FUOYE Journal of Engineering and Technology, Volume 7, Issue 1, March 2022 ISSN: 2579-0617 (Paper), 2579-0625 (Online)

# Weight Estimation Study of ABT-18 Unmanned Aerial Vehicle

[1]Ahmed A. Shinkafi, *[2]Ameer Mohammed, [3]Abubakar Isah and [1]Ananwune C. Olisaemeka
[1]Aerospace Engineering, Air Force Institute of Technology, Kaduna, Nigeria
[2]Mechatronic Engineering Department, Air Force Institute of Technology, Kaduna, Nigeria
[3]Automotive Engineering Department, Air Force Institute of Technology, Kaduna, Nigeria
**a.shinkafi@gmail.com | m.ameer@afit.edu.ng | dankade01@gmail.com | ameer.mohammed.13@ucl.ac.uk**

**ORIGINAL RESEARCH ARTICLE**
Received: 10-NOV-2021; Reviewed: 14-DEC-2021; Accepted: 10-FEB-2022
http://dx.doi.org/10.46792/fuoyejet.v7i1.732

**Abstract**- During the design process of any aircraft, weight is the most important variable. The cost of the aircraft and its performance depend on its weight to achieve its planned mission. This work estimated the weight of a converted ABT-18 aircraft to an unmanned aerial vehicle (UAV) which could be deployed for long-endurance surveillance missions. The study revealed that after all the modifications, the all-up mass (AUM) of 841 kg of the ABT-18 standard version is reduced to 789 kg for the ABT-18 UAV. Additionally, the operating empty mass of 538 kg of the ABT-18 standard version was reduced to 471 kg for the ABT-18 UAV. Thus, a reasonable amount of weight was reduced from the ABT-18 aircraft. Consequently, ABT-18 UAV performance will be improved; since the aircraft weight is reduced and will result in less fuel consumption and less emission of harmful gases.

**Keywords-** Aircraft Performance, Environmental Emission, Surveillance, Weight Estimation.

◆

## 1 INTRODUCTION

Unmanned aerial vehicles (UAVs) in recent times have found application in areas like agriculture, medical logistics in addition to military applications (Karthik et al., 2017; Khuntia & Ahuja, 2018; Triet et al., 2015; Yayli et al., 2017). Nevertheless, during the design process of any aircraft, weight is the most important variable that affects the cost and performance of the aircraft (Al-Shamma & Ali, 2013; Dababneha & Kipouros, 2018). Amarildo and Paulo (1999) stated that estimation of an aircraft weight in the conceptual design stage is a critical aspect of design process. Thus, weight prediction during the design of an aircraft is required for estimating its performance; determining its centre of gravity and undercarriage design. Also, it is useful for the careful valuation of aircraft design quality, and it influences the design decision (Al-Shamma & Ali, 2013; Bai et al., 2014; Essari, 2018; Shinkafi et al., 2021).

However, as reported by Thyagarajan and Sharma (2014), weight minimisation of an aircraft design is a subject of extreme importance considering the aspect of cost estimation. In the work by (Dababneha & Kipouros, 2018), it was revealed that reducing the weight of an aircraft structure has an impact in reducing its operating empty weight (OEW). Thus, letting the aircraft fly for a longer range and having a higher endurance. Again, the weight saved may be utilized to lessen the aircraft Maximum Take-off Weight (MTOW) or to increase the payload or fuel weight. For aircraft weight savings, advanced materials and sophisticated manufacturing methods are considered (Thyagarajan & Sharma, 2014). Where, rapid, graphical and semi-empirical methods are usually employed in weight estimation of an aircraft during its design process. More details about these weight estimation methodologies are found in (Al-Shamma & Ali, 2013; Dababneha & Kipouros, 2018; Thyagarajan & Sharma, 2014). The work by (Al-Shamma & Ali, 2013), carried out an aircraft weight estimation in an interactive design process where a new method was developed to increase the accuracy of estimating MTOW to better than 5%. The results of the study agreed with the published data of current Boeing 747-200B aircraft. The work by Gündüz et al. (2007) carried out weight estimation using Computer Aided Design (CAD) in initial rotorcraft design. The CAD method supports obtaining detailed weight calculation earlier in the design stage, and in turn, lessens development costs. This technique depends on CAD drawings of all components of the aircraft along with the whole aircraft.

