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Analysis of Quad copter Frame for Cost and Weight Reduction.

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Abstract: *Semi-Autonomous drones are being utilized in monitoring, transport, safety and disaster management, and other domains. Envisioning that drones form autonomous networks incorporated into the air traffic, it is described as a high-level architecture for the design of a collaborative aerial system consisting of drones with on-board sensors and embedded processing, sensing, coordination, and networking capabilities to make it semi-autonomous. It is implemented as a multi-drone system consisting of quad copters and demonstrate its potential in aerial monitoring for traffic surveillance. Traffic network analysis for the overall improvement of the traffic flow and safety conditions. However, in order to conduct a UAV-based traffic study, an extremely diligent planning and execution is required followed by an optimal data acquisition in the form of video feeds. Furthermore, it is illustrated as a design challenges and present potential solutions based on the lessons learned so far.*

Keywords: *Semi-Autonomous drone, drone design, traffic analysis, UAV based traffic study, live video feed*

I. Introduction

Semi-autonomous unmanned aerial vehicles (UAVs), also called drones, have received increasing interest for environmental and natural disaster monitoring, border surveillance, emergency assistance, search and rescue missions, and relay communications. Small multi copter are of particular interest in practice due to their ease of deployment and low acquisition and maintenance costs. Quad copters are light and affordable, and are capable of hovering and fast forward flight in narrow spaces. Research and development in small multi copter has started with addressing control issues, such as flight stability, maneuverability, and robustness, followed by designing autonomous vehicles capable of waypoint flights with minimal user intervention.

The drone must be easy to fly, fun and safe. Ease of flying means that the end-user shall only provide high level orders which must be handled by an automatic controller dealing with the complexity of low level sub-systems. Because the system is unstable, feedback is needed. In turn, this raises the issue of state estimation. Enjoyment is guaranteed by the capability of the control system to handle relatively aggressive maneuvers. Safety means that the vehicle control system must be robust to the numerous disturbances that can be met in practice as the UAV is used in various and unknown environments. Redundancy in the state estimation is the solution in this case. For these reasons, which will be developed further in this report from the automatic control theorist point of view, the critical points are the accuracy and the robustness of the vehicle state estimation. While absolute position estimation is not a strict requirement (at the exception of the altitude for safety reasons), it is of paramount importance to know the up thrust velocity during all the flight phases, so that it is possible to stop the vehicle and to prevent it from drifting. The capability of stopping the vehicle is a security requirement, while cancellation of the drift of the vehicle –which is particularly annoying— has a large added value in terms of end-user experience. Other key questions are stabilization and robustness. Finally, one shall realize that the UAV under consideration must be plug-and-play, in the sense, that it is not a laboratory experiment, and must fly semi-autonomously once it is handed out of its package by the end-user and it's the battery is loaded. No sophisticated calibration or tuning procedure can be performed by the end-user who is usually totally unfamiliar with control technology.

To address the problem of state estimation, UAV are usually equipped with embedded inertial sensors (gyrometers and accelerometers a sonar altitude sensor (or a barometer), and, often, an absolute position or velocity sensor such as a GPS or a camera feeding vision. This enables the user to control the drone with utmost accuracy even in intricate spaces and tight areas. These sensors also help in obstacle detection and avoiding the same with utmost ease.

II. Design And Calculation

II.I Calculations

Thrust Calculations:

Single Motor Thrust = 630g = 0.630kg
Total Thrust Force = 0.630 x 4 = 2.52kg
Mass of Drone = 1.2kg
Thrust produced should be greater than or equal to twice the mass of the drone.

Equivalent mass of drone = 2 x 1.2
= 2.4kg
As the mass acting is less than the thrust force produced, hence thrust produced is sufficient.

Main support for bolts:
Based on thrust force
Load acting on single bolt = (0.630*9.81)/2
= 3.09015N
Material for the bolt = C40 (steel)

Syt = 380N/mm^2
FOS = 1.5
Diameter of bolt:
$\sigma_t = F / \pi/4 \times d_c^2$
Where,
σ_t = Allowable tensile stress
F = Thrust force acting on single bolt
d_c = Minor diameter of bolt
$380 / 1.5 = 3.09015 / \pi/4 \times d_c^2$
d_c = 0.124mm
Shear stress (τ)
$\tau = F / \pi \times d_c \times t \times n$
Where,
τ = Allowable shear stress
F = Thrust force acting on single bolt
d_c = Minor diameter of bolt
t = thread thickness
n = number of threads in contact
$0.5 \times 380 / 1.5 = 3.09015 / \pi \times d_c \times 0.7 \times 3$
d_c = 0.0608mm

Diameter based on impact force
Height from where the object is dropped (h) = 5m
Weight of the drone = 1.2 x 9.81
= 11.772 N.

