3d printing of quadcopter: A Case Study

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Abstract- Additive manufacturing (AM) popularly known as Rapid Prototyping (RP) or 3D Printing technology has primarily been developed for the manufacturing Industry to assist in speeding up the development of new products.The objective of this paper is to design and fabricate Quadcopter components in 3D printing using Fused Deposition Modeling (FDM) technique and using Co-ordinate Measuring Machine (CMM) carrying out the dimensional error analysis of manufactured parts. Fused Deposition Modeling (FDM) is a RP (rapid prototyping) technique used to manufacture prototypes on additive manufacturing technology. The Fused deposition modeling (FDM) is one of the rapid prototyping technologies by which physical objected are created directly from CAD data. The quality of FDM fabricated parts are significantly affected by various process parameter used in this process. So it is necessary to optimize the process parameter of FDM to improve the quality of the parts. Primary process parameters such as layer thickness and part orientation in addition to their interactions are studied and analyzed in the present dissertation that influences the dimensional accuracy of the part produced by the process of Fused Deposition Modeling (FDM). Due to shrinkage of the filaments, the dimensions of the CAD model does not match with the FDM processed part. The shrinkage dominates along length, width and thickness of the build part. The error is analyzed and advancements are discussed. The 3D printed components are measured with CMM along lengthwise, width and thickness. The error obtained is the deviation between the CAD model and the 3D printed parts are noted. It has been found that there is difference in physical dimensions of the part which required to be minimized by correcting the process parameters.

Keywords –3D printing, FDM, Quadcopter, Error Analysis, CMM, Advancements

I. INTRODUCTION

The research on Micro Aerial Vehicles (MAV) is a comparably young field, which has emerged over the past few years. The on-going miniaturization of electric components such as electric motors and the improvements in microelectronics made it possible to build miniature planes and helicopters at relatively low costs. This development also made it possible to start imitating insect and bird flight, which need a sophisticated miniaturized actuation chain for their flapping wing motion. The project is to come up with small aerial vehicles that can operate independently from ground stations, performing certain operations such as surveillance or measurement, especially in environments that are hardly accessible or even dangerous for people in future. One of the goals of research on Micro Air Vehicles (MAVs) is to arrive at fly-sized MAVs that can fly autonomously in complex environments such MAVs form a promise for observation tasks in places that are too small or too dangerous for humans to enter. Their small size would allow the MAVs to enter and navigate in narrow spaces, while autonomous flight would allow the MAV to operate at a large distance from its user. Essentially, there are two main approaches to creating small autonomous ornithopters: bottom-up and top-down. In the bottom-up approach, one starts by creating all the tiny parts that are deemed important to a fly-sized ornithopter. In the last few decades, small scale unmanned aerial vehicles (UAVs) have become more commonly used for many applications. The need for aircraft with greater maneuverability and hovering ability has led to current rise in quadcopter research. The four-rotor design allows quadcopters to be relatively simple in design yet highly reliable and maneuverable. Cutting-edge research is continuing to increase the viability of quadcopters by making advances in multi-craft communication, environment exploration, and maneuverability. If all of these developing qualities can be combined together, quadcopters would be capable of advanced autonomous missions that are currently not possible with any other vehicle.

Recent advances in the fields of computer-aided design (CAD) and rapid prototyping (RP) have given designers the tools to rapidly generate an initial prototype from a concept. Rapid Prototyping **(**RP) refers to a class of technologies that can automatically construct physical models using additive manufacturing technology. RP can be defined as a group of techniques used to quickly fabricate the scale model of a part or assembly using 3-D computer aided design (CAD) data.

Rapid Prototyping has also been referred to as computer aided manufacturing, solid free-form manufacturing and layered manufacturing. RP have emerged a new innovation to reduce the time and cost of model fabrication by creating 3-D product directly from computer aided design, thus the designer is able to perform design validation and accuracy analysis. Development and use of RP has drastically expanded in the last 10 years followed by the development of 3-D CAD modeling often called "solid modeling". These 3-D CAD modeling allow designers to quickly create tangible prototypes of their designs, rather than just two-dimensional pictures. In addition to prototypes, RP techniques can also be used to make tooling and even production-quality parts. The integration of RP into the design provides some significant pedagogical benefits. These include component visualization, interface design, assembly, testing, etc.

