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A Review on Additive Manufacturing in Aviation Industry

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ABSTRACT: Additive manufacturing is changing the paradigm in the aviation industry. It provides opportunities to manufacture the complex parts that are too difficult to produce with legacy machining techniques like turning and milling operations. On the other hand, additive manufacturing provides advantages for weight reduction activities which has a vital importance in the aviation industry. Weight reduction directly reduces the cost of flight and hence provides opportunities for reducing the carbon emissions. In this paper, the correlation between additive manufacturing techniques and weight reduction is provided aiming to create situational awareness for academics, researchers and technical teams in their future studies. Weight reduction directly reduces the cost of flight and hence provides opportunities for reducing the carbon emissions. In this paper, the correlation between additive manufacturing techniques and weight reduction is provided aiming to create situational awareness for academics, researchers and technical teams in their future studies.

KEYWORDS: Additive Manufacturing, Aviation Industry, Weight Reduction.

I. INTRODUCTION

Additive Manufacturing uses a virtual, mathematical model to construct a physical artifact. For example, a designer in the process of creating a new laptop can use a software package to create a three-dimensional model of her creation, that can be manipulated and viewed on the computer screen. The 3D printer can take the symbolic representation of this new object and use it to build a full-size, physical model that can be held and manipulated, helping the designer to better understand the strengths and limitations of her design. (Gargiulo, E.P-1992).

An architect can turn the plans for a building into a three-dimensional model and then “print” a scale model to help him understand and communicate his design. An archaeologist can print duplicates of an important, but fragile, tool so that her students can hold it in their hands and better understand how it might have been used by an ancient civilization. A biochemist can print accurate models of DNA molecules, enlarged by many orders of magnitude, to help students and researchers better understand nature by engaging their hands as well as their eyes in comprehending the geometry of nature. And a student of the arts can create a unique object that would be difficult or impossible to build by hand. (Gargiulo, E.P., 1992,)

We will not here consider other types of computer-controlled manufacturing, such as subtractive machines, which work by cutting away from a larger piece of material in order to build a part. Additive rapid prototyping machines were first introduced twenty years ago, when 3D Systems introduced the Stereo lithography, or SLA machine. While these machines were remarkable for their ability to create complex parts, they were large, expensive, and difficult to operate. (Yaszemski, M.J., Lu, L., 2007)

The aerospace sector encompasses commercial and military aircraft, space launch and in-space systems, missiles, satellites and general aviation. The recent COVID-19 pandemic has had a substantial negative impact on aerospace sector revenue, with a decline from \$342.2 billion in 2019 down to \$298 billion in 2020. This decline was primarily caused by air travel restrictions,

social distancing protocols and other restrictions imposed on the commercial aviation industry during the ongoing COVID-19 pandemic. Despite this challenge, the aerospace sector is expected to grow to \$430.87 billion revenue by the year 2025. This growth is primarily due to the long-term demand for new commercial aircraft, increased global military expenditure, high market activity in the space sector and substantial research and development ongoing throughout the pandemic. Manufacturing in the aerospace sector is subject to numerous interacting technical and economic objectives of: functional performance, lead time reduction, light weighting, complexity, cost management, and sustainment. (C.L., Leong, K.F., Chua, 2001) Each of these objectives has strong relationships to one another

and considerations from each factor must be considered carefully when selecting an optimal design solution. The relative importance of these objectives depends on the specific aerospace application, but in general terms these objectives can be described as follows:

- The objective of lightweighting is tempered by the economic constraints of cost management, whereby a specific financial resource is available for a specific design objective. Cost management, lightweighting and lead time reduction objectives are interrelated, whereby the allowable system cost generally increases for solutions that are able to achieve lightweighting or lead time reduction objectives. Cost management applies to all aspects of component use, including certification and maintenance, and opportunities for cost management by reduced certification risk.
- A critical challenge to metal additive manufacturing (AM) applications in aerospace is the hurdle of certification; requiring that regulatory bodies be confident that the AM systems are fundamentally well understood, and can be repeatably designed and inspected such that reliability and safety expectations can be satisfied. These certification requirements vary according to the criticality of the proposed AM system as being safety or mission-critical or otherwise. Practical certification requires connection with existing standards for traditional manufacturing as well as to standards emerging for AM processes. Aerospace structures are generally high-complexity, low volume systems, where the challenges associated with sustainment can become substantial. Sustainment challenges include part availability for aging aircraft, remanufacture and repair, and recertification of existing aircraft for alternate uses.
- Complexity is inherent to the designs where often hundreds, or thousands of parts make up systems and subsystems to achieve the desired functional performance in the intended environment. These systems are integrated into the overall flight system that can often exceed millions of components. These component are high in complexity to allow for functional performance (structural, flow, thermal, reliability, durability, compatibility, etc.) as well as weight reduction. (Lisa Harouni-2006)

