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Implementation of FDM technology in MALE UAVs

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Abstract:

The FDM (Fused Deposition Modeling) technology can be exploited for manufacturing of Medium Altitude Long Endurance Unmanned Aerial Vehicles (MALE UAVs); specifically, fixed wing Radio-controlled (RC) aircrafts. There are numerous substantial advantages of using this technology over other conventional materials like Styrofoam sheets, Balsa wood, EPP Foam boards etc. Considering the ecological advantages, unlike other Fiber Reinforced Plastics (FRPs), Poly Lactic Acid (PLA) is completely biodegradable in nature. The main aim of using such material and development technique is its promptness in terms of manufacturing and its eco-friendliness. Moreover, it helps to increase strength of the structure while decreasing its weight, thereby improving the strength to weight ratio to a considerable extent. It gives a considerable amount of independence to a designer to strategically densify an area; which is to experience greater impact loading (for e.g. landing gear, nose tip etc.) and compensate the same by reducing weight wherever possible. The manufacturing complexities that are faced in fabricating an aerodynamic shaped fuselage using any other technique can be eradicated to a great extent. Furthermore, it provides an ease of manufacturing of a complex customized product consecutively imparting an excellent build-precision at an economic pricing strategy. Finally, an ample amount of time can be saved and unnecessary human intervention can be avoided in the event of mass-manufacturing.

Keywords

MALE UAVs, Fixed wing RC aircrafts, FRP, aerodynamic shaped fuselage, build-precision

1. Introduction

FDM is a powerful additive manufacturing technology generally used for prototyping, modeling and production works requiring medium to high end build-precision. It involves building of the parts layer-by-layer, following a bottom-up approach by continuous heating and extrusion of engineering-grade and high-performance thermoplastic filament. Typically, a fine ribbon of plastic (or any other material under consideration) is melted and facilitated through a computer controlled extrusion head, thereby producing the required component [1, 2]. The basic three-step process involved in the same is illustrated as follows:

Pre-processing: In this operation, a design file is imported and numerous slices (layers) are created. The preprocessing software calculates sections and "slices" the part design into many layers. Further, using this sectioning data, the "tool paths" or building instructions are generated by the software, which in turn drives the extrusion head to create the desired object.

Production: In this operation, the thermoplastic element is heated into a semi-liquid state and ultra-fine beads are deposited along the extrusion path [3]. The component can also be fabricated by using two materials simultaneously. In this case, two materials, one to make the part and other to support it, enter the extrusion head. It allows the separation of the material used for printing the object from the one which is used to print the support material.

Post-processing: In this operation, the support material is isolated completely from the main object and further processing (if required) is performed on the fabricated component.

2. Applicability in Fixed wing RC aircrafts

A RC aircraft is a flying gadget which can be remotely operated by an operator on the ground using a hand-held radio transmitter. A receiver is mounted within the craft, which establishes communication with the transmitter and sends appropriate signals to various servomechanisms which operate the control surfaces, thereby changing the orientation of the aircraft as per requirement. The considerable improvements in weight, performance capabilities, cost etc. have been carried out in propulsion systems, batteries, electronics etc. during the last two decades. This is primarily due to the fact that fabricating and flying RC planes has been growing substantially as a hobby during the said period. Nowadays, the RC aircrafts are commercially available in a wide variety of types and models.

Moreover, a lot of research is now being carried out to enhance the range and altitude capabilities is of MALE UAVs. The UAVs are implemented in a wide array of applications including surveying and mapping of construction sites, monitoring of oil and gas pipelines, precision agriculture, urban planning, aerial traffic and security watch, disaster management etc. Generally, slow speed reconnaissance application is taken into consideration where resolution and pixel quality matters. The present day RC aircrafts are even capable of carrying out autonomous missions and generate a huge amount of useful data which could be utilized in a wide variety of applications. Scientific, government and military organizations are also using RC aircrafts for experiments, gathering weather readings, aerodynamic modeling and testing. Furthermore, video and autonomous capabilities can be added and the UAVs can also be armed to perform specific missions.