Energy (E) = mgh
Where,
E = Energy
m = mass of drone
g = acceleration due to gravity
h = falling height

= 1.2 x 9.81 x 5
= 58.86 Kgm^2 / s^2
= 58.86 J
The length of the portion of the object that deforms on impact can be used as distance (d)
d = 0.02m
Impact force (F) = E / d
= 58.86 / 0.02

$= 2943$ N

Diameter in tension:

$\sigma_t = F / \pi/4 \times d_c^2$

$380/1.5 = 2943 / \pi / 4 \times d_c^2$

$\mathbf{d_c = 3.84}$**mm**

Diameter in Shear :

$\tau = 0.5 \times Syt / FOS$

$\tau = F / \pi \times d_c \times t \times n$

$0.5 \times 380 / 1.5 = 2943 / \pi \times d_c \times 0.7 \times 3$

$\mathbf{d_c = 3.5217}$ **mm**

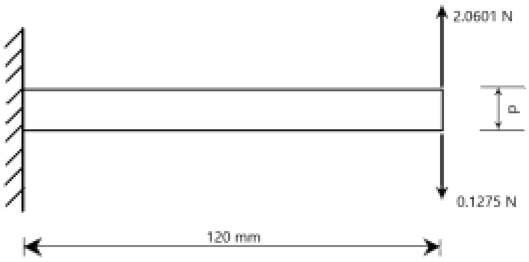
Hence, $d_c = 3.84$mm is selected and from standard chart we select M4 series of bolt.

Thickness of Plate

Bending Moment Calculation

$M = (2.0601 \times 120) - (0.1275 \times 120)$

$M = 231.90$ Nmm



Now,

$\sigma_b = 30$ Mpa ...(aluminum composite panel)

Bending equation for beam

$M/I = \sigma_b / y$

Where,

M = bending moment

I = Moment of inertia of area of cross section

σ_b = Bending stress

y = distance of extreme fibre from neutral axis

$M = (\sigma_b \times I) / y$

$231.90 = (2 \times 30 \times bd^3) / (12 \times d)$

$bd^2 = 46.38$ … (b = 10d)

