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Structural Analysis of FPV Drones for Enhanced Stability and Performance through Design Thinking Aproach: A Computational Study

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***ABSTRACT**: This paper presents a computational study on the structural analysis of FPV drones aimed at improving their stability during flight. The study focuses on the design and materials used for the drone's frame and supports and evaluates their effects on the drone's performance. A finite element analysis is performed to simulate different flight conditions and identify areas of stress concentration and potential failure. The results of the analysis show that the use of lightweight and high-strength materials such as carbon fiber can significantly reduce the weight of the drone and increase its structural integrity, resulting in improved stability and maneuverability. Moreover, the study suggests that careful design of the frame and supports, including optimizing the geometry and positioning of key structural components, can further enhance the stability and performance of FPV drones.*

***KEYWORDS:** Design optimization, Maneuverability, Aerodynamics, FPV drones, Structural analysis, Stability*

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I. INTRODUCTION

In recent years, first-person view (FPV) drones have revolutionized the industry of unmanned aerial vehicles (UAVs).. These agile and versatile drones have found applications in numerous fields, including aerial photography, cinematography, search and rescue, and environmental monitoring. However, the design and construction of these drones require careful attention to ensure that they are safe, stable, and able to withstand the stresses of flight. One of the key challenges in designing FPV drones is achieving structural stability. The structural design of these drones plays a critical role in ensuring their stability, durability, and reliability during operation. A weak or poorly designed structure can lead to mechanical failure, resulting in a loss of control or damage to the drone.

Structural analysis is, therefore, essential in optimizing the design of FPV drones and ensuring that they can withstand the rigors of flight. In addition to structural analysis, the development of advanced control algorithms and dynamic models has the potential to enhance the maneuverability and performance of FPV drones. These control strategies can improve the stability and control of the drone, allowing it to navigate complex environments and perform more advanced maneuvers.

The structural design and stability of FPV drones will be thoroughly examined in this article. We will examine pertinent literature that relates to the development and manufacture of FPV drones, including the use of strong and lightweight materials like carbon fibers. We will also discuss the role of finite element analysis in simulating different flight conditions and identifying areas of stress concentration and potential failure. Furthermore, we will explore the development of advanced control algorithms and dynamic models to improve the stability and maneuverability of FPV drones. This will include a discussion of sliding mode control and back stepping control as potential control strategies, as well as trajectory tracking and trajectory planning to improve the flight paths of FPV drones.

II. METHODOLOGY

1.CAD MODEL DEVELOPMENT

The first step was to create a CAD model of the drone using SolidWorks software. The CAD model included all components of the drone, such as the frame, arms, motors, and propellers. The CAD model was then imported into ANSYS software for analysis.

2.MESH GENERATION

A finite element mesh was generated for the drone model using ANSYS Mechanical. This mesh consisted of tetrahedral elements with a size of 1 mm.

3.MATERIAL PROPERTIES

The material properties for the drone were specified based on the materials used in its construction. Carbon fiber was used for the frame, supports, and other critical components, while aluminum was used for non-critical components. The following material properties were used

Carbon fiber: Density = 1.6 g/cm^3, Young's modulus = 230 GPa, Poisson's ratio = 0.3

4.BOUNDARY CONDITIONS

Boundary conditions were applied to the drone model to simulate the loads it would experience during flight. These loads included:

Gravity: A gravity load of 9.81 m/s^2 was applied in the negative z-direction.

5.ANALYSIS

Aerodynamic loads were simulated using a CFD analysis in ANSYS Fluent. The resulting aerodynamic forces were then applied to the drone model as external loads.