In the drive to improve efficiency continuously through cost, lead time reduction and attempts to lower the mass of flight components, high-performance materials are used, with increasingly complex designs. This must be done within a reasonable cost and schedule to meet commercial orders or mission requirements. Traditional manufacturing systems and strategies have been developed over many decades to accommodate these aerospace design objectives for numerous application types; however AM is and will continue to have a profound impact on the design and manufacturing. This AM digital transformation, often touted as Industry 4.0, will increase its market size in the aerospace sector to \$3.187 billion by the year 2025 with an average compound annual growth rate (CAGR) of 20.24% . Research into AM in aerospace has also seen exponential growth over the last decade. In addition to this scholarly literature, much relevant work exists in the form of technical reports, popular literature and publicity articles from commercial aerospace suppliers, with technical details sometimes restricted for commercial reasons. (Allen, J-2006)

II. FUTURE APPEARANCE OF AEROSPACE INDUSTRY WITH 3D PRINTING.

Nanocomposites are very attractive as materials because they combine the properties of nanomaterials as well as the host materials matrix . Adding nanoparticles can improve mechanical properties, enhance electrical and thermal conductivity, decrease sintering temperature, and can have an impact on the dimensional accuracy . One method to introduce nanomaterials in a 3D print object could be by having intermittent stoppages of the 3D print job and then adding the nanomaterials to the host matrix material either manually or automatically. The second method would be to pre-mix the nanomaterials with the host matrix and then 3D print using the mixture.

Areas where 3D printing could be adopted quickly would be unmanned air vehicles and experimental aircrafts, as these require the least regulatory scrutiny . 3D printing could also be adopted in operational aircrafts still in service long after their production has stopped. The parts for such aircrafts are difficult to support, but with 3D printing, this is no longer a problem. For example, the cockpit of the Panavia Tornado is now equipped with protective covers on radio switches produced by 3D printers while a similar device makes support structures for cabin crew seats on the Airbus A310 .

Despite on-going intense research works, the adoption rate of AM in aerospace manufacturing industry is still slow. This can be attributed to a couple of reasons. The primary concern is the strict certification requirements that are inherent to the safety of air and space crafts. Testing and safety standards for AM in aerospace are still under development. Also, it is not easy to identify a set of certification rules given that different AM technologies are still on their way to being fully matured. Another reason for the slow AM adoption is the high energy demand; it is sometimes many folds greater than the traditional manufacturing. These issues need to be addressed before aerospace industry fully adopts AM. (Barz A., Buer T.,2016)

But in general, AM is a promising proposition in terms of hard benefits as depicted.



Fig. 1. TO and AM of Airbus A320 nacelle hinge bracket. Left: TO design process. Right: Original bracket (top) and final TO optimized design (bottom) . Original steel bracket = 918 g; TO and AM bracket in Ti6Al4V = 326 g.(M. Lang,2019)

III. CHALLENGES AND OPPORTUNITIES

Overview

Metal AM technologies show great potential for technical and commercial advantages for aerospace applications, as is evident from the applications reviewed in the previous sections.

Despite the technical and commercial opportunities enabled by metal AM, these technologies are subject to unique challenges for implementation in aerospace applications. This section highlights some of the current major challenges and some future opportunities.

(M. D. Ugur, B. Gharehpapagh,2017)

Certification & standards

A major current challenge is the lack of technological standards and certification approaches present for metal AM in the aerospace industry, which is caused by the rapid growth in AM technologies over the last decade.