II.RAPID PROTOTYPING

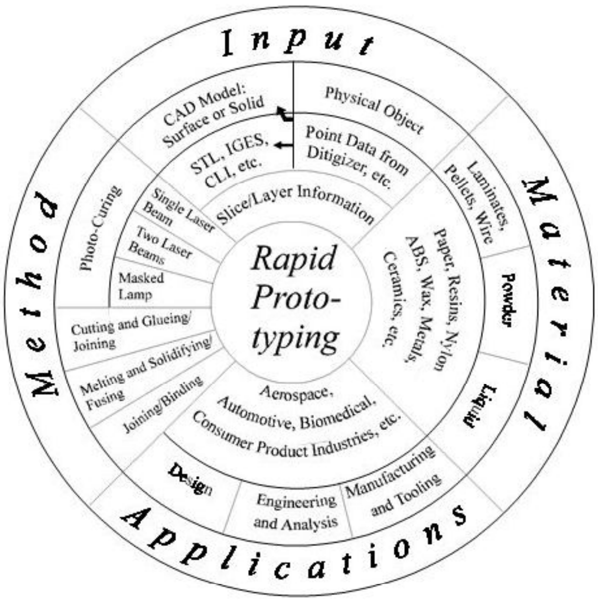


Figure 2.0: Rapid Prototyping Wheel depicting the four major aspects of RP

Input

Input refers to the electronic information required to describe the physical object with 3D data. There are two possible starting points — a computer model or a physical model. The computer model created by a CAD system can be either a surface model or a solid model. On the other hand, 3D data from the physical model is not at all straightforward. It requires data acquisition through a method known as reverse engineering. In reverse engineering, a wide range of equipment can be used, such as CMM (coordinate measuring machine) or a laser digitizer, to capture data points of the physical model and "reconstruct" it in a CAD system.

Method

While they are currently more than 20 vendors for RP systems, the method employed by each vendor can be generally classified into the following categories: photo-curing, cutting and gluing/joining, melting and solidifying/fusing and joining/binding. Photo-curing can be further divided into categories of single laser beam, double laser beams and masked lamp.

Material

The initial state of material can come in either solid, liquid or powder state. In solid state, it can come in various forms such as pellets, wire or laminates. The current range materials include paper, nylon, wax, resins, metals and ceramics.

Applications

Most of the RP parts are finished or touched up before they are used for their intended applications. Applications can be grouped into (1) Design (2) Engineering, Analysis, and Planning and (3) Tooling and Manufacturing. A wide range of industries can benefit from RP and these include, but are not limited to, aerospace, automotive, biomedical, consumer, electrical and electronics products.

Figure 2.1 Sample Model of rapid prototyping

The categories of rapid prototyping technologies are listed below:

1. Fused Deposition Modelling (FDM)
2. Stereo lithography (SLA)
3. Selective Laser Sintering (SLS)
4. Laminated object manufacturing (LOM)
5. Electron Beam Melting (EBM)

III. CAD DESIGN

The entire model of Quadcopter is designed using CATIAV5 (CAD tool).

Each part of the Quadcopter is designed under mechanical tools incorporated in CATIA.

The entire parts have been assembled to obtain the final product. It is further constrained in accordance with the kinematics simulation to view the motion of the copter.

To be precise, the following steps were followed in CATIA.

- ✓ Design of each component.
- ✓ Modeling the each component.
- ✓ Assembly of each part to obtain the final product.