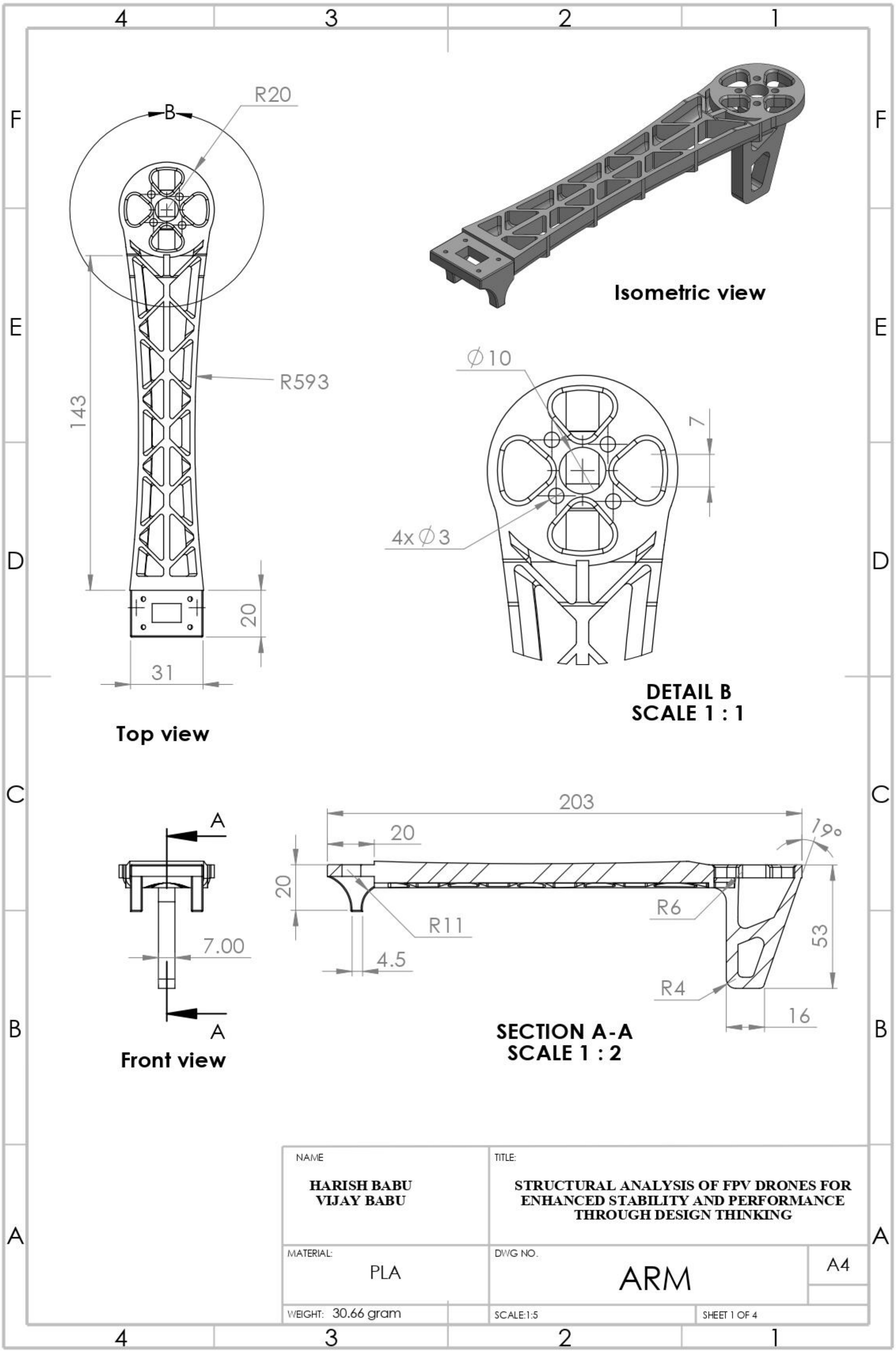
The analysis was performed using ANSYS Mechanical. The analysis included a static structural analysis to determine the stress and deformation of the drone under the applied loads.

The results of the analysis were then post-processed in ANSYS to obtain stress, strain, and deformation plots for the drone model.

III. DESIGN

1.The design of FPV drones plays a critical role in their overall performance and stability during flight. One key consideration is the choice of materials, as lightweight and high-strength materials such as carbon fiber can significantly improve the structural integrity of the drone while reducing weight. Carbon fiber has excellent strength-to-weight ratios, making it an ideal material for the frame, supports, and other critical components of the drone. The aerodynamics of the drone is another important factor to consider in its design. The shape and configuration of the drone can affect its stability and maneuverability during flight. Some researchers have explored the use of winglets, similar to those used in aircraft, to improve the aerodynamic performance of FPV drones.

2.Design optimization is another crucial element in the design of FPV drones. Finite element analysis (FEA) can be used to simulate different flight conditions and identify areas of stress concentration and potential failure, allowing for design optimization and improvements in structural integrity. Overall, the design of FPV drones requires a comprehensive understanding of their aerodynamics and structural requirements. The use of high-strength materials, aerodynamic design optimization, and FEA can help to improve the performance and stability of these drones during flight.



