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In Part 1 of this series, an overview of China's additive manufacturing industry was presented. In Part 2, focus is placed specifically on developments in China's aviation and aerospace industries.

Introduction

In China, as it has been in the United States, defense industry and military involvement play integral roles in additive manufacturing (AM) development and application. This is especially true in aviation and aerospace. Already, Chinese media reports are stating that AM-created parts are being used in the J-15, J-16, J-20, and J-31 jet fighters, the Y-20 transport, and the C919 commercial airliner.

Moreover, China's breakthroughs are gaining high-level attention. In January 2013, a Beijing team of AM researchers led by Wang Huaming received first prize in the State Technological Invention Award (国家技术发明奖) for the use of laser metal deposition to produce what is claimed to be the world's largest 3D printed titanium component—a four meter long primary load-bearing structure that will be used in the C919.[1] In March, at the Chinese People's Political Consultative Conference (CPPCC), J-15 chief designer Sun Cong presented on the military achievements in additive manufacturing.[2]

Initial Development and Benefits

China began work on titanium laser additive manufacturing (LAM) in 1995, three years after the United States made public classified work begun ten years earlier under Department of Defense guidance.[3] Different types of

1 Shi Yang, "钛合金3D打印 2012中国第一发明" [Titanium Alloy 3D Printing—2012 First Prize Invention in China], Guanchazhe , January 21, 2013, http://www.guancha.cn/shi-yang/2013_01_21_122111.shtml.
2 "中国将推出全球首个使用3D打印技术的新一代战机" [China to Launch World's First Use of 3D Printing Technology in New-Generation Fighters], 东方军事 [Eastday Military], March 21, 2013, http://mil.eastday.com/m/20130321/u1a7271729.html.
3 "Titanium Alloy 3D Printing—2012 First Prize Invention in China."

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LAM exist. Laser metal deposition (LMD), the method where most of China's research seems to be focused, is performed by using a laser to melt a pool of metal on a surface and then depositing metal powder through a nozzle into the pool to create a layer of material. Layers are added until a structure is formed.

At first, China tried to replicate U.S. progress, establishing research labs in universities and setting up research institutes. In 2000, Professor Wang Huaming at the Beijing University of Aeronautics and Astronautics formed a new team of researchers. With funding from numerous sources, including the PLA General Armament Department, the Commission for Science, Technology and Industry for National Defense, the National Natural Science Foundation, and the "973" and "863" programs, over the next decade Wang's team developed the LMD technology that would win China's top technology award this past January.[4]

In aircraft production, the use of LAM has two main benefits—cost and efficiency. Compared to traditional methods of subtractive manufacturing, little scrap or waste is produced by additive manufacturing. LAM is cited by Chinese media as saving 90 percent of raw material at 5 percent of the cost of the same part produced through subtractive manufacturing. These numbers, of course, would vary depending on the component being printed.

LAM can also be used to repair damaged parts. Instead of scrapping and replacing damaged components, metal powder can be fused directly onto damaged areas, restoring the original strength of the component. Moreover, LAM (and AM in general) can produce structurally complex shapes that would be cost-prohibitive or even impossible to create using traditional manufacturing processes. In aircraft design, this allows engineers to optimize weight allocation by creating parts that contain only the necessary material without leaving behind material that traditional methods would have difficulty extracting.

Global Applications in Aviation and Aerospace

While China claims to have printed the largest titanium component using LAM, it is not alone in its application of additive manufacturing to aviation and aerospace. In the United States, LAM has been used to make nonstructural production flight hardware components for Air Force fighter jets. More than 900 F-35 parts will be made using AM.[5] Honeywell's T-Hawk Micro Air Vehicle is already using polymer parts made by laser sintering.[6] In February 2012, Dynamet Technology received a qualification approval from Boeing to supply titanium alloy products for structural components on commercial aircraft, which Boeing plans to use as substitutes for parts currently made from standard machined grades of the alloy.[7] In other applications, a rover being designed by NASA for human use on Mars uses about 70 parts, including its pod doors, camera mounts, and vents and housings, made from fused deposition modeling, a type of additive manufacturing.[8]