3.1Creation of the parts in Mechanical Design Solutions

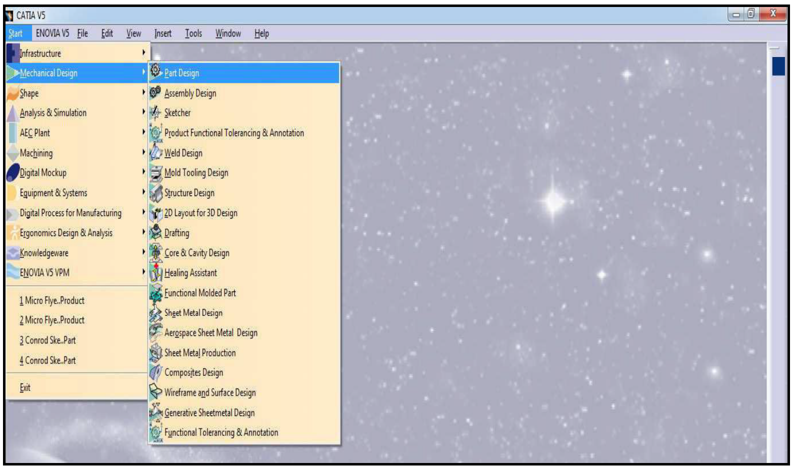


Figure 3.0Creation of part design

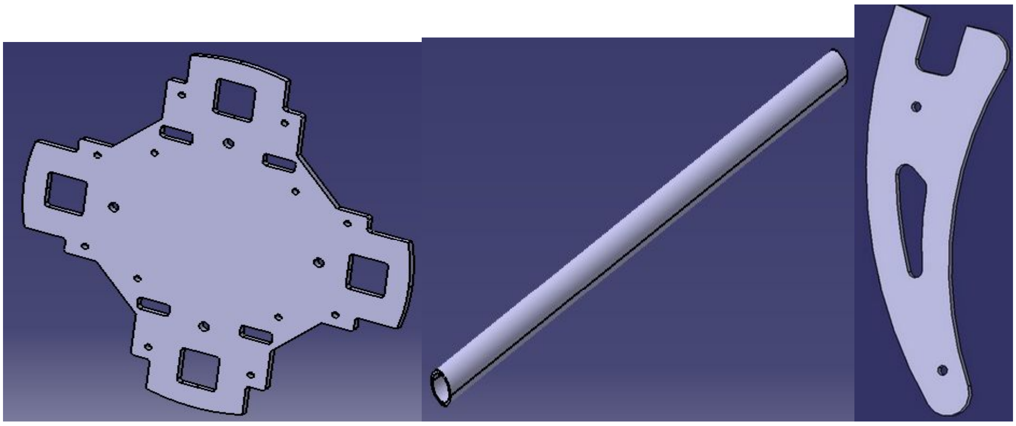
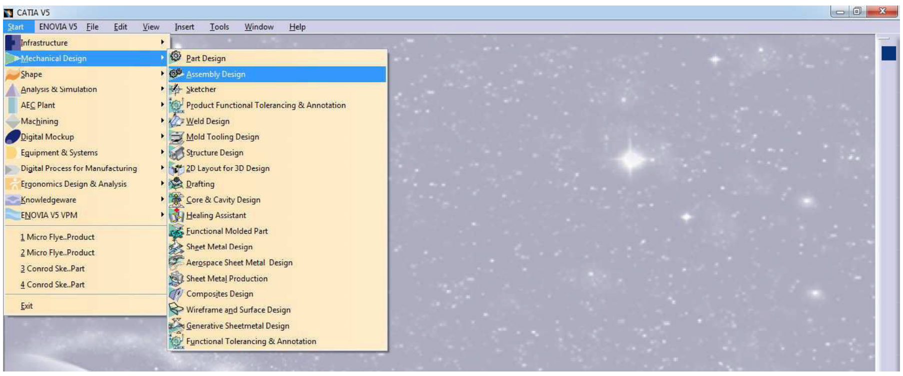