When such a vast multitude of applications are to be catered, utmost care has to be taken in terms of manufacturing such aircrafts. The use of new materials and manufacturing techniques can be explored to obtain substantial advantages over the conventional ones. One such manufacturing technique is FDM; which provides an ease of manufacturing of a complex customized product consecutively imparting an excellent build-precision at an economic pricing strategy. The conventional manufacturing techniques (employing materials like EPP foam boards, Balsa wood etc.) are typically subtraction processes where a model a built by removing material bit by bit from the commercially available blocks of standard sizes. On the other hand, FDM technology is an additive manufacturing technique where a model is built by adding material layer by layer with desired precision [3]. The addition process is entirely computer-controlled. The inexpensive and rapid development of FDM prototypes greatly reduces design to production time and allows for much higher return on investment [1].

Subtractive methods of manufacturing also possess some serious limitations as compared to additive manufacturing techniques. Firstly, a lot of raw material is wasted as the major portions of the blocks of raw material might be left unused depending upon the complexity of the model to be fabricated. Secondly, in case of brittle materials, machining cracks can be introduced while machining. Thirdly, it may not prove to be economic for manufacturing highly complex components [4]. A variety of materials can be utilized for 3D printing the desired model. The selection of material is typically performed on the basis of its area of application, desired stress bearing capability, operational temperature range, material density and tensile strength. The basic ranges of materials include PLA (Poly Lactic Acid), ABS (Acrylonitrile Butadiene Styrene), polyamide, polycarbonate, polyethylene and polypropylene. For advanced FDM applications, materials like silicon nitrate PZT, aluminum oxide, hydroxyapatite, carbon fiber and stainless steel can be utilized [5]. We have fabricated the fuselage of the RC aircraft using PLA.

Although the entire aircraft can be extensively developed using FDM technology by employing 3D printers, however it may not be always feasible to fabricate those parts which have large dimensions (i.e., length, width or height) as the bed size of the 3D printer is limited. We have implemented the same on fuselage of the aircraft; which is discussed in detail in the following section.

3. Development and Analysis of 3D printed fuselage

The fuselage is the backbone of an airplane, which acts as a piece of correspondence for power plant, wing and tail. It is a critical part of the plane as it serves as housing for payload as well as many other components. It constitutes a geometrically significant volume of the entire structure and experiences significant loading during landing [6, 7]. Henceforth, many weight, aerodynamic and structural constraints that must be considered during design of a fuselage. Moreover, the length of the fuselage also affects the stability of the airplane. Considering the aerodynamic perspectives, it is important that the body is streamlined so that air is able to flow around it in such a way so as to keep the drag effects low [6, 7].

It can be appreciated that using FDM additive manufacturing technology, an aerodynamic shaped fuselage can be fabricated very easily. This sort of liberty cannot be guaranteed by any other

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conventional manufacturing technique and materials. However, the materials like Styrofoam sheet provide other advantages like high flexibility as well as breakage resistance, but due to its non-aerodynamic shape, the drag force thus experienced becomes much higher and it has low fitness ratio which resists its acceleration. On the other hand, if Balsa wood is used for fabricating the same, the process is cumbersome as well as time consuming. Moreover, it also delivers less build-precision and the manufacturing complexity is extremely high. Although Balsa wood provides adequate strength to the fabricated structure, the material itself is very brittle in nature thereby compromising the robustness of the model. So, the disadvantages clearly overweigh the advantages, thereby rendering FDM technology as the optimum choice; specifically for low volume customized parts [8].

In a nutshell, the advantages of exploiting the FDM technology instead of conventional materials for the said application are listed below:

- Bio-degradable.
- High strength to weight ratio.
- Ease of manufacturing.
- High build-precision of the object.
- Saving in time and decrease in human intervention, if mass manufacturing is desired.

The conventional manufacturing techniques offer a uniform density of the material throughout the volume of the fabricated structure. The designer cannot strategically differentiate the modeling of parts handling a greater amount of impact loading from the ones which are to experience normal stresses during the operations. However, the FDM technology provides the liberty to the designer to densify an area which is to experience greater impact loading and compensate the same by reducing weight wherever possible in the entire structure volume [9].

