ELECTRIC POWER RESEARCH INSTITUTE

Quick Insight Brief: Additive Manufacturing to Support Spare and Replacement Items

RESEARCH QUESTION

Promising strides in advanced manufacturing techniques such as laser light measurement and additive manufacturing have occurred over the past few years. Additive manufacturing processes can be used to produce items made of steel, thermoplastic, and ceramic. A number of additive manufacturing processes exist, each with distinct advantages and disadvantages. When used in combination with advanced measuring methods, additive manufacturing techniques have potential to be the next-generation solution to support spare and replacement items for obsolete equipment.

Deploying new technologies in a nuclear environment can be challenging. In addition to obtaining equipment, start-up includes development of processes, procedures, and quality controls. While it may not be practical for every organization to implement multiple additive technologies, the potential exists to share resources, and to share information on the types of applications to which each additive technology is applied.

What can be done to efficiently deploy additive manufacturing and related measurement technologies to support nuclear power plant spare and replacement item needs?

KEY TAKEAWAY

The increasingly diverse capabilities of advanced manufacturing offer enormous potential as a tool to help manage part obsolescence and provide an alternative method to acquire replacement items that are difficult to purchase. A collaborative effort has potential to increase the efficiency and speed of deployment in the nuclear industry. Collaboration can enable sharing of measurement and manufacturing capabilities, processes, procedures, and information on the types of replacement items fabricated using additive manufacturing.

KEY POINTS

- Applications for additive manufacturing include rapid prototyping, creating tooling/fixturing, and manufacturing parts on-demand.
- Practical challenges to application of advanced manufacturing include concerns about counterfeiting, quality assurance techniques for verification that items meet design, and control of the software and digital equipment used in advanced manufacturing processes.

- Several EPRI members have started to investigate the use of additive manufacturing and advanced measurement technologies.
- A number of additive manufacturing technologies are commercially available, and are in use by other industries (e.g., automotive, aerospace, medical, etc.).

WHAT IS ADDITIVE MANUFACTURING?

Additive manufacturing is a subset of advanced manufacturing and is different in some respects from other advanced manufacturing techniques being researched by EPRI such as Powder Metallurgy-Hot Isostatic Pressing (PM-HIP). Additive Manufacturing (AM) is the term used to describe advanced manufacturing technologies that build three dimensional objects by adding layer-upon-layer of material. Additive technologies exist for a variety of materials including thermoplastics, sand, carbon fiber, metals, concrete, and ceramics. The wide range of additive technologies and methods include:

- Binder jetting
- Material Jetting
- Directed Energy Deposition (DED)
- Powder Bed Fusion (PBF)
- Material Extrusion
- Sheet Lamination
- Vat Photopolymerization

Each method has advantages and disadvantages related to material used for fabrication, size limitations, accuracy, suitability for structural applications, post-processing, and so forth.

Key components in an additive manufacturing process include raw materials, additive manufacturing equipment, and the computer programs necessary to translate digital data into manufacturing instructions.

ADVANTAGES OF ADDITIVE MANUFACTURING AND ASSOCIATED TECHNOLOGY

When used in concert with advanced measurement techniques, additive manufacturing is capable of quickly creating replacement items. Readily available equipment such as laser and structured light scanners can be used to quickly scan an existing item, digitize the information, and convert the data into a format that can be used to manufacture a prototype or final-use item. The ability to quickly and accurately measure and fabricate or "print" existing devices can enhance support of aging and obsolete equipment.

The wide range of material options for additive manufacturing lends the technology to fabrication of many different types of structural, electrical and mechanical items. Advanced manufacturing is being considered and could be rapidly adopted for many non-pressure-retaining and non-structural applications in a nuclear power plant. In addition to direct fabrication of items, additive manufacturing can be used to create tooling and enable rapid prototyping. Due to accuracy and removal of limitations associated with traditional machining and fabrication methods, additive manufacturing can also be used to improve replacement item designs, creating stronger parts, finer filters, etc.

Licensees can adopt additive manufacturing as can suppliers, and the ability to transmit digital information supports collaborative efforts between them. In cases where a specialized additive manufacturing process is required, potential exists for a licensee to scan an item and email the digitized information to a specialty supplier for printing. This provides a tremendous opportunity to ensure and expedite availability of obsolete items.

Additive manufacturing offers opportunity to improve replacement item design, enhanced ability to establish suitability of replacement items, reduced lead-time, and significant cost savings for low volume replacement parts and assemblies.

CHALLENGES

Several challenges are involved in adopting additive manufacturing to support spare and replacement items for nuclear plants, and in particular safety-related equipment. Once equipment is selected procedures and processes for using the equipment must be established. For safety-related applications, activities to assure quality must be incorporated in the processes. Quality assurance may be different as items are being created from the design information, instead of being built to meet a design. Quality assurance provisions need to address measurement or reverse-engineering activities associated with the original item as well as creation of CAD/CAM data and fabrication of the replacement item. Although a wide range of additive manufacturing raw materials exist, equivalency of the additive material to the original material must be established. Depending upon the application, this could involve comparison of chemical composition, mechanical properties, electrical properties, and so forth.