These standards need to be refined and agreed upon across industry to assure the repeatability, reliability and quality of AM components for aerospace sector applications. Major governing bodies such as the European Union Aviation Safety Agency (EASA), NASA, European Space Agency (ESA), and Federal Aviation Administration (FAA) are imposing increasingly strict testing protocols and certifications that are required for the use of aerospace components in service for both mission-critical and non-critical applications.(M. D. Ugur, B. Gharehpapagh,2017)

Design for AM

Design for AM (DfAM) can be used to optimize the design for the best manufacturing quality, minimizing support structures and post processing requirements.

This can also be done in combination with build simulations to determine optimal orientation of the part on the build platform, help determine build strategies to minimize residual stresses and resulting distortion, and minimizing support structures.

Such simulations and DfAM methods are time consuming and dependant on the engineering skill of the AM engineer, and on the computing power of the computer used, but may be necessary. (M. D. Ugur, B. Gharehpapagh,2017)

IV. POWDER REMOVAL & POST PROCESSING

Post-processing is a critical step in metal AM that is often underestimated. For complex parts with fine feature sizes, trapped powders can be a challenge to remove. This is compounded by the difficulty in handling such powders due to safety concerns. Typical approaches involve rotational movements, tapping and blowing powders out of surface cavities and channels. Trapped powders can be observed in CT scans, but may be permanently trapped if not removed

prior to heat treatment.(Chua, C.K., Du, Z., 2001). Further post-processing steps might involve support removal, surface finishing and other heat treatments. For all post processing steps, care must be taken to prevent damage (e.g. when removing supports) to ensure the part conforms to the design and does not include surface damage. Surface polishing, machining or other processing is further challenged as AM part complexity increase and must be carefully designed for early in the process.(Chua, C.K., Du, Z., 2001)

V. 3D PRINTING & INDUSTRY 4.0

The 4 th Industrial revolution or Industry 4.0 encompasses a variety of technologies and this German concept is going to change the manufacturing industry. It involves the various concepts such as inter- machine communication, Internet of Things (IoT) so as to enable automation and develop machines with minimum technical intervention by humans. Keeping in view the technical aspects of 3D printing and the goals of Industry 4.0, 3D printing is an important component in the concept of Industry 4.0. Further, the recent advancements in the area of 4D Printing wherein development of smart materials has become possible has further increased the role of additive manufacturing in the industry 4.0. While the concept of Industry 4.0 also involves digitalization of industries, 3D printing can play a vital role in the industry 4.0 scenario. Industry 4.0 also aims to develop an industrial set up wherein, the systems are autonomous and there is sufficient inter- connectivity amongst the employees, machines, suppliers and the end users. In the aforementioned discussion, we have included the different materials, processes and technologies related to 3D Printing. The various benefits of 3D Printing such as digital data transfer, remote access, need for minimum human intervention, ability to develop complex geometries and smart materials, less wastage, less post processing requirement shall help to achieve the goals of Industry 4.0. (B. Gharehpapagh-2017)

VI. CONCLUSION

3D printing is definitely revolutionizing the world of manufacturing, even in a most advanced and sophisticated industry like aerospace industry. This industry works around 2 basic principle requirements – low weight and high safety. 3D printing has been able to aid reduction in weight through complex and net shape manufacturing with less number of joints and intricate geometry. However, from the safety aspect, it is still a long way before being the reliable standard. Many challenges such as, printing patterns, porosity built-up, uneven print flow, etc. need to be solved and eliminated completely. It is just a matter of time. Once that happens, 3D printing would replace more and more traditional manufacturing techniques currently used in the aerospace industry and will definitely have a sustained adaptation and growth.

At present, 3D printing technology is beginning in the manufacturing industries, it offers many benefits to the people, company and government. Therefore, more information is needed to progress on ways to enhance the adoption of 3D printing technology. The more information about 3D printing technology will help the company and government to upgrade and improve the infrastructure of 3D printing technology. Thus, this paper is to overview the types of 3D printing technologies, materials used for 3D printing technology in manufacturing industry and lastly, the applications of 3D printing technology. In the future, researchers can do some study on the type of 3D printing machines and the suitable materials.

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