ISSN No:-2456-2165

# The Additive Manufacturing Technologies in the Aviation Industry with the Perspective of Weight Reduction

T. Saracyakupoglu*
Department of Mechanical Engineering, Ostim Technical University
Ankara - Turkey

**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.**

***Keywords:-*** *Additive Manufacturing, Aviation Industry, Weight Reduction.*

## I. INTRODUCTION

The aviation industry is a “strategic high-tech industry” which reflects a country's overall national robustness and the overall industrial level [1]. International Civil Aviation Organization (ICAO) declares that the global air traffic has doubled in size once every 15 years since 1977 and will continue in this trend [2]. Furthermore, the International Air Transport Association (IATA) declares that 8,2 Billion people will fly in 2037 means that there’s an increasing demand from customers for flying more frequently at the global stage [3]. For meeting this increasing air traffic demand and replacing the retired airplanes until 2037 approximately 161.500 new commercial airplanes will be delivered by the aircraft manufacturer companies. The distribution of brand-new airplanes is presented in Table 1.

| Aircraft Manufacturer | Number of Aircraft |
|---|---|
| Boeing | 42.730 |
| Airbus | 37.400 |
| Comac | 42.702 |
| Bombardier (2017-2036) | 25.100 |
| Embraer | 10.550 |
| ATR | 3.020 |
| **Total** | **161.502** |

Table 1:- The projection of the market-dominating aircraft manufacturers until 2037 [4,5,6,7,8,9].

It is worth noting that, the total brand-new commercial aircraft number will be more than 161.500 considering general aviation airplanes and small-sized manufacturers. Consequently, the aviation industry is a booming sector with trillion dollars of market value and therefore the competition is fierce.

On the other hand, additive manufacturing is a disruptive technical innovation whose history goes back nearly three decades [10]. It gives opportunities to manufacture the parts which were never before possible with using conventional subtractive, chip-away machining processes. Since the aviation materials are highly engineered they are generally hard to handle and expensive. In this context, during manufacturing operations, the material wastage is an unwanted situation. On the other hand,
since traditional CNC machining processes are subtractive techniques, the material wastage could be as high as 98% [11].

“Buy-to-Fly ratio” is a key indicator of the benefit-cost analysis in the manufacturing industry. It can be defined as the weight ratio between the raw material used for a part and the weight of the part itself. With the benefit of additive manufacturing technologies, the buy-to-fly ratio can be as low as 1:1 whereas it can be as high as 33:1 in some cases with legacy methods. [12]. Besides, for additive manufacturing processes compared with traditional machining processes scraps can be as low as 10%, parts costs down can be as low as 50%, time-to-market down can be as low as 64%, part weight down can be as low as 64% [13]. In this context, weight reduction is important for cost-effectivity. The weight reduction can be advantageous to use less material and to avoid to consume energy in transportation. It also benefits of reducing pollution emissions [14].

## II. MATERIALS AND METHODS

In the open literature, an investigation has been executed for figuring out the weight reduction studies in the aviation industry. It has been observed that with the benefits of the additive manufacturing technologies many advantages have been reflected to airplane manufacturer companies. e.g. General Electric (GE) which is an airplane engine manufacturer, produced a fuel nozzle for Leading Edge Aviation Propulsion (LEAP) engines, had 20 parts combined into one part, manufactured in a single machine and weighed 25% less than the traditionally produced predecessors [15]. In October 2018, GE announced that 30.000th nozzle was produced at GE's facilities [16]. It is also reported by GE, that the nozzle is five times more durable than those manufactured using legacy methods [17]. In accordance with GE sources, the total manufacturing will be around 40.000 by 2020 [18].

In another study, European Aeronautic Defense and Space Company (EADS) redesigned the nacelle hinge brackets of Airbus A320. The brackets weight saved up to 64% while keeping the mechanical features satisfactory [19].

In another study, for an Airbus project which is called as SAVING, by redesigning the seat buckles of Airbus 380, 55% weight has been saved over seat buckles. With the help of the additive manufacturing techniques, weight reduction is almost a total 72,5 kg of weight if all the seat buckles of the Airbus 380 which 853 seats were to adopted [20]. With project SAVING, totally "3.3 million liters of fuel savings" is targeted to gain over the service life of the Airbus A380 aircraft [21].