To increase the functionality, range and endurance of an existing aircraft; it could be modified to a UAV. Items like camera and supply drop mechanism could be incorporated on the aircraft. As such, this work estimates the weight of a modified ABT-18 that is converted to a UAV. However, the various design weight estimation methods mentioned cannot be employed since the aircraft is an existing crewed aircraft, see Fig. 1. The major changes include its propulsion system and camera installation for surveillance. These changes require that its weight be assessed to fully analyse its performance, centre of gravity determination, design of the undercarriage and providing weight limits to various departments to set a goal for the structural and systems design. Thus, the methodology in this study is basically identifying the masses of the components to be removed or modified. This is achieved using software modelling and physical measurements. The aircraft weight is anticipated to be considerably changed from the original ABT-18 aircraft.

Thus, this work estimated the weight of a converted ABT-18 aircraft to a UAV which could be deployed for long-endurance surveillance missions. The rest of the paper is organised as follows. The methodology for weight estimation is presented in Section 2. Section 3 presents

---

*Corresponding Author

**Section C-** MECHANICAL/MECHATRONICS ENGINEERING & RELATED SCIENCES
**Can be cited as:**
Shinkafi A.A., Mohammed A., Isah A. and Olisaemeka A.C. (2022): Weight Estimation Study of ABT-18 Unmanned Aerial Vehicle, *FUOYE Journal of Engineering and Technology* (FUOYEJET), 7(1), 57-60. http://dx.doi.org/10.46792/fuoyejet.v7i1.732

and discusses the obtained results. Concluding remarks are presented in Section 4.

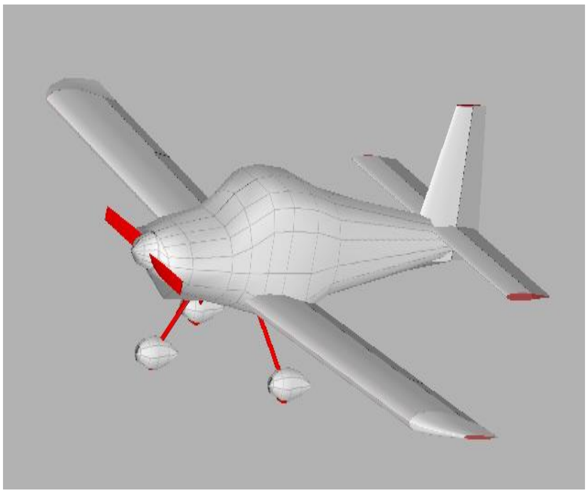


Fig. 1: ABT-18 aircraft CAD model

## 2 METHODOLOGY

An aircraft is an arrangement of lots of parts; the wing, engine, fuselage, and tail, plus the payload and the fuel. Individually, these parts have weight which can be calculated using Newton's weight, Equation 1. In this study, the Software modelling was done using CAD and physical measurements involved the use of electric weighing device (see Fig. 2). These were used to obtain detailed masses of the components. The major changes in the ABT-18 aircraft include its propulsion system and camera installation for surveillance among others. Therefore, the structural weight estimation will not be covered. The mass of the components to be eliminated or modified were identified appropriately as well as the mass of the additional components required to operate the aircraft as a UAV.

$$W = m \times g \quad (1)$$

where w is the weight, m is the mass, and g is the gravitational constant which is 9.8 meters/square sec. The overall weight, W of the aircraft is basically the summation of the weight of all of the components, see Equation 2.

$$W = w_{component\ 1} + w_{component\ 2} + w_{component\ 3} + \cdots \quad (2)$$

For UAV operations, the pilot and other related components are not needed. Therefore, the cockpit will be moved to a ground station among other components. Besides doing away with some components, specific components of the ABT-18 aircraft will be modified to facilitate the aircraft to operate as a UAV. These components include the engine, propeller, engine mount among others. Also, the design of the UAV is based on long-endurance missions. Thus, some components are needed for the effective operation of the ABT-18 aircraft. The most important components needed include the auxiliary fuel tank for the long endurance mission and the surveillance camera. The remaining needed components consist of avionics equipment, antennas, servos, etc.