d = 1.66 mm

From manufacturer's catalogue nearest standard thickness of available sheet

d = 3mm

b = 30mm

II.II Design

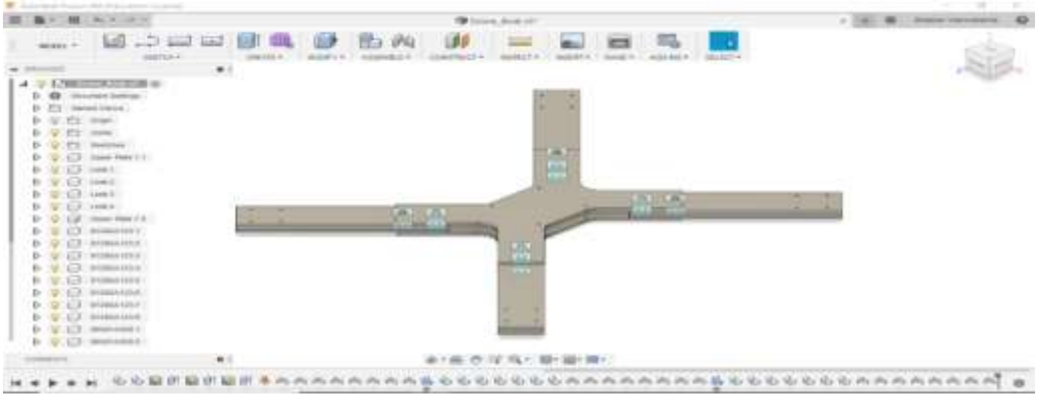


Fig 1: Standard orientation of drone frame

Fig 2: Front view of drone frame

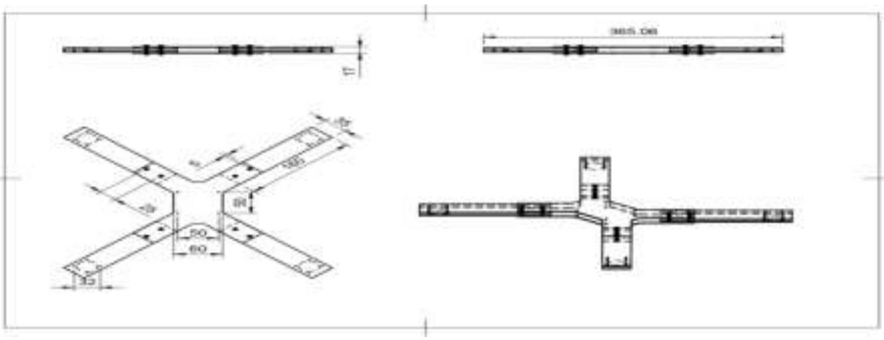


Fig 3: Dimensions of Frame

III. Analysis

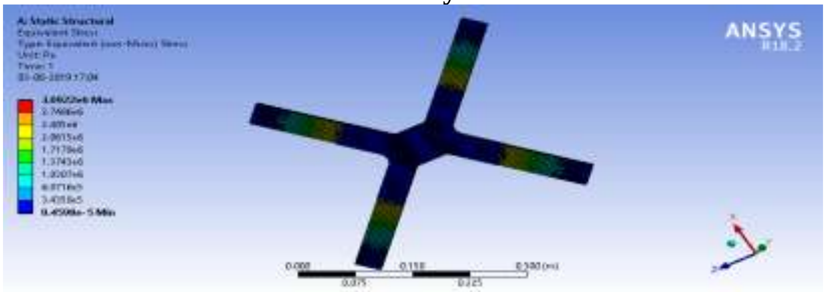


Fig 4: Equivalent (Von-Mises) Stress (top view)

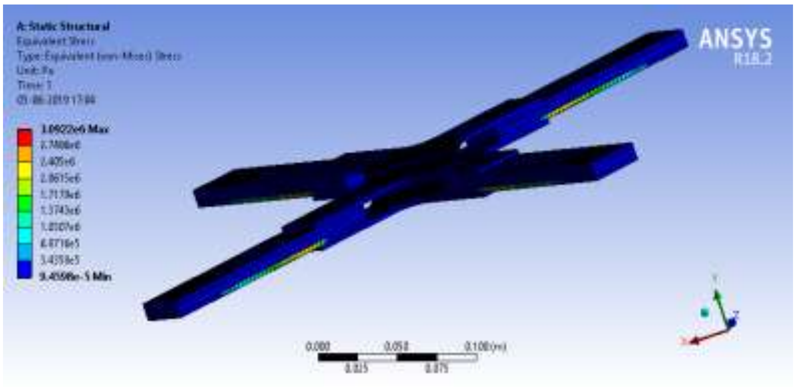


Fig 5: Equivalent (Von-Mises) Stress (front view)

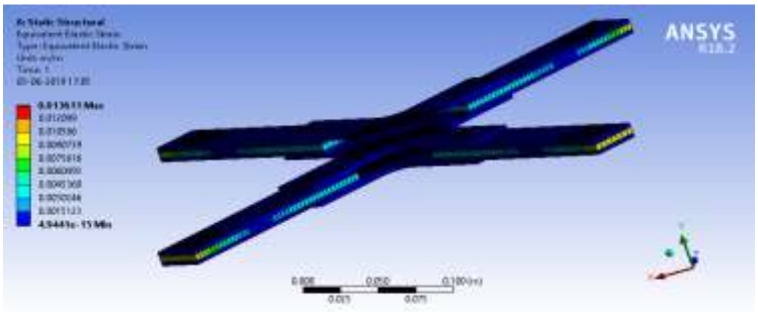


Fig 6: Equivalent elastic strain (von-mises)

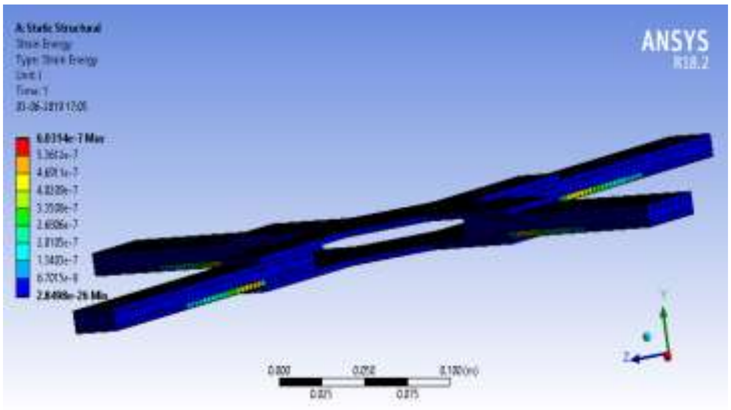


Fig 7: Strain energy (front view)