Outside of the United States, a new research venture between Airbus, Aerosud, and the South African Council for Scientific and Industrial Research hopes to create large and complex aerospace components. Their prototype machine is expected to be completed in March 2013 and then begin a two-year testing, evaluation, and process development phase.[9] In smaller components, the European Aeronautic Defense and Space Company (EADS) Innovation

4 "中国首创3D打印造飞机钛合金大型主承力构件" [China the First to 3D Print Large Primary Load-Bearing Structures from Titanium Alloy], 环球网 [Huanqiu], January 21, 2013, http://mil.huanqiu.com/china/2013-01/3564094.html.

5 "Slideshow: 3D Printing Will Go to Mars," DesignNews, September 13, 2012, http://www.designnews.com/author.asp?section_id=1392&doc_id=250614.

6 "Slideshow: 3D Printing Will Go to Mars."

7 Ann Thryft, "More Than Cars Drive Powder Metals," DesignNews, August 1, 2012, http://www.designnews.com/document.asp?doc_id=248266.

8 "Slideshow: 3D Printing Will Go to Mars."

9 Natasha Odendaal, "Airbus, CSIR, Aerosud Sign Titanium Manufacturing Research Agreement," Engineering News, September 13, 2012, http://www.engineeringnews.co.za/article/airbus-csir-aerosud-sign-titanium-manufacturing-research-agreement-2012-09-13.

Works printed metal hinges for engine covers that met performance requirements in tests for conventional parts in 2011.[10] More recently, EADS used LAM to print an Airbus A380 wing bracket with a more complex shape than the original bracket design.[11]

Applications in Aviation and Aerospace in China

Reports of AM aviation and aerospace developments in China seem to be keeping pace with global trends. In 2010, through the primary research of Huang Weidong at the State Key Laboratory of Solidification Processing at Northwestern Polytechnical University in Xi'an, LAM was used to produce a three-meter long central wing spar that will be used in COMAC's C919 passenger jet.[12] In Beijing, Wang Huaming's team manufactured the C919's front windshield frame in 2009 and a central wing rib in 2010.[13]

These achievements may be an example of technological leapfrogging in China. Compared to the United States and Europe, China lags behind in traditional large titanium component manufacturing, creating a large barrier to meeting the C919's demands.[14] Components such as the C919's front windshield frame, for example, for which no domestic manufacturer exists, were originally planned to be outsourced to foreign suppliers. The windshield frames were to be purchased from a European company at a price of USD 500,000 per frame, with a two-year manufacturing cycle. In 2009, however, Wang Huaming's team reportedly produced the frame in only fifty days at one-tenth the cost.[15] In 2010, the same technology was used to manufacture a central wing rib for the C919. Notable beyond the manufacturing of this component, the roughcast weight of the printed wing rib was 136 kg, 91.5 percent less than the expected 1,607 kg weight that traditional forging would have supplied. Performance testing also showed the printed component outperformed a traditionally manufactured one.[16]

The applications of LAM extend beyond the C919. Sun Cong, chief architect of the J-15, reported that a J-15 variant that took its maiden flight in October 2012 included many titanium main bearing components printed using additive manufacturing, including the complete nose landing gear. Just recently, transport aircraft Y-20 chief designer Tang Changhong stated that the Y-20 is also using 3D printed parts.[17] Reports show that other aircraft, including the J-16, J-20, and J-31, are also being designed to use 3D printed titanium and M100 steel.[18] These military achievements are likely headed by AVIC Ground Laser Technology Co. (中航天地激光科技有限公司), a new company jointly formed in 2011 by Wang Huaming, AVIC Heavy Machinery Co., AVIC Capital, and BUAA Holdings Co. Among

10 Kevin Bullis, "GE and EADS to Print Parts for Airplanes," MIT Technology Review, May 9, 2011, http://www.technologyreview.com/news/423950/ge-and-eads-to-print-parts-for-airplanes.