Fig. 2: Electric weighing device

# 3 RESULTS AND DISCUSSION

## 3.1 WEIGHT OF COMPONENTS ELIMINATED

Table 1 presents the components (with their corresponding weight) that will be removed from the aircraft due to its transfiguration to a UAV. Fig. 3 shows the weight percentage of components to be removed.

As observed the aircraft weight is decreased considerably because the two pilots weighing 80 kg are removed. This represents 67% savings in weight.

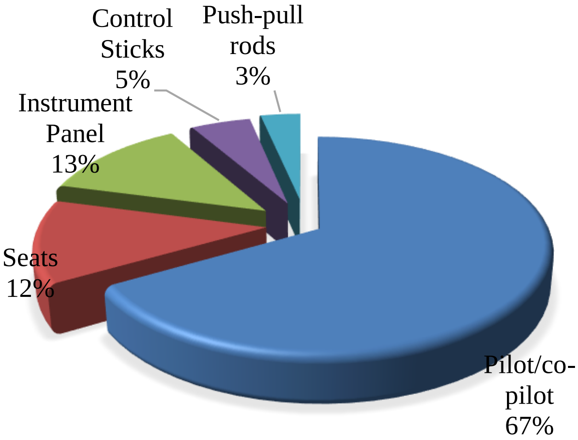


Fig. 3: Breakdown of percentage of mass of components removed.

Table 1. Mass of components to be eliminated

| Components | Qty. | Component mass (kg) | Total mass (kg) |
|---|---|---|---|
| Pilot/co-pilot | 2 | 80 | 160 |
| Seats | 2 | 15 | 30 |
| Instrument Panel | 1 | 30 | 30 |
| Control Sticks | 2 | 6 | 12 |
| Push-pull rods | 2 | 4 | 8 |
| | | **Total** | **240** |

Table 2. Mass of components prior to and after modifications

| Component | Mass Before Modification (kg) | Mass After Modification (kg) | Mass Difference (kg) |
|---|---|---|---|
| Engine | 117 | 78 | 39 |
| Propeller | 11.5 | 7.2 | 4.3 |
| Engine mount | 8.8 | 6 | 2.8 |
| Bulk head | 15 | 14.5 | 0.5 |
| Nose landing gear | 18.9 | 25 | -6.1 |
| Main landing gear | 58.7 | 60 | -1.3 |
| Speed brake and servo | 4 | 5 | -1 |
| **Total** | **233.9** | **195.7** | **38.2** |

Table 3. Masses of additional components required for the UAV operation

| Component | Qty. | Mass of components (kg) | Total mass (kg) |
|---|---|---|---|
| Surveillance camera | 1 | 20 | 20 |
| Auxiliary fuel tank and fuel | 1 | 130 | 130 |
| Elevator servo | 4 | 3 | 12 |
| Aileron servo | 4 | 3 | 12 |
| Rudder servo | 2 | 3 | 6 |
| Flap servo | 4 | 3 | 12 |
| Speed brake servo | 1 | 2 | 2 |
| Antenna | 1 | 0.2 | 0.2 |
| Battery | 1 | 7 | 7 |
| Avionics equipment | 1 | 25 | 25 |
| **Total** | | | **226.2** |

### 3.2 COMPONENTS MODIFIED

Table 2 presents the mass of some of the components modified. The highest weight is recovered through the type of engine carefully chosen. The engine of the ABT-18 aircraft (Textron Lycoming 0-360 A1A) weighs up to 117 kg (dry weight). Textron Lycoming 0-360 A1A is a four cylinder, horizontally opposed four-stroke engine. Whereas, the engine carefully selected for the ABT-18 UAV (UL350is) weighs 78 kg. Similarly, UL350is is a four cylinder, horizontally opposed four-stroke engine featuring modern fuel injection. Accordingly, 39 kg was recovered by changing the engine of the aircraft. Conversely, observing Table 2 for instance, the landing gears have their masses increased when the aircraft is modified.

### 3.3 MASS OF ADDITIONAL COMPONENTS REQUIRED TO OPERATE THE AIRCRAFT AS A UAV

Table 3 presents the components needed to be incorporated into ABT-18 aircraft for effective UAV operations. Fig. 4 shows the weight percentage of the components to be added. Fuel and the fuel system dominated the weight of the newly added components. The antenna has the smallest contribution with less than 1%.