NAME
HARISH BABU
VIJAY BABU

TITLE:
STRUCTURAL ANALYSIS OF FPV DRONES FOR ENHANCED STABILITY AND PERFORMANCE THROUGH DESIGN THINKING

MATERIAL: PLA

DWG NO. ARM

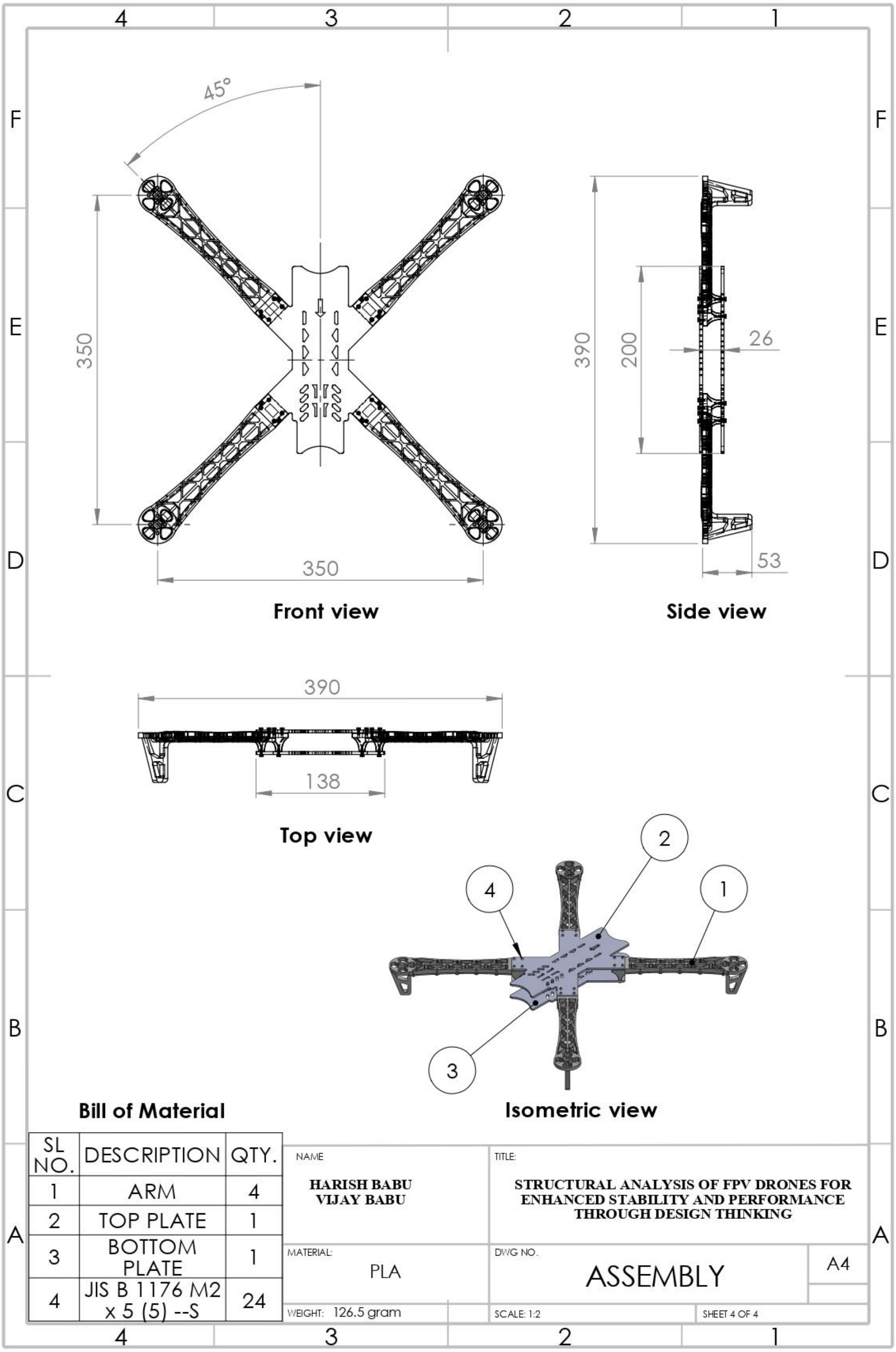
A4