11 "Slideshow: 3D Printing Will Go to Mars."

12 "激光立体成形：迈向世界领先的步伐" [Laser Solid Forming: Steps Towards the World Leader], 人民网 [People], August 3, 2012, http://finance.people.com.cn/n/2012/0803/c153578-18667333.html.

13 "China the First to 3D Print Large Primary Load-Bearing Structures From Titanium Alloy."

14 "Laser Solid Forming: Steps Towards the World Leader."

15 "北航王华明团队：炼就飞机装机神奇'变形术'" [Beijing University of Aeronautics and Astronautics Wang Huaming's Team: Refining the 'Polymorph' Magic of Aircraft Installed Capacity], 中国教育新闻网 [China Education News], January 19, 2013, http://www.jyb.cn/high/gdjyxw/201301/t20130119_525451.html.

16 "China the First to 3D Print Large Primary Load-Bearing Structures From Titanium Alloy."

17 "运20、歼15广泛使用3D打印迎重磅利好" [Y-20 and J-15 Widely Use 3D Printing, Welcoming Considerable Benefits], 人民网 [People], March 22, 2013, http://scitech.people.com.cn/n/2013/0322/c1007-20878491.html.

18 "媒体称歼20歼31运用3D打印技术降低结构重量" [Media States J-20 and J-31 Use 3D Printing Technology to Reduce Structural Weight], 新浪军事 [Sina], March 15, 2013, http://mil.news.sina.com.cn/2013-03-15/0958718589.html.

the shareholders, AVIC owns 51 percent of the company's holdings.[19] Another player may be Wuhan Binhu Mechanical and Electrical Co. (武汉滨湖机电技术产业有限公司), a company founded by Huazhong University of Science and Technology, where its former manager Cai Daosheng has commented that the company's technology was suitable for producing missiles and that it had many military projects already.[20]

Conclusion

The application of AM in the defense industry is expected to grow as new techniques are developed and refined and as additional materials are introduced. Military and aviation fields are especially suited to be early adopters of AM technology. Additive manufacturing is still expensive and not suited for adoption by mass manufacturing models, but orders in the defense industry that require fewer part orders can benefit from the technology.[21] Highly important, however, along with the opportunity to create more complex and lighter components, is the ability of Chinese manufacturers to domestically produce components that otherwise would have to be outsourced. By keeping pace with global trends, Chinese government officials and researchers hope to bolster their defense industry and play a leading role in the next technological revolution.

19 "王华明获得国家技术发明奖一等奖 中航重机ST航投沾光" [Wang Huaming Receives First Prize in State Technological Invention Award, AVIC Heavy Machinery and ST Air Share in His Glory], 凤凰网 [Phoenix News], January 19, 2013, http://finance.ifeng.com/stock/ssgs/20130119/7577444.shtml. See also 中航重机股份有限公司：关于控股公司中航天地激光科技有限公司股东王华明教授获得国家技术发明一等奖的公告 [AVIC Heavy Machinery: Notice of Holding Company AVIC Ground Laser Technology Co. Shareholder Professor Wang Huaming Receiving First Prize in State Technology Invention], July 7, 2011.

20 Dawei Yu, "China's 3D Printing: Not a Revolution—Yet," Caixin Online, February 18, 2013, http://english.caixin.com/2013-02-18/100491820_2.html.

21 "3D Printing Is Here—But the Factory in Every Home Isn't Here Yet!" Deloitte Canada, http://www.deloitte.com/view/en_GX/global/industries/technology-media-telecommunications/tmt-predictions-2012/technology/ab173e14447a4310VgnVCM1000001a56f00aRCRD.htm#.UVCALRysjTo.