In the military aviation side, side there are some studies also such as Lockheed Martin's F-35 engine Bleed Air Leak Detector bracket (BALD), the buy-to-fly ratio is reduced to 1:1, as against the 33:1 ratio possible by legacy methods with the advantage of 50% in total cost [22].

## III. PERSPECTIVE OF WEIGHT REDUCTION

In Fig 1. it is shown that for operational cost, the top driver is the fuel consumption with the percentage of 33,4%. The second item, "Aircraft Ownership" is far below than fuel item with its 10,6 percentage [23]. It is worth noting that, fuel usage means some other energy consuming process such as extraction, processing, distribution, and storage of the fuel. So it can be figured out that, decreasing the fuel cost will provide benefits of making cheaper flights.

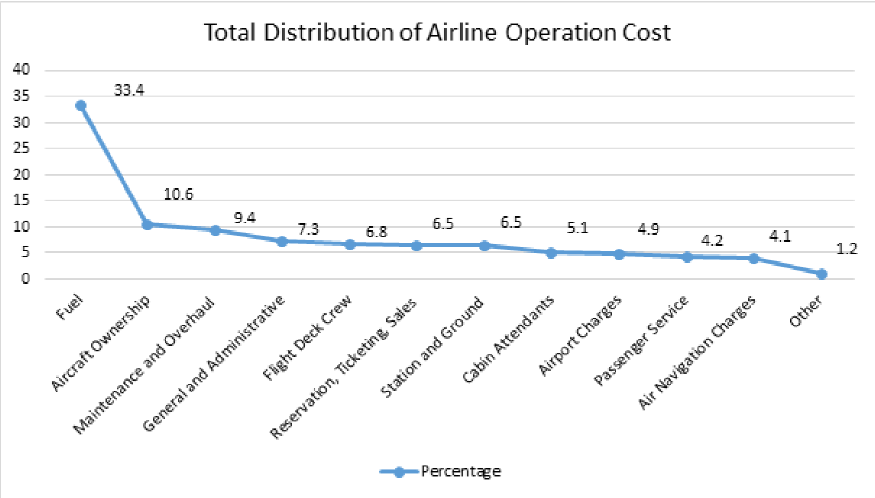


Fig 1

Reducing one pound of weight from each aircraft of a 600+ fleet of commercial aircraft could save about 11,000 gallons of fuel annually [24]. The reduction of 1 kg built-in aircraft weight is able to reduce carbon emissions by 0,94 kg for the case of the Boeing 747-400 which has maximum-take-off-weight is 396,890 kg and by 0,475 kg in the Airbus A330-300 which has maximum-take-off-weight is 242,000 kg. Furthermore, with a reduction of 1 kg of carbon emissions can also save up to 0,3 kg of aviation fuel [25].

Thanks to the weight reduction studies in Boeing, for the aircraft type, Boeing 777-300 has improved its fuel economy against Boeing 767-300 and managed to take up to 368 passengers compared to 269 passengers in Boeing 767-300 ER [26]. So the weight reduction provides benefits of fuel saving and carrying more passengers.

## IV. CONCLUSIONS

This study highlights the importance of weight reduction studies in the aviation industry. Weight reduction is possible by the implementation of additive manufacturing processes into the airplane manufacturing industry. Additive manufacturing processes appear almost perfectly suited to aviation industry, allowing lighter parts to be produced for a lower cost but with the mechanical features equal to conventional machining techniques.

With the increasing demand for more flying, there will be a fiercer competition in the aviation industry. Using the additive manufacturing technologies in the aviation industry have benefits of reduction of the weight of the airplane, thus reducing the fuel consumption and therefore carbon emissions. In the aviation industry, the percentage of additively manufactured part usage will increase because of additive manufacturing techniques' unbeatable advantages.

## REFERENCES

[1]. Fei Ma,Wenjun Cao,Yuguo Luo,Yang Qiu, "The Review of Manufacturing Technology for Aircraft Structural Part", Elsevier, 2016, pp 1

[2]. International Civil Aviation Organization (ICAO), Capacity and Efficiency Report, 2016–2030 Global Air Navigation Plan, 2016; pp 7

[3]. IATA, Forecast Predicts 8.2 billion Air Travelers in 2037, www.iata.org/pressroom/pr/Pages/2018-10-24-02.aspx, last accessed : 04th June 2019

[4]. Boeing, Commercial Market Report, 2018-2037, USA, 2018; pp 3

[5]. Airbus, Global Market Forecast, Global Networks Global Citizens, 2018-2037, France, 2018;

[6]. COMAC releases Market Forecast Report (2018-2037), www.english.comac.cc/news/latest/201811/14/t20181114_6610546.shtml, last accessed: 04th June 2019.