WEIGHT: 30.66 gram

SCALE:1:5

SHEET 1 OF 4

FIG I -ARM



Bill of Material

SL NO.	DESCRIPTION	QTY.
1	ARM	4
2	TOP PLATE	1
3	BOTTOM PLATE	1
4	JIS B 1176 M2 x 5 (5) --S	24

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MATERIAL: PLA

DWG NO. ASSEMBLY

A4

WEIGHT: 126.5 gram

SCALE: 1:2

SHEET 4 OF 4

FIG II STRUCTURE OF FRAME

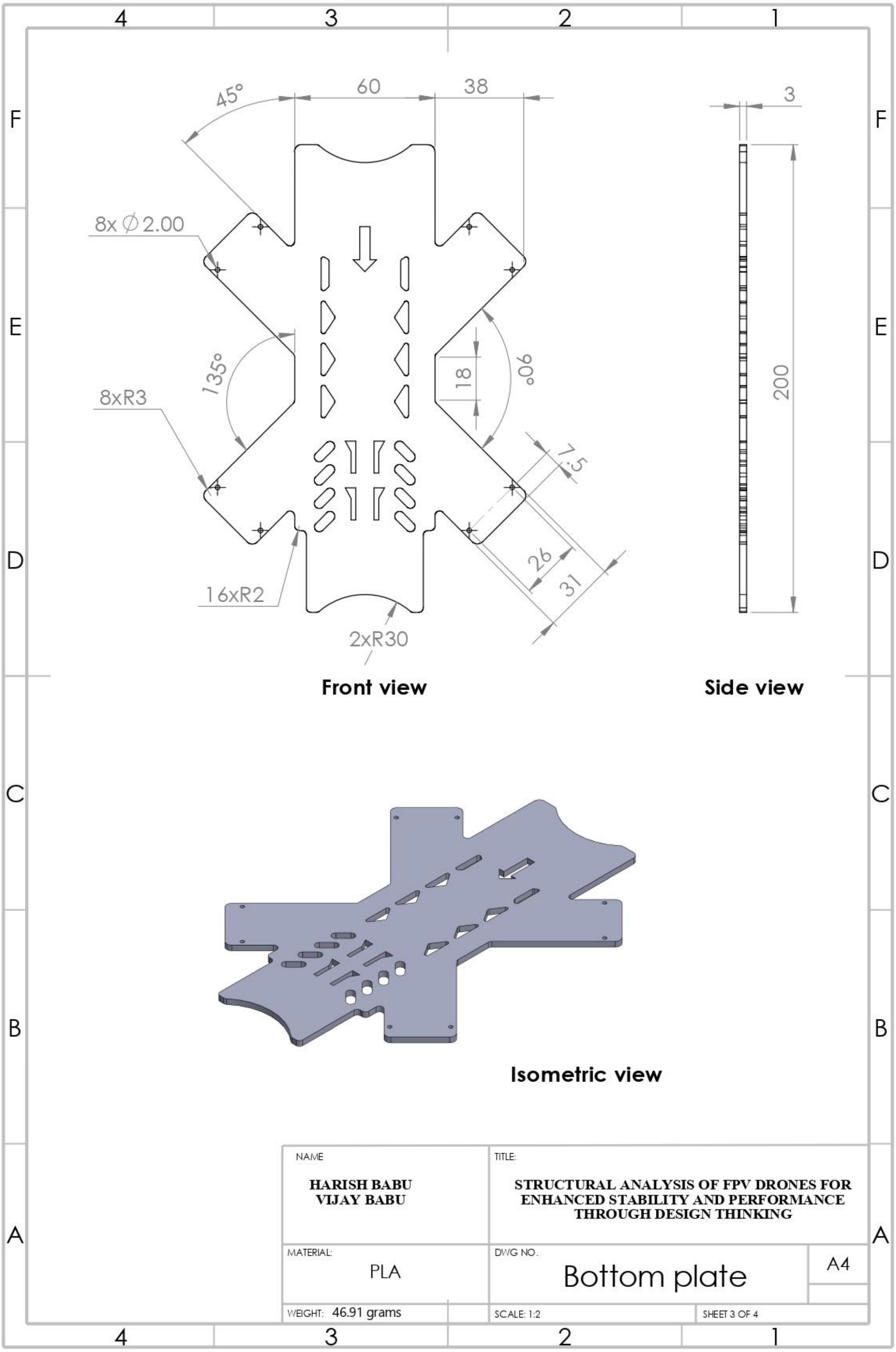
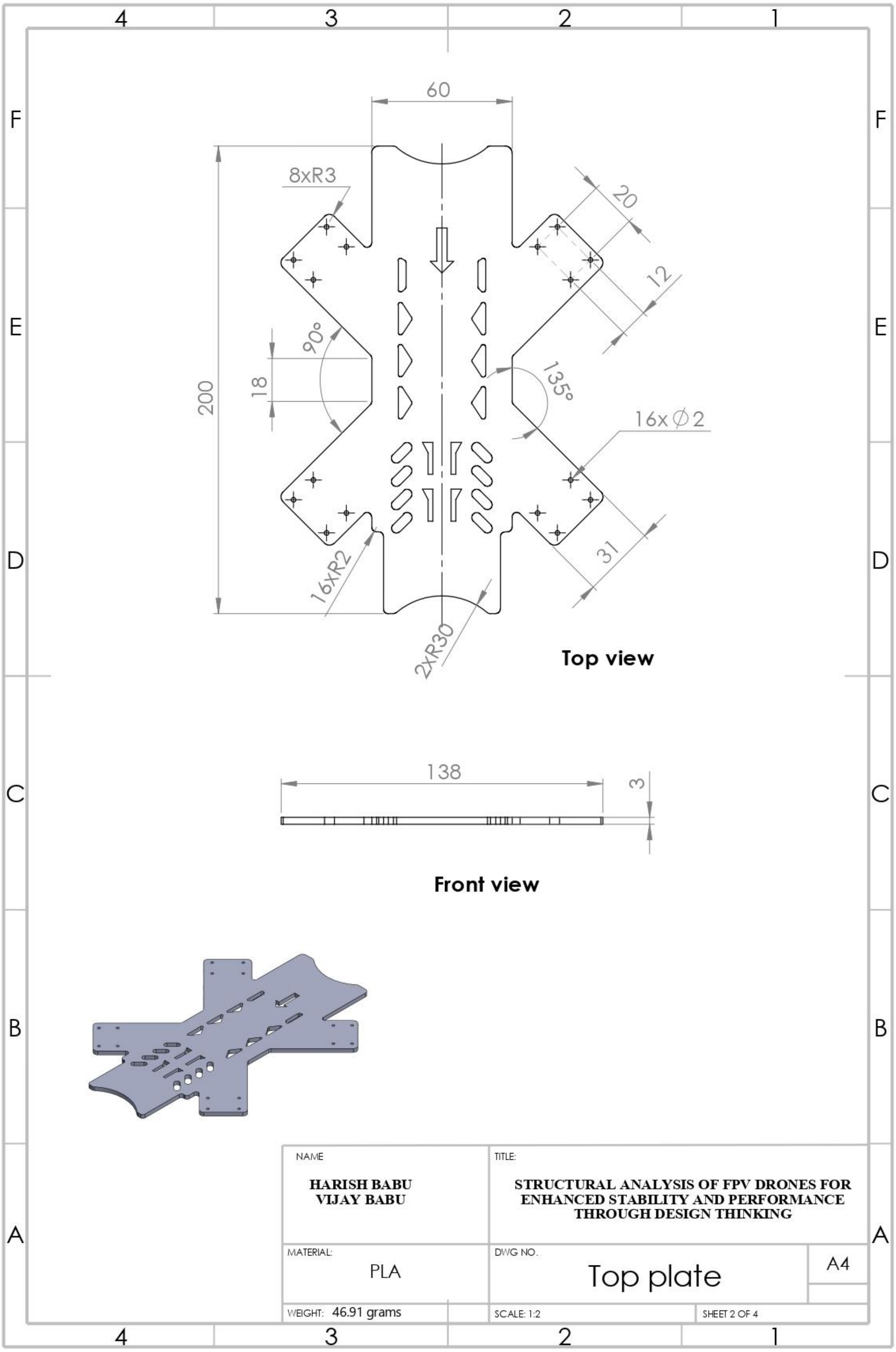