4. Stress Analysis of the Fuselage

After performing a substantial number of iterations, the final model was fabricated; which was aerodynamically stable as well as mechanically robust. The stress analysis has been performed using FEA simulations through licensed ANSYS® tool. Two different cases pertaining to nose impact analysis and belly impact analysis have been considered and the corresponding results are shown in Figures 2 and 3 respectively.

The 3D view of the fuselage developed is shown in Figure 1.

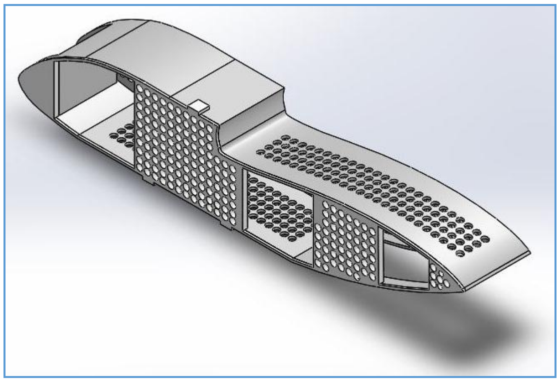

Figure 1. 3D view of the fuselage

Nose Impact Analysis

Result Interpretation:

The analysis is oriented in such a manner that the wing berth is taken as fixed support whereas, the motor mount is assumed to have a ramped up force impact on it. The feature shows that the maximum deformation would occur at the joint of two different parts which were manufactured separately and then joined together using cyanoacrylate.

Max Force Applied:	25 N
Max Deformation:	1.09 mm

Belly Impact Analysis

Result Interpretation:

As the fuselage is deemed to land on its belly during the landing approach. Moreover, in any case the first impact would be on the bottom surface only. Considering the purview of the given problem statement, the analysis is shown above where the impacts on grilled bottom and wall surfaces have been shown.

Max Force Applied:	25 N
Max Deformation:	1.1435mm

5. Conclusion

The FDM technology can be efficiently exploited for fabrication of UAVs with excellent build precision and high strength to weight ratio of the fabricated structure. It also allows varied material composition on different parts of the component to meet suitable application demands. It is completely biodegradable in nature and is highly cost-effective manufacturing technique. During mass

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manufacturing, human intervention can be avoided and a lot of time can be saved. The complexity in manufacturing is highly reduced by employing the additive manufacturing process through 3D printing. The final model fabricated by assembling the 3D printed fuselage and other necessary components is shown in Figure 4.