In addition to implementing the technology, it will be important to promote the ability of engineers and supply chain personnel to recognize and identify potential applications for advanced manufacturing. Several EPRI members reported that their interest in additive manufacturing began when an employee experimenting with additive manufacturing at home suggested it as a potential solution for an emerging plant need. If you are someone who started your career before the advent of the internet, you can identify with the time it took to consider searching the web as a primary step in seeking information instead of referencing old textbooks, trade journals, and the like.

EMERGING APPLICATIONS FOR ADDITIVE MANUFACTURING AND ASSOCIATED TECHNOLOGY

Prototyping

An EPRI member utility used light scanning and 3D modeling to reverse-engineer a multiple piece steel assembly illustrated in Figure 1. Although traditional machining was required to manufacture the assembly, the utility used additive manufacturing to create plastic prototypes from the modeling and used them to verify proper fit and function prior to engaging a machine shop to create the assembly pieces.

Tooling and Fixturing

A supplier that regularly participates in EPRI's Joint Utility Task Group meetings used additive manufacturing to create the white fixturing shown in Figure 2 for use in aligning LEDs during assembly of a replacement control module circuit card. Additive manufacturing offers a quick and cost-effective alternative to create custom tooling and fixturing.

Manufacturing Parts on-Demand

Additive manufacturing can be used to print parts used in plant systems and components as well as items used for maintenance.

An initial effort to purchase OEM replacements for a set of male and female obsolete multi-pin connectors resulted in an estimated forty-six (46)-week lead-time at a total cost of $120,000 with a minimum order of 100 male and 100 female connectors. A third-party supplier was able to use structured light measurement to reverse engineer the obsolete pin connectors and fabricate them using a ceramic additive manufacturing

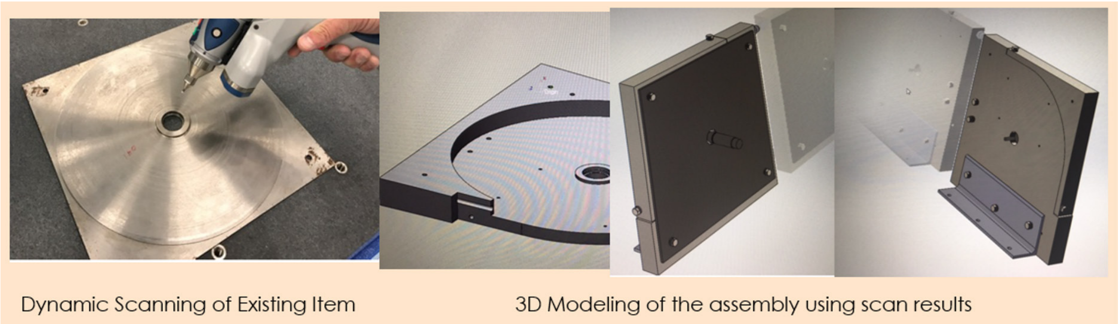

Figure 1. Multiple-piece steel assembly reverse engineered using laser light scanning, modeled, and prototyped using additive manufacturing to confirm fit prior to using the modeling results to manufacture the pieces in a traditional machine shop

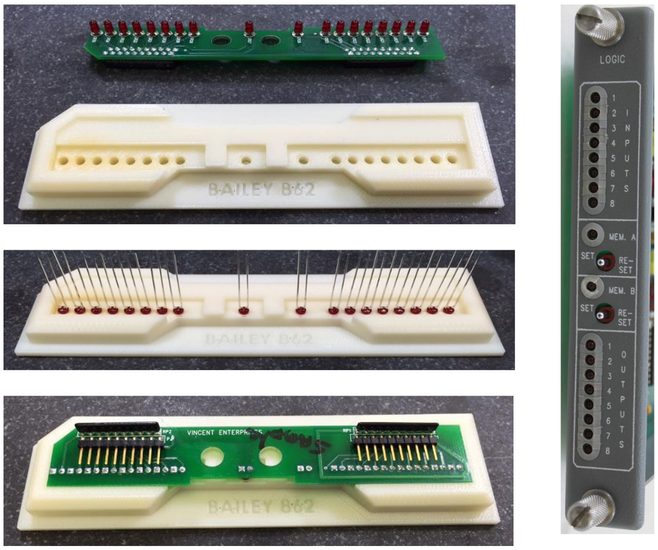

Figure 2. Fixture created using additive manufacturing to align light emitting diodes for successful placement in circuit card and fit in replacement module chassis

process in three weeks. Figure 3 shows the electronic image of the connector body and the resulting connector fabricated using fused deposition modeling. Print time for each connector was ~3 hours, and cost per connector was $150 each with no minimum order requirement. A similar effort to successfully reverse engineer an obsolete circuit card connector resulted in similar savings.