FIG III BOTTOM PLATE



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HARISH BABU
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TITLE:
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MATERIAL: PLA

DWG NO. Top plate

A4

WEIGHT: 46.91 grams

SCALE: 1:2

SHEET 2 OF 4

FIG IV – TOP PLATE

IV. ANALYSIS IN ANSYS

We used ANSYS to simulate the drone's response to various flight conditions, including accelerations, vibrations, and aerodynamic forces. We constructed a three-dimensional model of the drone using CAD software, defining its geometry, materials, and other physical properties. The model included the frame, supports, and other critical components of the drone.We then applied loads to the model to simulate different flight conditions, including sudden stops, turns, and turbulence. We analyzed the model's response to these loads, identifying areas of high stress and potential failure. Based on these results, we optimized the design of the drone, using ANSYS to simulate and evaluate different configurations and materials.

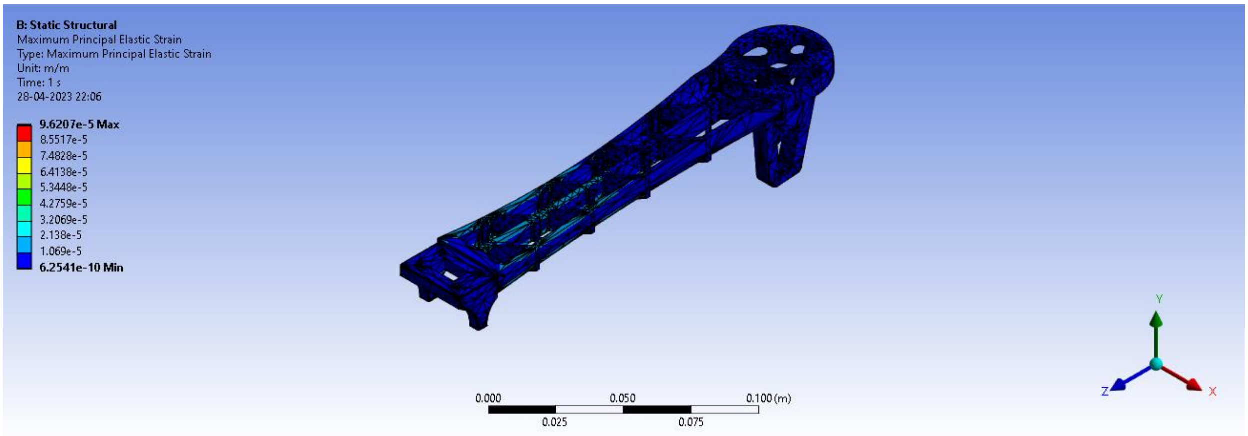


FIG V - ANSYS STRESS

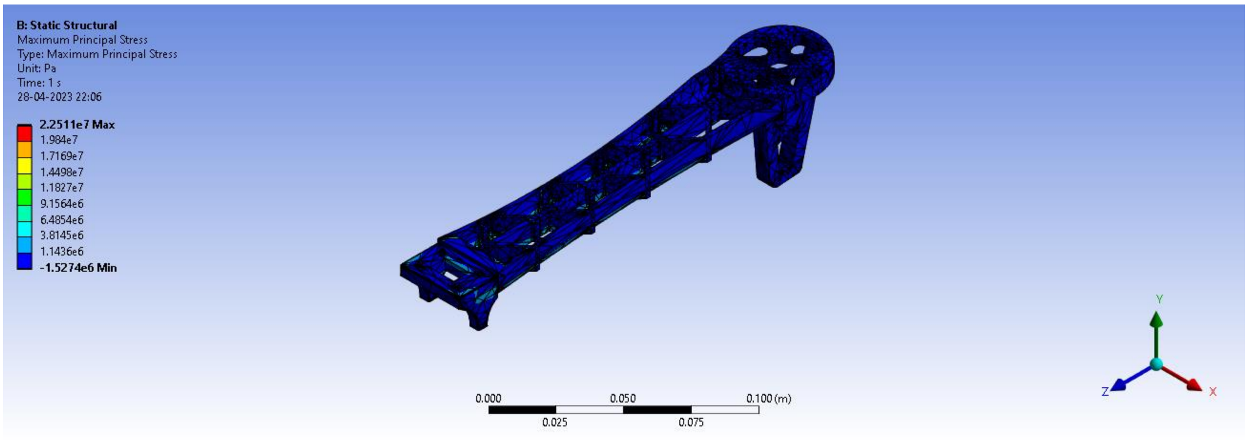


FIG VI - ANSYS STRAIN

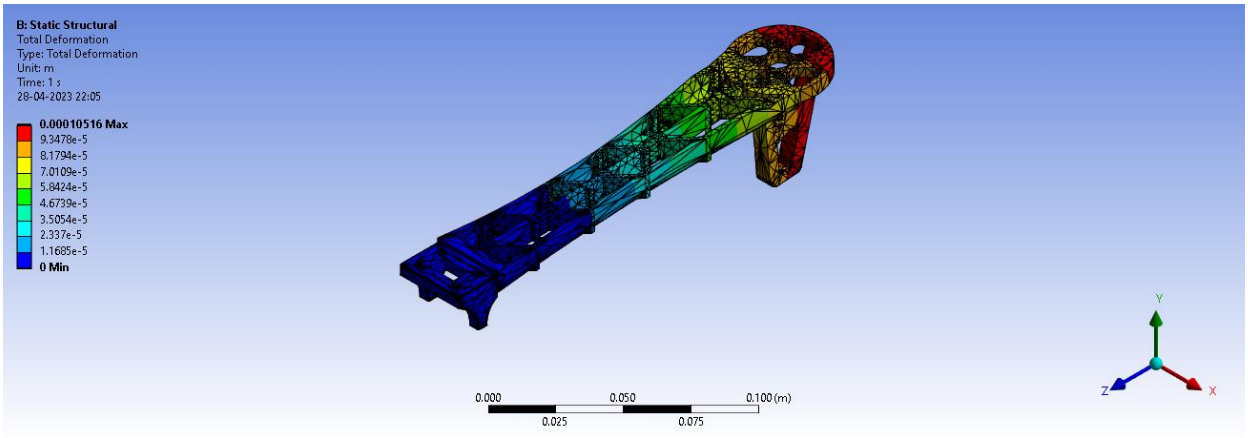


FIG VII - DEFORMATION

V . CFD

FPV drones are lightweight, high-performance quadcopters that require careful design to achieve maximum speed, agility, and stability. The aerodynamics of the drone play a critical role in achieving these goals, and CFD analysis can be used to simulate and optimize the airflow around the drone. CFD analysis can also be used to study other aspects of FPV drone design, such as thermal management and vibration control.

