizing labor hours, raw materials usage, and hazardous waste. Another example is an AV8-B drill guide which is made in one week by AM methods as opposed to the previous three-to-five week process.

Personal protective equipment needed for AM part building includes safety eyewear and heat-resistant gloves for use when taking a product out of the machine.

This form block and top were created through the AM process. Sheet metal to make aircraft skins will be formed with these parts.

This AV8-B Harrier jet drill guide is made in one week by AM– a time savings of two to four weeks.
Ramsey Davis

LEFT: The nozzle inside the Fortus computer ejects molten plastic which hardens into the desired shape to make a part.

RIGHT: A radiography scanner is necessary for inspecting for defects internal to denser metallic parts. Safety measures must be taken to ensure that the scanner is not activated when technicians are in the area.

Keiko Sapp

Patternmaker Caleb Guelich, left, and engineer Justin Reynolds from FRCE, inspect polymer form blocks made through FDM, a type of AM. The form blocks, made in a matter of hours overnight, were used to create repair parts for a damaged AV-8B Harrier. Using conventional methods, creating these tools could have taken two to three weeks.

Step 2: Support Material Removal Process

Support material is removed by hand or by a chemical immersion process. Hand removal can be accomplished by using tools such as pliers, and the removed plastic materials can be recycled. The chemical removal process uses a heated ultrasonic tank with a caustic solution at the operating temperature of 160 to 170 degrees Fahrenheit. The caustic solution dissolves the plastic support material; however, large-sized undissolved plastics that come off the product must be removed by filtering in order to extend the solution's operating capability. As the pH depletes, the plastic removal process will take longer, and the solution color becomes a milky brown that can discolor products. For this reason, the manufacturer recommends replenishing the solution when the pH level drops below nine. Although the manufacturer does not require a post-rinse process, FRCE is establishing immersion rinse tanks to remove any residual contaminants from products after the caustic immersion process. Although the spent solution is considered hazardous waste, the impact of the spent waste solution for disposal via FRCE's industrial waste treatment plant is unknown at this time.

The heated caustic solution can irritate or burn the skin, eyes, and respiratory tract. Adequate ventilation, emergency showers, and eye-wash stations are required per OSHA 29 CFR 1910.124, General Requirements for Dipping Operations.

Step 3: Final Surface Finishing Process

The final step is surface finishing, which smooths out the surface by sanding or varnishing. FRCE accomplishes the final surface finish by hand. Although the amount of plastic dust created by the hand sanding process is small, dust can accumulate quickly and is considered combustible. Local exhaust ventilation systems are used to eliminate plastic dust during sanding, and wet cloth wipes are used to clean up the work benches. Housekeeping is the key to keep fire hazards under control and prevent possible flash fires or explosions.

Findings

The environmental benefits of AM are energy savings through the elimination of high temperature foundry operations, reduced hazardous material usage compared to conventional machining processes, and reduced spent metal working fluid disposal cost. The environmental impacts of spent caustic solutions with dissolved plastics need to be evaluated.

More cost savings can be gained by minimized the use of raw materials and lead time improvement. The lifespan of plastic tooling is unknown; however, proper indoor storage to avoid direct sun light is recommended.

From a safety standpoint, AM provides a safer work environment by reducing hazardous material usage, and presumes reductions in mishaps by minimizing the physical labor hours of conventional processes.

Future References for Additive Manufacturing Metal Products

FRCE is evaluating another form of AM known as directed energy deposition for manufacturing metal aircraft components, metal tooling, and for performing component

repairs. These technologies use either a laser beam or electron beam to melt metal powder and/or wire to produce the end product. Compared to thermoplastic FMD technology, safety concerns and environmental impacts are greater with directed energy deposition technologies. These concerns are due to the nature of the metal powder, the use of laser or electron beams, and the advanced radiography scanner used for inspection.

During directed energy deposition processes, metal powder is transported by an inert gas and fused by a laser. Metal powders including nickel, cobalt, stainless steel, titanium and aluminum alloy are currently under evaluation at FRCE for this process. Since titanium alloy and aluminum alloy powders are highly combustible, care must be taken in the storing, handling, and processing of these metal powders. Ventilation, explosion-proof vacuum cleaners, natural fiber bristle brooms/brushes should be used to avoid accumulation of metal dust in the work environment. Metal powders must be stored in climate controlled storage separately from water, acids, halogens, oils, and general combustibles, such as paper and wood. In case of fire, blankets and Class D fire extinguishers must be available. Water, ABC-type fire extinguishers, and carbon dioxide may not be used on this type of fire.

The laser used in directed energy deposition is a Class 4 hazard. This means that there is a hazard to the eye from the direct beam, from specular reflections (the mirror-like reflection in which a ray is reflected in a single outgoing direction), and possibly from diffuse reflections. This type of laser also has the potential to damage skin and start fires. Necessary personal protective equipment includes static dissipating safety shoes, long heat-resistant gloves, laser safety spectacles or goggles, and coveralls as required.

Oxygen monitors are also required in the work area to prevent inert gas asphyxiation.

For the denser metallic parts, the use of a radiography scanner is necessary for inspecting for defects internal to the part. The scanner is a large X-ray inspection tool housed in a room that can hold at least one or two inspectors. The scanning space is guarded by lead shielding or lead glass walls to protect from X-ray emission. Additionally, lockout/tagout procedures are needed to prevent the scanner from accidentally being turned on while inspectors are inside.

Conclusion

AM at the FRC level has great potential to support the warfighter and maintenance activities safely and cost-effectively. By using AM, the impact on the environment is minimized as AM is a cleaner fabrication process compared to the foundry operation and conventional machining processes. AM produces near zero raw material waste and reduces the amount of spent metal working fluid used. The health and safety of the user, however, must remain on the forefront. ⚓

Keiko Sapp
Fleet Readiness Center East
252-464-5259
DSN: 451-5259
keiko.sapp@navy.mil

For More Information

FOR MORE INSIGHTS into the in-roads made by AM technologies into Fleet operations, read our article "Navy Explores the Future of 3D Printing: CDSA Dam Neck, CNSL & NAVAIR Host Workshops for Deckplate Sailors & Industry Partners" in the fall 2014 issue of *Currents*. You can browse the *Currents* archives at the Department of the Navy's Energy, Environment and Climate Change web site at http://greenfleet.dodlive.mil/currents-magazine.