Table 4 compares the all-up-mass (AUM) and operating empty mass (OEM) of the aircraft for the standard ABT-18 and ABT-18 UAV. A total mass of 240 kg will be removed from the standard ABT-18 aircraft, see Table 1. Additionally, the overall mass that will be brought into the ABT-18 UAV is 226.2 kg; of which, 58% is the auxiliary fuel tank and the fuel inside, see Table 3.

Fig. 5 shows that considerable mass was reserved merely in the course of modification of the components. The mass of the components added, 240 kg is appropriately close to the mass of the components removed, 226.2 kg. This is due to the great amount of supplementary fuel contributing about 58% of the total mass added. Table 4 shows that there was insignificant mass savings in the all-up mass (AUM), 6% compared to the mass savings in OEM, 12.5%. This is as a result of the weight of the pilot/passenger eliminated from the aircraft, which is balanced by the mass of fuel added to increase the endurance and range of the aircraft. Nevertheless, it is noteworthy that there was a decrease in weight for the OEM of the aircraft, because the associated systems and components with crewed aircraft have been eliminated.

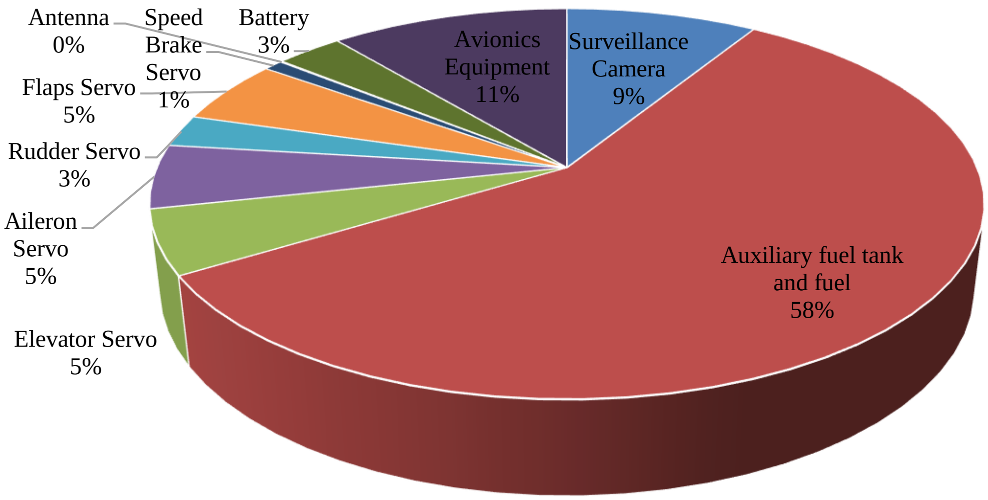
From Table 4, it can be ascertained that the gross weight was reduced from 841 kg to 789 kg while the empty weight reduction of the aircraft was also significantly reduced from 538 kg to 471 kg. However, the reduction of the gross weight is insignificant as the empty weight reduction. This is because the mass of pilots and related components have been substituted through integrating a supplementary fuel tank to the UAV for range and endurance.

Presently, the aviation industry is responsible for about 2-3% of the total $CO_2$ emissions (36 billion metric tons) are of anthropic origin. In the future these emissions are estimated to likely increase as $CO_2$ emissions due to air transportation increase by 75% between 1990 and 2012. This is expected to grow by 300% in 2050 except precautionary actions are taken (Centracchio et al., 2018). Thus, by converting the ABT-18 aircraft to UAV, there could be a significant reduction in fuel consumption because of the reduced weight of the aircraft.

Table 4. Mass comparison for ABT-18 (Standard Version) and ABT-18 UAV

| Aircraft version | AUM (kg) | OEM (kg) |
|---|---|---|
| ABT-18 standard version | 841 | 538 |
| ABT-18 UAV | 789 | 471 |

http://dx.doi.org/10.46792/fuoyejet.v7i1.732



l components required for the UAV operation

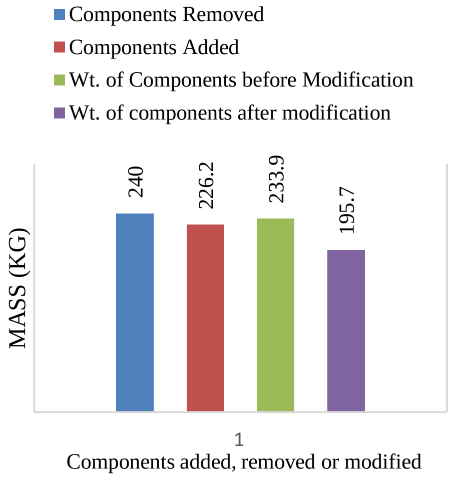


Fig. 5. Chart summarizing weight balance for the ABT-1 UAV.