Figure3.1 3D modeled components in Catia

3.2 Creation of the assembly in Mechanical Design Solutions



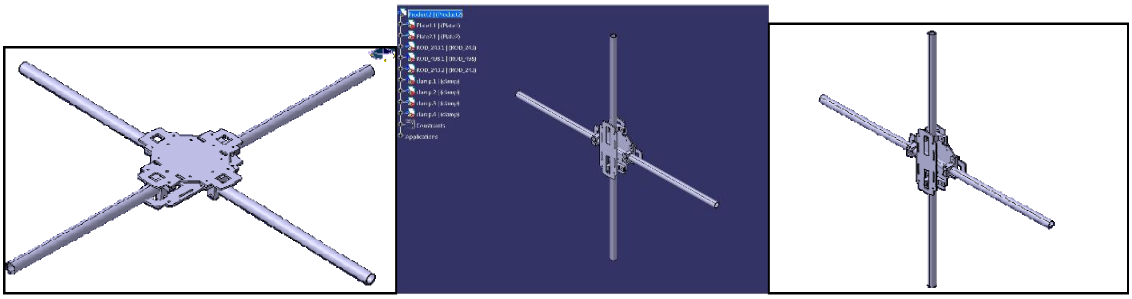


Figure 3.2 3D assembled views of Quadcopter components

IV. FABRICATION

FDM is the RP technology that forms 3-D object from CAD generated solid or surface models. It was developed by S. Scott Crump, in the late 1980s, was commercialized in 1990 and sold since 1991. Similarly, with most other additive manufacturing processes FDM works on an "additive" principle by laying down material in layers. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn on and off the flow. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a CAM software package. The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle as a result, the designed object emerges as a fully functional 3-D part, with the help of support material.

Several materials are available with different trade-offs between strength and temperature properties. As well as ABS (Acrylonitrile Butadiene Styrene) polymer, the FDM technology can also be used with polycarbonate, polycaprolactone, polyphenylsulfones and waxes. A "water-soluble" material can be used for making temporary supports while manufacturing is in progress

Material type

- Solid (Filaments).

Material used

- Thermoplastics such as ABS, Polycarbonate.
- Polyphenylsulfone, Elastomers.

Max part size

- 36.00 x 24.00 x 36.00 in.

Min layer thickness

- 0.0050 in.

Tolerance

- 0.0050 in.

Surface finish

- Rough.

Build speed

- Slow.

FDM segments

- Machine.
- Catalyst EX.
- Smoothing and cleaning machine.

Machine Specifications

Machine: Dimension1200ES
Manufacturer: Stratasys
Technology Used: FDM (Fused Deposition Modelling)
Model material:

ABSplus P430 in ivory, white, black, red, olive green, nectarine, fluorescent yellow, blue or gray
Support material:
Soluble Support (SST)
Build size:
254 x 254 x 305 mm (10 x 10 x 12 in)
Cost of Printing: 25$/Hr
Layer thickness:
.254 mm (.010 in) or .330 mm (.013 in) of precisely deposited ABS*plus model* and support material.
Workstation compatibility:
Windows XP/Windows 7
Network connectivity:
Ethernet TCP/IP 10/100Base-T
Size and weight:
838 x 737 x 1143 mm (33 x 29 x 45 in)s
148 kg (326 lbs)
Power requirements:
110–120 VAC, 60 Hz, minimum 15A dedicated circuit; or 220–240 VAC 50/60 Hz, minimum 7A dedicated circuit

