A New Capability for Advanced Precision Manufacturing

Freeform Printing in Three Dimensions

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The Army Research Laboratory (ARL) and Southern Methodist University (SMU) recently introduced the acquisition of rapid manufacturing equipment that can successfully build complex prototypes and functional components using metal powders, particularly Ti-alloys. The system uses an electron beam as a heat source and operates in a vacuum environment.

In October of 2007 the US Army Research Office provided SMU with a grant to develop the Advanced Precision Supply Parts Manufacturing Program, which would benefit ARL's Weapons and Materials Research Directorate. As part of this grant, SMU, in cooperation with ARL, proposed the acquisition of the newest generation machines that perform solid free form fabrication of fully dense components starting with metal powder as the raw material. The machine acquired is based on a patented technology called "CAD to Metal"®.

The operating principle of the electron beam melting (EBM) process is similar to the operating principle of the selective laser sintering or stereo-lithography process. A solid model of the component is sliced into thin layers. The shape of each layer is used to control a focused electron beam during the sintering of a thin layer of metal powder, which is spread across the powder bed. The sintering process of the layer is done in two steps. First, the top layer of powder is preheated with an electron beam of lower power. Second, the layer of powder is melted using the electron beam at maximum power. Once this sintering process is complete, a new layer of powder is spread over the just sintered layer in order to continue the building of the 3D structure in a layered fashion. Currently, a 4 kW electron beam is used as the heat source, and the entire process is performed in a vacuum.[1]

Compared to laser-beam direct metal deposition, EBM has many advantages, such as higher energy efficiency; easier manipulation; application on any electrically conductive materials, including highly reflective ones; and higher quality buildups since the process is performed in a vacuum. EBM can build solid, porous or hybrid structures that have applications in different industries such as aircraft, automotive, marine equipment, and aerospace. Currently, there are three materials successfully employed by the EBM system: Ti-6Al-4V, Ti-6Al-4V-ELI and a cobalt-chrome alloy. There have been reports of successful usage of other materials such as stainless steel, tool steel, and aluminum alloys for building components by EBM.[1]

In January of 2008, the EBM apparatus was installed at SMU's Research Center for Advanced Manufacturing.[2] This system has two interchangeable working chambers: one is tall and narrow and the other is wide and shallow. The build tank of the taller chamber has dimensions of 7.87 x 7.87 x 13.78 inches. The build

Figure 1. **Component with 3D cooling channels built of Ti-6Al-4V powder by the electron beam process. (Photo provided courtesy of ARCAM AB) [1]**

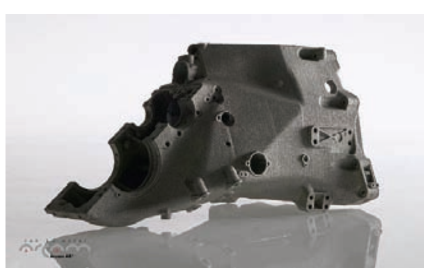

Figure 2. **A complex housing built of Ti-6Al-4V powder by the electron beam process. (Photo provided courtesy of ARCAM AB) [1]**

Figure 3. **A skull built of cobalt chromium alloy by the electron beam process. (Photo provided courtesy of ARCAM AB) [1]**

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Figure 4. **3D component built by the electron beam process. (Photo provided courtesy of ARCAM AB)**

Figure 5. **3D component built of Ti-6Al-4V by the electron beam process.**

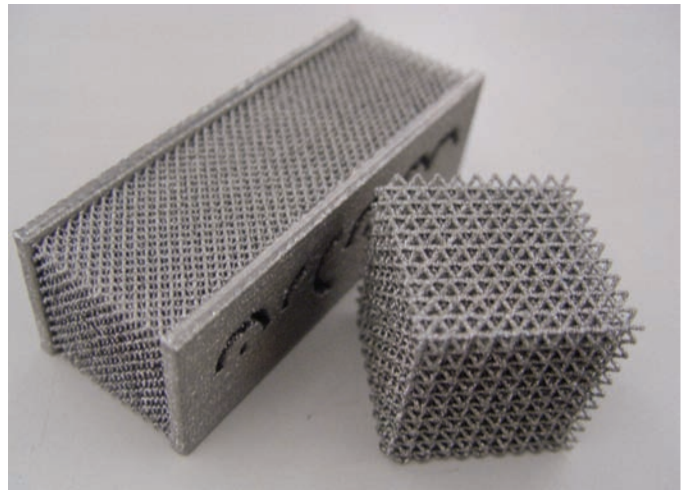

Figure 6. **Lattice structures built of Ti-6Al-4V by the electron beam process.**

tank of the wider chamber, which has the shape of a cylinder, has a diameter of 11.81 in. and height of 7.87 in. This new apparatus, which was made available in May of 2007, has a number of improvements with respect to the older system, such as a 75% larger buildup tank, new software, better heat model and beam quality control. The positioning accuracy of the electron beam has been improved from +/- 0.002 in. to +/- 0.001 in. The thickness of each layer can range from 0.001 to 0.04 in., and the buildup rate is 0.24 in. per hour. [1]

In order to further enhance the direct metal deposition based on the electron beam process, it will be necessary to study the interaction of the electron beam with different types of materials; develop a procedure for qualifying the mechanical and physical properties of the fabricated components; increase the deposition speed; improve the surface quality; and increase the buildup size. Figures 1 through 7 show a variety of components and structures that have been built by the EBM machine.

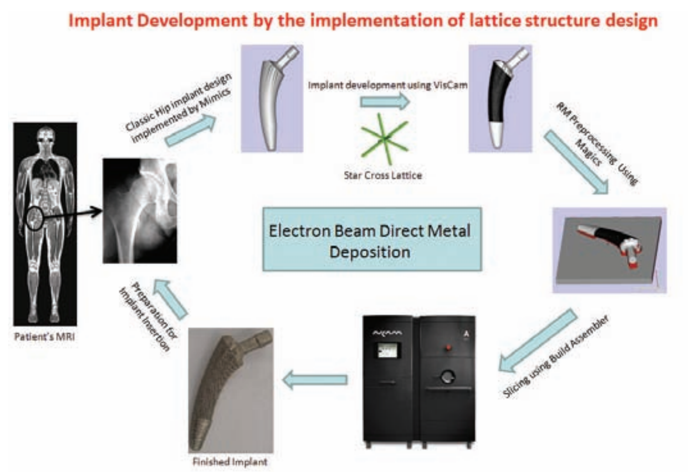

Figure 7. **Application of electron beam system in building medical models and implants.**

NOTES & REFERENCES

* CAD to Metal is a registered trademark of the Arcam AB Company, Sweden.
[1] www.arcam.com
[2] www.engr.smu.edu/rcam and www.engr.smu.edu/clam

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Ms. Pauline Smith is a research chemist at the US Army Research Laboratory with concentration in coatings development and application. Her efforts are focused on research activities and programs to develop and formulate enhanced coatings for DoD equipment with a particular emphasis on US Army tactical vehicles and munitions. Material systems are developed for the direct support of our current armed forces and the Army-After-Next. Prior to joining ARL in 1999, she worked at AKZO Nobel, as a Coatings Formulator and as an Analytical Chemist. Ms. Smith has 17 years of diverse experience in the coatings industry.

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