The benefits of CFD analysis in FPV drone design include the ability to visualize and quantify the behavior of air around the drone, identify areas of high drag or turbulence, and optimize the shape, size, and weight distribution of the drone. CFD analysis can also be used to optimize the placement of the drone's components, such as the motors and battery, to improve the drone's stability and control.

S.no	Parts	Nos	Material	Weight(g)
1	Arm	4	PLA	30.66
2	Bottom Plate	1	PLA	46.91
3	Top Plate	1	PLA	46.91
4	Jis B 1176 M2 Screw	24	Stainless steel	12.4

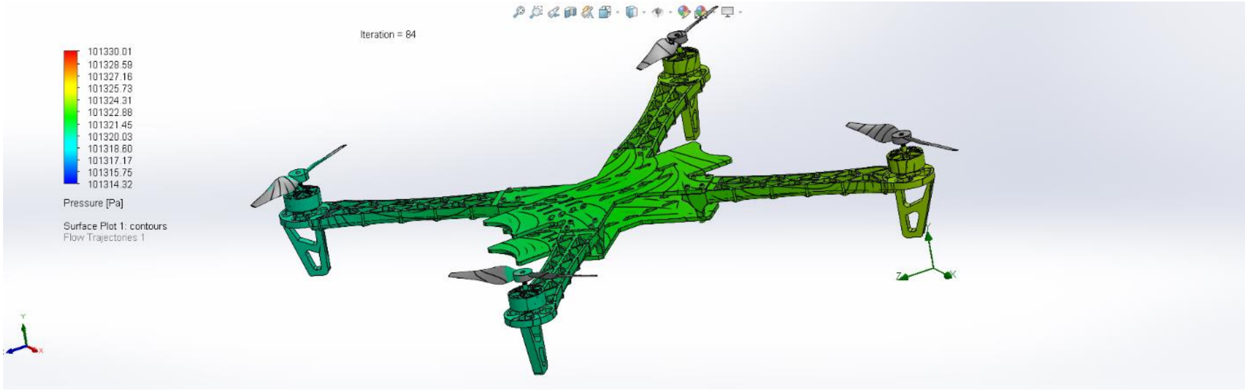


FIG VIII – cfd of frame

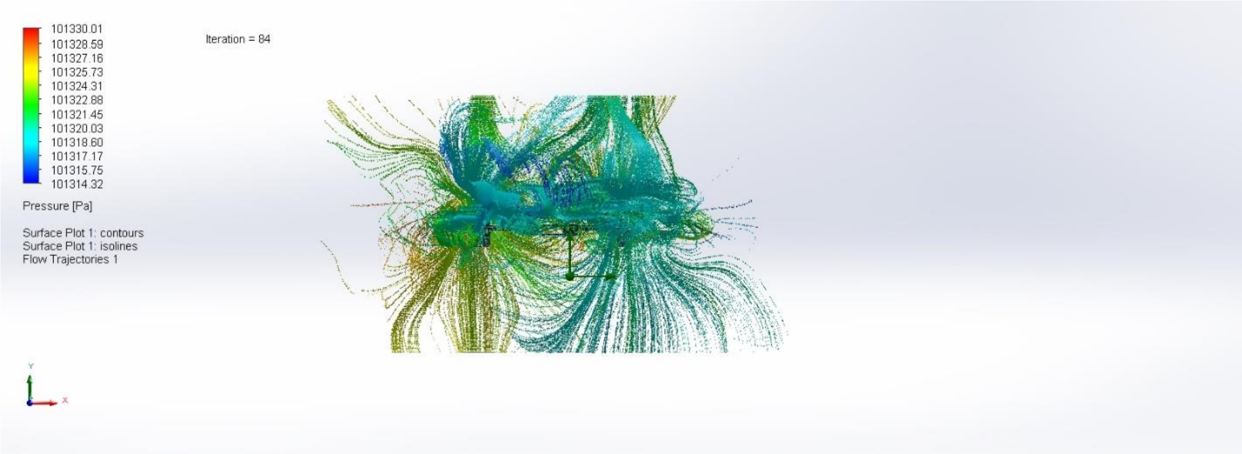
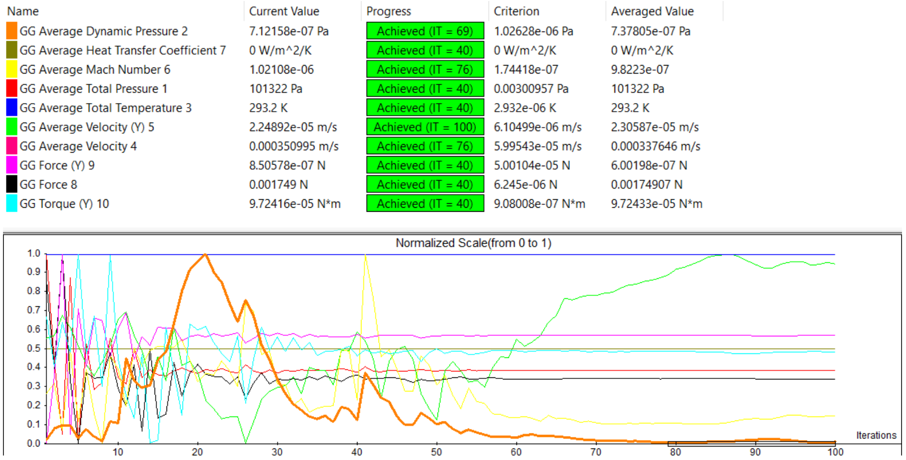