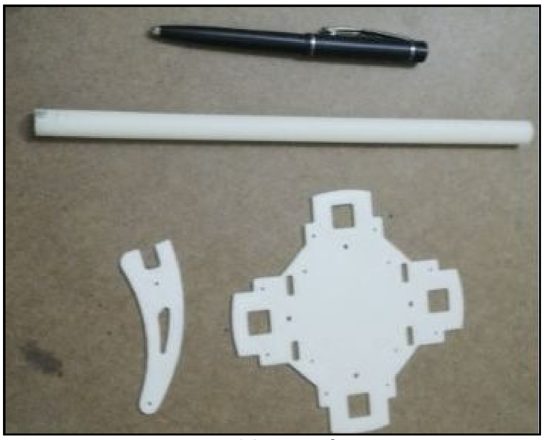


Figure 4.0 3D Printed parts

Time taken to print the components

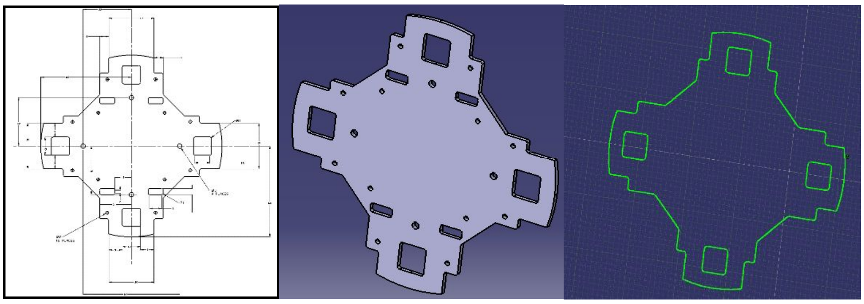
S.No	Name	Quantity	Time(Hrs)	Model Mat'l	Support Mat'l
1	Plate	2	1.47	1.88	0.83
2	Shaft_Small	4	4.43	2.1	0.04
3	Semi-circular plate	8	1.31	1.25	0.71
		Total	8.01		

V. ERROR ANALYSIS

CMM output will be in the form of “res”, dwg&resfileswhich consists of number of points as shown below.
Error Analysis part is carried out with reference to the results taken with the help of Co-ordinate Measuring machine (CMM).

Input:

The values or the dimensions considered for 3D modeling (CAD Design) of the part are shown below.



Distance (dx1)
Original distance = 30 mm
Average distance after printing =29.9272 mm
Deviation dx1=30-29.9272=0.0728 mm
Distance (dx2)
Original distance = 64 mm
Distance after printing = 63.0888 mm
Deviation dx2= 0.9112 mm
Distance (dx3)
Original distance = 32 mm
Distance after printing = 31.5444 mm
Deviation dx3= 0.4556 mm
Thickness (t)
Original = 2 mm
Obtained =1.8mm
Deviation = 0.2 mm
Holes measurement
Original dimensions:
Ø 2mm - 12 places
Ø 3mm - 4 places
Dimensions after printing:
Ø 1.8 mm - 12 places
Ø 2.8 mm - 4 places
Deviation for each hole is approximately 0.2 mm.

Results:

Distance	Distance (mm) (before printing)	Distance(mm) (After printing)	Deviation(mm)
dx1	30	29.9272	0.0728
dx2	64	63.08888	.09112
dx3	32	31.5444	.4556
Thickness (t)	2	1.8	.2

Locations	Diameter of hole (mm) (before printing)	Diameter of hole (mm) (After printing)	Deviation (mm)
12 places	2	1.8	0.2
4 places	3	2.8	0.2

VI. ADVANCEMENTS

We focused on few topics for better prototype results which can be bought by making advancements in material and machine through which dimensional accuracy is attained.

The change in material can bring us many results such as,

- ✓ Diminishing the use of support material
- ✓ Cost effective and
- ✓ Dimensional accuracy

Firstly, ABS plus material is used as the model material in FDM machine for which support material consumption will be high. So to overcome this, we introduced a new material called POLYPROPLENE which is also known as propene, through which the above objectives can be attained.

Advancement in machine:

At present, the machine consists of an extrusion head to which, model material and support material nozzles are extruded. The support material first deposits the material to make base for the model and with the help of the blowers, the material solidifies and forms a model. And the same thing happens with the model material. But here, as per the material chosen we are introducing two other extrusion heads, namely: Hot air extrusion head, Cold air extrusion head, to eliminate the use of blowers.

The use of the hot air extrusion is to servethe purpose of blower. Wherein, the cold air extrusion is used for the solidifying purpose of the material deposited on the foam board.

Hence with the help of the above mentioned extrusion heads, the material depositing on to the pack can easily be solidified with the temperatures chosen and thus a good, robust prototype isformed without any accuracy and shrinkage problems. Thus, this is the small advancement introduced into the machine with respect to the material chosen.