An EPRI member utility was unable to find a replacement for a broken multimeter testing module handle. The OEM was unknown, and no design information was available. The original handle was scanned using structured light. Although it was missing the pieces that had broken, the data was modeled using appropriate software and 3D printed in Carbon fiber reinforced nylon using fused deposition modeling.

An EPRI member utility urgently needed an annunciator name plate housing to support an outage. The OEM quoted a 3-month delivery. The utility scanned the housing using structured light, and modeled it using appropriate software. The utility did not have appropriate additive manufacturing equipment to fabricate the housing but was able to email the file with the completed model to an additive manufacturing shop, that printed the housing using liquid photopolymer stereolithography, and delivered 100 pieces in less than 1 week.

Another EPRI member that has been using additive manufacturing for over a year reports that they have made or prototyped the following types of items:

- Diesel generator sync selector switch
- Chart Recorder Take-up Reel Parts
- Auxiliary Boiler Lens Cap

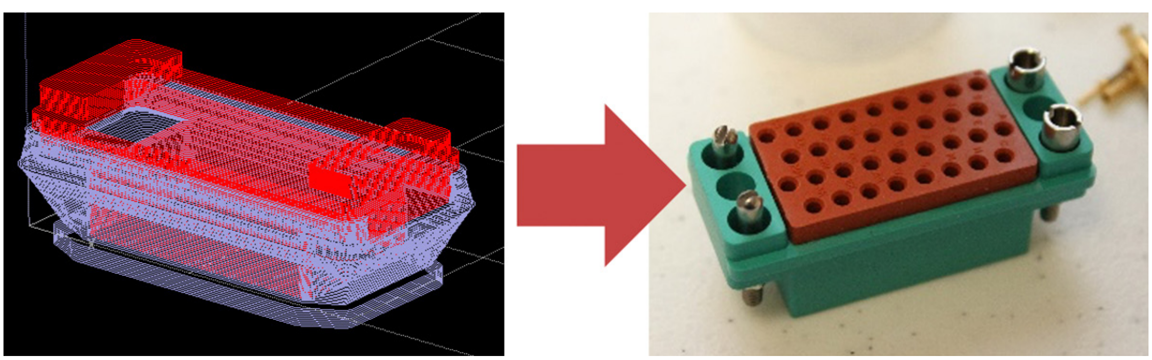

Figure 3. Replacement connector model generated from laser light scanning and the multi-pin connector the model was used to manufacture with additive technology

There are many potential spare and replacement part applications for additive manufacturing, and new ones are being identified regularly.

NEXT STEPS

Assistance from industry is needed to set the stage for advancing use of additive manufacturing in the spare and replacement item arena. Using information provided by industry, activities such as the following will be instrumental in indicating additive technologies and applications that will provide immediate impact in nuclear spare and replacement item applications.

Catalog additive technologies in use by EPRI members (6 months)

Catalog additive manufacturing and associated technologies being implemented by member utilities and their suppliers to develop an understanding of those that are most valuable. Additionally, capture the types of spare and replacement items that each technology is well-suited to manufacture. A survey of EPRI members and associated suppliers is currently underway as a first step.

Create a library of applications (6 months – ongoing)

Develop a library of spare and replacement part applications to capture the types of spare and replacement items that have been successfully manufactured. This information can be made available to EPRI members to promote recognition of opportunities to use the technology and experience the resulting benefits. As an example, obtaining spare and replacement parts for chart recorders has been challenging for many years due to obsolescence. Awareness that one EPRI member has successfully reverse engineered a chart recorder take-up reel will help other members identify the opportunity to do the same and reduce the engineering time needed to determine the appropriate additive manufacturing method and material.

Explore process, procedure, quality control, and best practices (12-18 months)

As the additive manufacturing and associated technologies in use are identified, begin development of guidance that captures best practices and innovative ways to successfully implement the technologies to support both safety-related and non-safety-related spare and replacement items.

Establish equivalency of additive manufacturing raw materials to their traditional counterparts (12 months)

As applications are identified, develop standardized evaluations for the versatile additive manufacturing materials to demonstrate equivalency with the type of materials use to fabricate the original parts being replaced.

Inventory additive manufacturing capabilities (6 months – ongoing)

Develop an inventory of EPRI member and supplier additive manufacturing capabilities. There is potential to share resources such as additive manufacturing and laser light measurement machines. EPRI members that have capabilities with a particular additive manufacturing process might be able to manufacture certain spare and replacement items for other members or provide associated services. Eventually, this could lead to development of regional additive manufacturing centers that specialize in spare and replacement items.

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Advanced Nuclear Technology

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