IS ANYONE PRINTING GEARS USING METAL ADDITIVE MANUFACTURING?
After months of investigation, AGMA’s Emerging Technology Committee has found that additive manufacturing, particularly 3D printing, has the potential to provide many opportunities for gear manufacturers.

By MARY ELLEN DORAN

The AGMA Emerging Technology Committee wanted to look at additive manufacturing through the lens of the goal of the committee: “Identify, investigate, and inform AGMA members of Emerging Technologies that may disrupt or significantly impact the gear manufacturing industry.”

We started out with one question: Is anyone printing gears using metal additive manufacturing?

Our goal was to seek answers and report back to the AGMA community. Eight months later, we are here to report that not only have we seen — and touched — a variety of printed gears from several distinct metal additive manufacturing processes, but we also have gathered enough information to publish a paper on the topic, provide answers to members’ questions during a webinar, and provide a high-level, hands-on tour of metal 3D technology for members.

For those who are not aware, AGMA has been doing work in emerging technology for the last two years. In October 2018, the Association created five unique subcommittees in the areas of 3D metal printing, electric drive technology, Industrial Internet of Things (IoT), new materials, and robotics & automation. Each committee has a chair and participants who come from within AGMA member companies. Additionally, we have sought out experts to provide information to committee members.

Right from the start, the 3D Printing Committee and the New Materials Committee combined forces to tackle the subject of additively manufactured gears. Our 3D Chairman, Justin Michaud, CEO of REM Surface Engineering, had done work with some companies in this space and started to do research on the machines and processes. Bill Bennet, a metallurgist with Ellwood National Forge, began work into the materials side of additive. We reached out with questions to a known expert in the field, Kirk Rogers PhD. Rogers is a materials scientist who has done extensive work in additive manufacturing with GE and is now a consultant at The Barnes Group Advisors. He became a technical adviser to the group and eventually became the lead author of the AGMA paper, Additive Manufacturing Technologies for Gears, available free to AGMA members through the store on the website.

THE PAPER

The paper provides a high-level overview of the Additive Market and descriptions of the seven types of additive manufacturing processes as defined by the American Society of Testing Materials (ASTM), Committee F-42. It then goes into a discussion of this technology specific to gear manufacturing.

Here are some of the high-level points that the committee would like to share:

- Because of similar drivers in other industries, production of metal AM systems and materials sold into AM have been growing at greater than 20 percent compound annual rate since 2014.
- While AM systems were invented more than 30 years ago, they were primarily thought to be used to customize our environment. This technology is also well-known for the ability to reduce the price of complex components, to reduce the number of assembly parts in high-level assemblies, and to provide next generation performance by enabling complex designs. It has only been in recent years that these processes are being looked at and developed as a mass production technology.
- From a materials perspective, metal AM has been dominated by titanium alloys, nickel and cobalt-based superalloys, and stainless steels. Lack of familiar gear steels is one of the factors that has limited the adoption of AM in the power transmission industry. But some of the steels normally used for gear making are available, and more materials are being brought to market every day.
- There is an increase in the number of vendors producing metal AM machines. In 2010, there were seven companies. Now, there are more than 25.
- Specific for gear manufacturers, the most important point of the paper is that production of Grade 2 requirement gears by additive manufacturing is a reality for prototyping and low-volume applications, and several newer machine manufacturers hold promise to manufacture near net shape gear blanks with high productivity and lower cost than was possible only two years ago.
- But it is important to stress the point that the process of additive right now does not mean that a manufacturer can just print gears and be finished. All AM processes that were reviewed by the committee produce parts that require some sort of post-processing, including thermal process. A typical surface roughness on “good” additive processes is roughly 200 to 500 Ra. One example is laser powder bed machines, which produce approximately five miles of welds per cubic inch of material. The end piece will need thermal treatment that is either a stress release or normalizing treatment to develop the microstructure that gives the mechani-
cal properties wanted. The surface finish in AM processes can be compared to a casting surface, and for gears, it would require heat treat and other surface treatment finishing.

