

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

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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.**

**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
<b>Total</b>	<b>161.502</b>

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 30,000<sup>th</sup> 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.

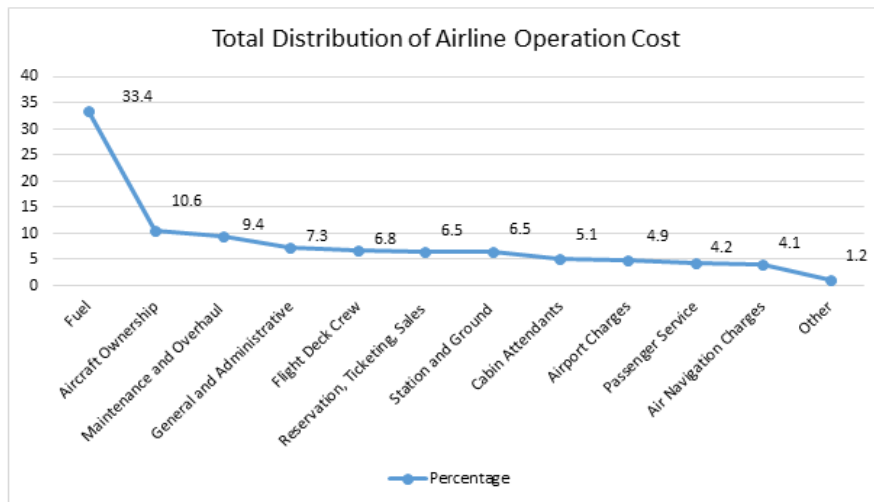


Fig 1

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.

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