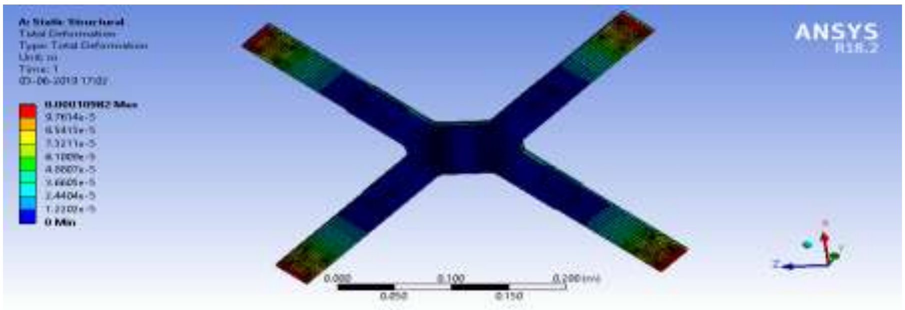


Fig 8: Total Deformation (top view)

III.I Analysis Report

First Saved	Monday, June 3, 2019
Last Saved	Monday, June 3, 2019
Product Version	18.2 Release
Save Project Before Solution	No
Save Project After Solution	No

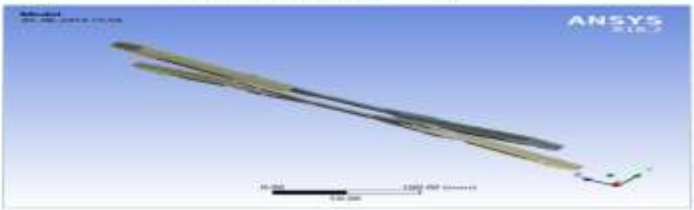


Fig 9: Frame Model

Object Name	Solid	Solid	Solid
State	Meshed		
Graphics Properties			
Visible	Yes		
Transparency	1		
Definition			
Suppressed	No		
Stiffness Behavior	Flexible		
Coordinate System	Default Coordinate System		
Reference Temperature	By Environment		
Behavior	None		
Material			
Assignment	Aluminum Alloy	Foam Material	Aluminum Alloy
Nonlinear Effects	Yes		
Thermal Strain Effects	Yes		
Bounding Box			
Length X	137.89 mm		
Length Y	3. mm	5. mm	3. mm
Length Z	137.89 mm		
Properties			
Volume	16638 mm³	27812 mm³	16687 mm³
Mass	4.6087e-002 kg	1.3906e-002 kg	4.6223e-002 kg
Centroid X	94.773 mm	94.892 mm	
Centroid Y	-10.056 mm	-6.0602 mm	-2.0602 mm
Centroid Z	113.56 mm	113.68 mm	
Moment of Inertia Ip1	4.7661 kg·mm²	1.4541 kg·mm²	4.7717 kg·mm²
Moment of Inertia Ip2	102.48 kg·mm²	30.967 kg·mm²	102.94 kg·mm²
Moment of Inertia Ip3	97.781 kg·mm²	29.571 kg·mm²	98.233 kg·mm²
Statistics			
Nodes	2815	1052	1058
Elements	1685	470	473
Mesh Metric	None		

Table 1: Mesh

Object Name	Mesh
State	Solved
Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Relevance	0
Element Order	Program Controlled
Sizing	
Size Function	Adaptive
Relevance Center	Medium

Element Size	5.0 mm
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Slow
Initial Size Seed	Assembly
Span Angle Center	Coarse
Bounding Box Diagonal	490.720 mm
Minimum Edge Length	0.10 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Triangle Surface Mesher	Program Controlled
Topology Checking	No
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	25860
Elements	13351

Table 2: Static Structure

Object Name	Analysis Settings
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Analysis Data Management	
Solver Files Directory	C:\Users\Bhaskar\AppData\Local\Temp\WB_BHASKAR-PC_Bhaskar_22040_2 \unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

IV. Conclusion

We have used ACP for building the frame of the drone which can be used as an alternate material for manufacturing the frame. Due to use of ACP the cost of frame has reduced considerably and the frame provides good stability during flight. Due use of these materials the weight of the drone has reduced and thus the stability of flight has improved. Optimization in design of frame helped to efficiently use the surface of the frame and increased overall aesthetic appeal. Lighter and strong materials reinforced limbs and specially designed middle frame helped to achieve greater ergonomic advantage and material saving.

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