[7]. Bombardier Commercial Aircraft, 2017-2036 Market Forecast, Canada, 2018; pp 6

[8]. Embraer, Market Outlook Report 2018-2037, Brazil, 2018; pp 6

[9]. ATR, Turboprop Market Forecast 2018-2037, France, 2018; pp 6

[10]. Dipaola M., Wodajo M. F. 3D Printing in Orthopaedic Surgery, 2019, Elsevier, UK, 2019; pp 4

[11]. Allen, J. An Investigation into the Comparative Costs of Additive Manufacture vs. Machine from Solid for Aero Engine Parts. Manufacturing Technology Rolls-Royce plc, Unclassified Report, UK, 2006; pp 1

[12]. Barz A., Buer T., Haasis H.-D., A Study on the Effects of Additive Manufacturing on the Structure of Supply Networks, International Federation of Automatic Control, Elsevier, UK, 2016; pp 4

[13]. Deloitte University Press, Additive manufacturing takes flight, 3D opportunity in aerospace and defense, USA, 2014; pp 4

[14]. Ceruti A., Marzorca P.,Liverani A., Bil C., Maintenance in Aeronautics in an Industry 4.0 Context: The Role of Augmented Reality and Additive Manufacturing, Journal of Computational Design and Engineering, Elsevier, UK, 2019; pp 5

[15]. GE Reveals How Greg Morris Created the 3D Printed Nozzle for the LEAP Jet Engine, www.3dprintingmedia.network/ge-reveals-greg-morris-created-3d-printed-nozzle-leap-jet-engine/, last accessed : 04th June 2019

[16]. New manufacturing milestone: 30,000 additive fuel nozzles, www.ge.com/additive/blog/new-manufacturing-milestone-30000-additive-fuel-nozzles, last accessed : 04th June 2019.

[17]. GE9X;World's First Plant to Print Jet Engine Nozzles in Mass Production, www.ge.com/reports/post/91763815095/worlds-first-plant-to-print-jet-engine-nozzles-in/, last accessed : 04th June 2019.

[18]. Gorelik M., Additive Manufacturing for Reactor Materials and Components Public Meeting, November 28-29, 2017, North Betesda, MD, USA; pp 35:8

[19]. Weihong Z., Zhu J., Gao T., Topology Optimization in Engineering Structure Design, Elsevier, UK, 2016; pp 258

[20]. Badiru A., Valencia V. V., Liu D., Additive Manufacturing Handbook, Product Development for the Defense Industry, Taylor and Francis Group, USA, 2017; pp 272.

[21]. Sarat S, Yifan LV, Hewitt A, Chalk R., Thomas W and Jordison D, Additive Manufacturing for the Aircraft Industry: A Review, Journal of Aeronautics & Aerospace Engineering, Spain, 2019; pp 8

[22]. Dehoff R, Duty C, Peter W, Yamamoto Y, Chen W, et al. Case study: Additive manufacturing of aerospace brackets. Advanced Materials and Processes, 2013; pp 171

[23]. Ferjan C., Airline Operational Cost Task Force (AOCTF), Airline Cost Management Group (ACMG), Airline Cost Conference, Swiss, August 26-27, 2014; pp 12

[24]. www. 3D opportunity in aerospace and defense, Additive manufacturing takes flight, Deloitte University Press, 2014; pp 4, 19

[25]. Tsai W.H., Chang Y.C., Lin S.J., Chen H.C., Chu P.Y., (2014). A green approach to the weight reduction of aircraft cabins, Journal of Air Transport Management, Elsevier, UK, 2014; pp 71.

[26]. Mansor M.R., Nurfaizey A.H., Tamaldin N., Nordin M.N.A., Natural fiber polymer composites: utilization in aerospace engineering, In: Biomass, Biopolymer-Based Materials, and Bioenergy: Construction, Biomedical, and other Industrial Applications, Woodhead Publishing, Elsevier, UK, 2019; pp 220