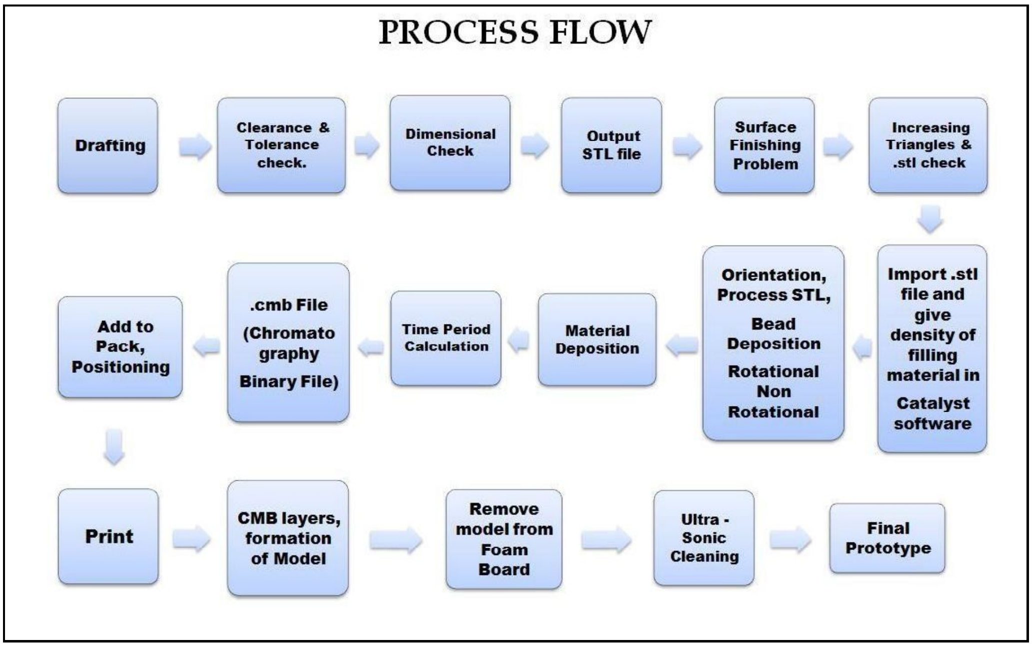


Fig 4.0 Process flow

Firstly, the design must be drafted in the CAD file. Once the drafting is done then a check is conducted for the clearance and tolerance to avoid round off errors and instabilities followed by dimensional check. Then the file is exported into STL (standard template library) file, as it is the only format compatible to the Catalyst software (machine software).

If there is any surface finishing problem arises, then triangulation method is implemented by increasing the triangles in CAD and again rechecking the STL file.

Once the STL file is ready, it must be imported into the software and give the necessary inputs like layer resolution, model interior (density of filling material) and support fill, etc., in the next step the design is oriented in orientation process. When the orientation is done, the software calculates the material required and time period of the final prototype.

Then the STL file is converted into CMB file to feed the machine by adding it to pack. Thus, the design is ready for printing in layer by layer method. After completion of the prototype, it must be removed from the foam board and subject it to ultrasonic cleaning for the removal of support material.

Hence, final prototype is done.

V. CONCLUSIONS

As stated above this project focused on error analysis, few topics to achieve better prototype results by making advancements in material and machine through which dimensional accuracy is also attained.

- ✓ There is 0.2 mm deviation in the hole dimensions for a hole of dia 3mm and 2 mm
- ✓ There is a 0.2mm deviation in the thickness for a thickness of 2mm.

Results due to change in material are:

- ➢ Diminishing the use of support material.
  By the change of material from ABS plus to Polypropylene, the consumption of support material is reduced.

- ➢ Cost effective
  Since the support material usage is reduced and the polypropylene material is also of low cost when compared to ABS plus, we gained cost effectiveness.

- ➢ Dimensional accuracy
  Due to the advancements in material and machine the dimensional accuracy is achieved.

To conclude, the advancements provide highest quality in design prospects which ensures better results, convenience and moreover a perfect design.

VI. FUTUREWORK

The future scope of the paper is that it can effectively employed for Air force Deployment, In-the-open extended surveillance, Advanced Flight control, Swarm operations, Remote tag and target, Precision engagement, Remote or autonomous Chemical /biological /Nuclear research, Terrain adaptability.

We have published paper on Innovation for safe travel in International Journal of Innovations in Engineering and Technology (IJIET). The main extension of this work is to increase the use of Additive Manufacturing in our daily printring. In future, we can see 3D printers at home.

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