## 4 CONCLUSION

Converting the ABT-18 into a UAV resulted in a reasonable reduction in weight. In this study, there is a 6.18% reduction in all-up-mass and 12.5% reduction in operating empty mass. These changes will affect the aircraft performance besides reduction in harmful emissions from the aircraft. Generally, aircraft weight estimation and minimization are subjects of extreme importance; since both the performance and cost of the aircraft are affected by the aircraft weight.

## REFERENCES

Al-Shamma, O., & Ali, R. (2013). Aircraft Weight Estimation in Interactive Design Process. *72nd Annual Conference of Society of Allied Weight Engineers*, 18–23.

Amarildo, M., & Paulo, C. B. (1999). Parametric Study of Transport Aircraft Systems for Estimation of ERJ-145ER Components Weights. *15th Brazilian Congress of Mechanical Engineering*, 1–10.

Bai, C., Mingqiang, L., Shen, Z., Wu, Z., Man, Y., & Fang, L. (2014). Wing weight estimation considering constraints of structural strength and stiffness in aircraft conceptual design. *Int'l J. of Aeronautical & Space Sci.*, *15*(4), 383–395. https://doi.org/10.5139/IJASS.2014.15.4.383

Centracchio, F., Rossetti, M., & Iemma, U. (2018). Approach to the Weight Estimation in the Conceptual Design of Hybrid-Electric-Powered Unconventional Regional Aircraft. *Journal OfAdvanced Transportation, 2018*.

Dababneha, O., & Kipouros, T. (2018). A Review of Aircraft Wing Mass Estimation Methods. *Aerospace Science and Technology*, *72*(January), 256–266.

Essari, A. M. (2018). Estimation of Wing Weight in Conceptual Design Phase for Tactical Unmanned Aerial Vehicles. *Journal of Alasmarya University: Basic and Applied Sciences Volume*, *3*(1), 53–68.

Gündüz, M. E., Khalid, A., & Schrage, D. P. (2007). Weight Estimation Using CAD In The Preliminary Rotorcraft Design. *33rd European Rotorcraft Forum Kazan, Russia*, 1–12.

Karthik, M. A., Srinivasan, K., Srujan, S., Subhash-Holla, H. S., & Suraj-Jain, M. (2017). Design and CFD Analysis of a Fixed Wing for an Unmanned Aerial Vehicle. *International Journal of Latest Engineering Research and Applications (IJLERA)*, *2*(7), 77–85.

Khuntia, S., & Ahuja, A. (2018). Optimal Design and CFD Analysis of Wing of a Small-Scale UAV to Obtain Maximum Efficiency. *Journal of Aeronautics & Aerospace Engineering*, *07*(01). https://doi.org/10.4172/2168-9792.1000207

Shinkafi, A., Oyenusi, F., **Mohammed, A.,** Udeagulu, C., Ademuwagun, A., and Ubadike, O. (2021). Preliminary Engine Sizing for a Tactical Unmanned Aerial Vehicle. *ATBU Journal of Science, Technology and Education*, 9(3), 268 – 277.

Thyagarajan, S., & Sharma, N. (2014). Aircraft Mass Estimation Methods. *International Journal of Engineering and Management Research (IJEMR)*, *4*(5), 170–178.

Triet, N. M., Viet, N. N., & Thang, P. M. (2015). Aerodynamic Analysis of Aircraft Wing. *VNU Journal of Science: Mathematics – Physics*, *31*(2), 68–75.

Yayli, U. C., Kimet, C., Duru, A., & Cetir, O. (2017). Design optimization of a fixed wing aircraft. *Advances in Aircraft and Spacecraft Science*, 4(1), 65–80. https://doi.org/10.12989/aas.2017.4.1.065