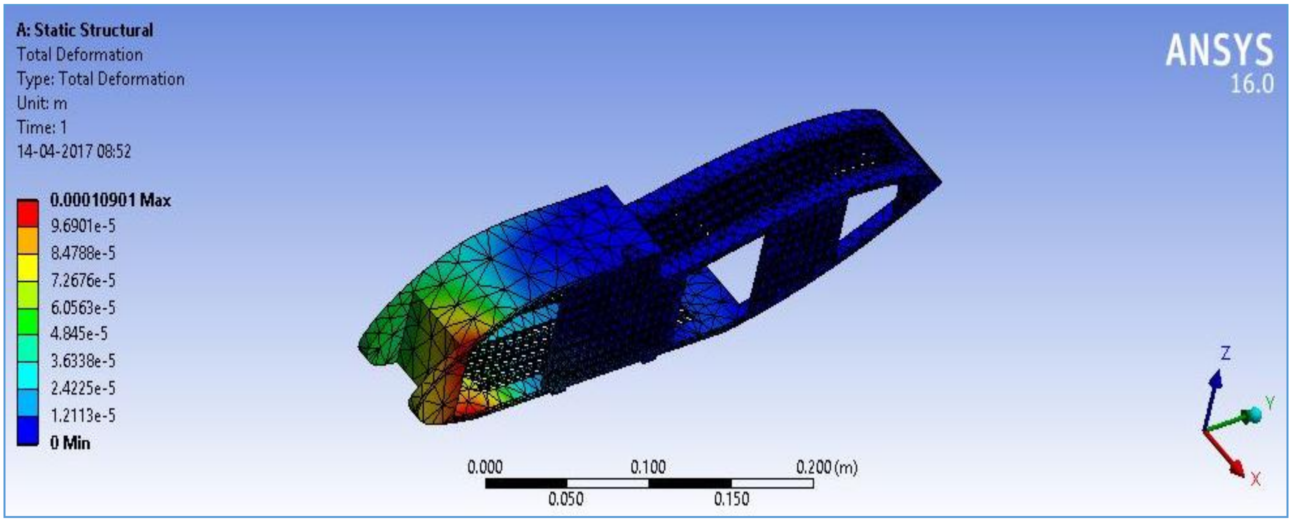

Figure 2. Nose impact analysis of the fuselage.

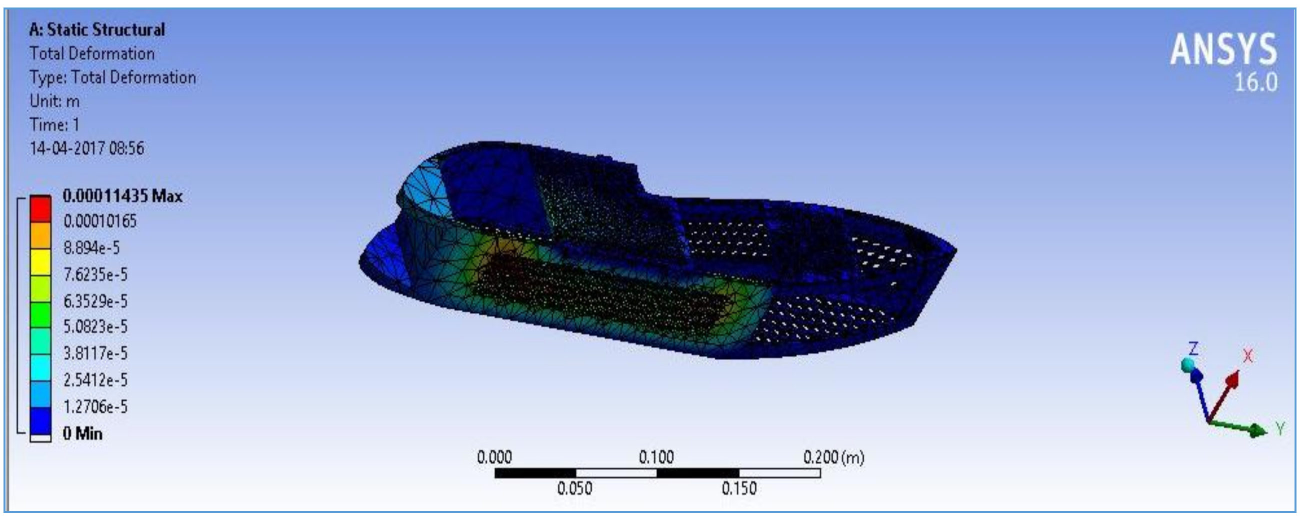

Figure 3. Belly impact analysis of the fuselag

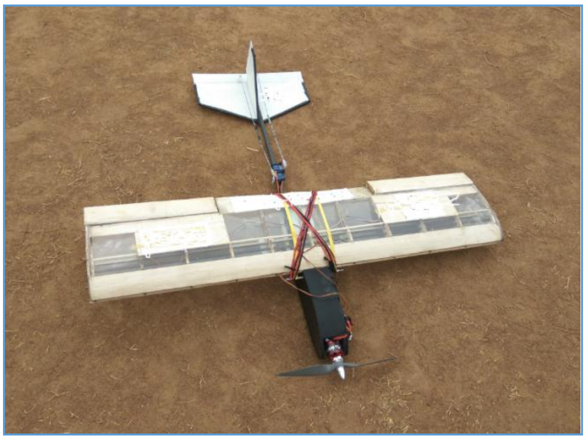

Figure 4. Final model aircraft constructed using the 3D printed fuselage.

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