FIG IX – AIR FLOW



Name	Current Value	Progress	Criterion	Averaged Value
🟧 GG Average Dynamic Pressure 2	7.12158e-07 Pa	Achieved (IT = 69)	1.02628e-06 Pa	7.37805e-07 Pa
🟫 GG Average Heat Transfer Coefficient 7	0 W/m^2/K	Achieved (IT = 40)	0 W/m^2/K	0 W/m^2/K
🟨 GG Average Mach Number 6	1.02108e-06	Achieved (IT = 76)	1.74418e-07	9.8223e-07
🟥 GG Average Total Pressure 1	101322 Pa	Achieved (IT = 40)	0.00300957 Pa	101322 Pa
🟦 GG Average Total Temperature 3	293.2 K	Achieved (IT = 40)	2.932e-06 K	293.2 K
🟩 GG Average Velocity (Y) 5	2.24892e-05 m/s	Achieved (IT = 100)	6.10499e-06 m/s	2.30587e-05 m/s
🟪 GG Average Velocity 4	0.000350995 m/s	Achieved (IT = 76)	5.99543e-05 m/s	0.000337646 m/s
🟪 GG Force (Y) 9	8.50578e-07 N	Achieved (IT = 40)	5.00104e-05 N	6.00198e-07 N
⬛ GG Force 8	0.001749 N	Achieved (IT = 40)	6.245e-06 N	0.00174907 N
🟦 GG Torque (Y) 10	9.72416e-05 N*m	Achieved (IT = 40)	9.08008e-07 N*m	9.72433e-05 N*m

FIG X – GRAPH OF CFD

V. CONCLUSION

In conclusion, structural analysis and CFD analysis are two powerful tools that can be used in FPV drone design to optimize performance, durability, and stability. Structural analysis allows designers to identify areas of the drone that are at risk of failure and make design changes to improve its strength and durability, while CFD analysis allows designers to visualize and quantify the behavior of air around the drone and optimize its aerodynamics.

By combining these two types of analysis, designers can create FPV drones that are not only structurally sound but also aerodynamically optimized for maximum speed, agility, and stability. The results of these analyses can be used to make design changes that improve the drone's overall performance, while also reducing the risk of failure or damage during flight.

While there are challenges associated with both structural analysis and CFD analysis, such as computational intensity and model simplifications, these tools offer significant opportunities for future research and development. By continuing to refine these analysis techniques, researchers can create more advanced models that capture the full range of physical phenomena involved in FPV drone flight, leading to even more optimized designs in the future.

VI. LITERATURE REVIEW

In recent years, FPV drones have become increasingly popular for both recreational and professional use due to their maneuverability and versatility. However, the design and construction of these drones must take into account various factors that can affect their stability and performance. Researchers have explored different approaches to optimize the design of FPV drones, including the use of lightweight and high-strength materials such as carbon fiber, as well as careful design of the frame and supports. Finite element analysis has been used to simulate different flight conditions and identify areas of stress concentration and potential failure.

Studies have also focused on developing control algorithms and dynamic models to improve the stability and maneuverability of FPV drones. Sliding mode control and backstopping control have been investigated as potential control strategies, and simulations have been used to evaluate their effectiveness. Trajectory tracking and trajectory planning have also been studied to improve the flight paths of FPV drones.

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