Additive manufacturing provides many opportunities for gear manufacturers. Probably the biggest opportunity is complex geometries. Designers can start to think about things they have always wanted to be able to do but have been hindered by conventional manufacturing processes. Additive provides the opportunity to introduce internal cooling or lubrication channels that allow you to put the lubrication in the exact position that would be most beneficial to the heavy-load application. Additive can also help reduce gear system inertia through new designs that are difficult to manufacture conventionally. Designers can improve the durability through the use of multiple optimized materials in a single part. And AM can be used to reduce product-development time and time-to-market.

Probably the most obvious opportunities for gear manufacturers right away are to use AM technology to design and print customized aids, tools, jigs, and other solutions in-house to reduce current development times.

THE WEBINAR

During our metal 3D printing member webinar on May 1, more than 25 questions were fielded by Dr. Rogers by the more than 60 attendees. He provided information on the largest size gears that can be made using laser-powder fusion. On most machines, it is 9.5 inches square; however, the largest machines available have 500mm x 800mm build platforms, so there is the possibility for something in the realm of 15 to 17 inches in diameter. He described the accuracy for laser sintered parts is plus-or-minus about 0.1mm, but that it does vary by application and system. And he provided specifics on machine and materials manufacturers.

Dr. Rogers was asked his thoughts on the future of AM in gear manufacturing. The question specifically asked for a 10-year projection. He was quick to answer that in 10 years he would "expect some very high-end industrial applications being run-of-the-mill, normal, almost boring because it is done by two or three different manufacturers." You can access the full webinar through the AGMA website.

THE TOUR

The final piece of the AGMA 3D Printing Emerging Technology Trifecta was a 3D metal printing tour on the floor of the RAPID/TCT Show on May 23. AGMA set-up formal meet-and-greets with 13 companies that spanned the depth and breadth of both machine makers and material developers. The tour included stops at:

- 3DEO
- Desktop Metal
- EOS North America
- GE Additive
- GEFERTEC GmbH
- GKN Powder Metallurgy
- HP
- Markforged

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Figure 1: Fully heat-treated and machined gears that were 3D printed. These are single tooth bending fatigue gears, which is why they are missing teeth. (Courtesy: QuesTek)
Included on the tour were three AGMA members with distinctly different products.

In mid-April, Mitsubishi Heavy Industries announced the commercialization of a metal 3D printer. The company’s machine, called LAMDA, uses directed energy deposition (DED) technology. Advanced features include inert gas shielding and process monitoring for quality control and documentation. Blended product materials provide increased design flexibility. Applications range from aerospace, automotive, and energy sectors, as well as repair of parts and near net shape parts of Ti alloy.

Committee member Jeff Grabowski was on hand to provide members information on QuesTek and its development of materials for additive. QuesTek is a global leader in integrated computational materials engineering and designs and develops new high-performance alloys for specific customer applications. It is also well known in the industry as the designer of Ferrium® C64® gear steel, licensed to Carpenter Technology and is being qualified for next generation aerospace transmission applications. C64 steel is one of the few carburizable steels that have been successfully atomized and processed via AM. (Figure 1)

And Chairman Justin Michaud discussed the work of REM Surface Engineering in the field of AM. REM is known for its isotropic super-finishing technology, which provides finishes that can increase efficiency and wear resistance as well as bending fatigue resistance in AM applications. Each of the three companies were so vastly different in their placement in the additive field that they were a nice inclusion to the more traditional names in machines and materials developers as well as some newcomers to the industry.

We had 30 individuals from AGMA member companies who attended the tour. The attendees spanned the industry with individuals from machine tool companies, materials development organizations, steel producers, and gear manufacturers. In the post-survey tour, there were two questions that had interesting results for the committee: 73 percent of attendees considered themselves as intermediate in their knowledge of the additive industry. And when asking their reason for attending, nearly 27 percent answered “my company has been looking to invest in this technology.” So, it is not surprising that 20 percent of attendees answered “likely” or “very likely” when asked if they would invest in this technology in the next 12 months.

In the coming months, the committees plan to continue to monitor the development of materials that can be used to print gears. We will work with our members to get more examples of 3D printing gears, as available, and we will watch as the machine technology that has been designed for mass production in additive expands its use in the marketplace to see the future possibilities for the mass production of gears using this technology.

ABOUT THE AUTHOR
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