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DESIGN AND ANALYSIS OF DRONE FOR WEIGHT MANAGEMENT FOR DELIVERY IN URBAN AREAS

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Abstract

The topic of the project is to represent the development of drone in delivery field on urban areas by reducing weight from a standard weight from 2.2kg to 2kg or less in our own designs with the strength to carry a payload of 3.5 – 5 kg by selecting the appropriate material. We are going to design two drones with different shapes and comparing these two drones. The design is basically designed in 3D modelling software Fusion 360 and the weight is checked , its bare weight is reduced with generative design where the unwanted metal is removed and the required area is filled with the material of the desired strength, to make it even clear that different designs of drone is designed and it's checked whether our design is able to lift the payload it is analyzed in Ansys and the frame strength is checked using the Structural and Modular Analysis and the sustainability of the drone in the wind conditions is checked and analyzed using CFD

Keywords: various designs, weight reduction; Ansys; Structural Analysis; Air flow analysis (CFD) .

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1. INTRODUCTION

Drone becomes a regular use in this period even some reputed industries are using drones for delivering purpose like Amazon in a huge amount, but in this topic, we done an survey in the drone specification in delivery , especially in urban areas and we have found some issues in that, the weight of the drone , the payload weight to be carried ,the area range covered by the drone with payload, the altitude of the drone reached by avoiding the disturbance during cruse .The main issue from this problem is taking the weight of the drone used for delivery, where the weight of the drone is reduced by our designs,with the same specifications used in the normal drone According to our survey, the weight of a typical delivery drone is 2.2 kg, including components like battery, camera, motor, propeller, etc., but the aim is to design 2 drones in different configurations that weigh 2 kg or less to support a given payload. Designed drones' material (carbon fiber reinforced polymers) are used with CFRP. Ansys software is used to analyze airflow analysis and structural analysis

2. PROBLEM OVERVIEW

The problem with delivery using a drone is delivering the packages to the right places Meanwhile, the drone faces many problems, such as carrying weight while flying, altitude control, battery power, timing, delivery location, etc. One of the main reasons is weight control. The problem is the amount of payload carried by the drone, some drones available in the market are used to carry minimum weight, some drones are used for professional use, they are used to carry around 250kg, as urban areas require drones used to deliver packages, medicine, etc., a normal delivery drone is taken and its self-weight is 2.2 kg, so the power used for take-off is high and the remaining power is used for hovering. This causes huge power loss, affecting the drone's performance in delivering the load

3. WEIGHT AND THRUST CALCULATION

Weight is an important part of the drone, which depends on the weight of the individual components used and the frame weight of the drone.

Components	Weight A (in Kg)	Wright B (in Kg)
Drone frame	0.975	1.180
Propeller	0.032	0.032
ESC	0.056	0.056
Battery & Motor	0.524	0.524
Camera and other	0.150	0.150
Total	1.737	1.9

Table1.Component weight

The weight of the component is noted as 762 g, which is taken from Table 1. The frame weights of drone A and B are 975g and 1180g, and adding these to the component masses gives a total mass of 1.737Kg and 1.9Kg, and considering the gravitational constant, the mass is 16N and 18N, by converting newton to Kgf the calculated thrust is 1.6Kgf and 1.8Kgf ,by using power to weight ratio method ,the thrust required for single motor, to lift and to hover the drone, must be twice the normal thrust therefore the thrust needed is 0.8Kgf and 0.9Kgf

When the drone is with payload, the thrust required for lifting and hovering is calculated by adding the payload mass to the empty weight of the drone and using the same calculation the thrust of the drone is calculated as 2.5Kgf and 2.7Kgf. Calculated thrust is for a 3.5 kg payload

4. DESIGN APPROACH

4.1 Drone Design

The drone design is done using Fusion 360, a 3d software where the dimension of the drone is 450mm. The design of the drone is determined to be a multi-rotor quadcopter, the frame design is X-frame. The rationale behind the design of the X-frame is that it has great flexibility and predictability in their handling and manages weight by evenly distributing own and payload weight.

Specifications	Dimension (mm)
Category	Mini
Frame size	450
Propeller size	254
Centre Base	15x10
Arm Length	14
Base Height	56.4
Motor shaft diameter	3

Table 2. Drone Specifications

4.2 Generative Design

Generative design is a design that produces design results based on multiple iterations through AI, which is done from a basic outline of ideated design. Formative design provides outputs through boundary and load condition, material is filled in the region according to the conditions. Generative design consists of three phases: **Define**, **Develop**, and **Explore**. Defining is where we identify our problems, correct some constraints and inform the system. Generating means that the computer applies the constraints given by the user to the design and the output design is created from all possibilities. Exploration is the stage where the generated output is viewed by the user and decided to use it as the main design with the help of AI. The drone's creation design uses obstacle geometry to create a boundary where the required material must be filled. Precise geometry acts as a link to the material, with the AI determining where the material should start and where it should end AI in generative design starts to generate a different iteration from the design and shows some iteration output according to the given constraints. From these publications 4 designs are suitable and 2 designs are finalized from there, these 2 designs are compared and selected on the basis of frame weight and minimum safety factor, these 2 designs are with the shape of Rectangular and Hexagonal

5. ANALYZATION OF DRONE FRAME

5.1 Structural Analysis

After several iterations from generative design,2 selected drones are analysed to check design robustness, for which structural analysis is used.

Structural analysis of the drones is done considering its empty weight and payload load conditions. The payload starts from 3.5 kg to 5 kg and the results of the drones are listed.

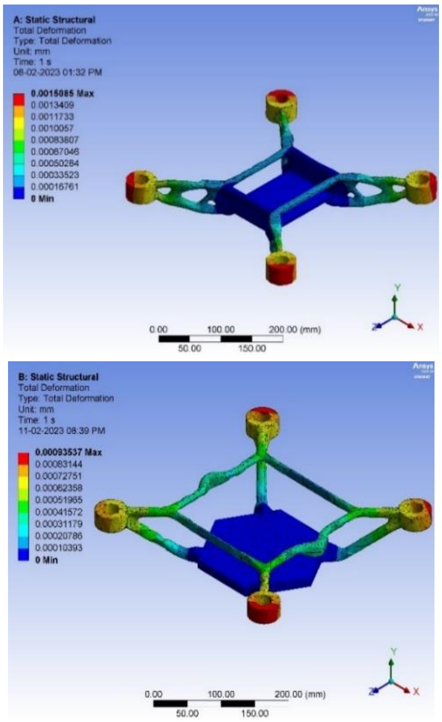


Fig 1: - Total deformation of drone A&B

The maximum of 0.001508 mm and 0.000935 mm total deformation value occurs when the drone A&B undergoes a load condition of 3.5kg

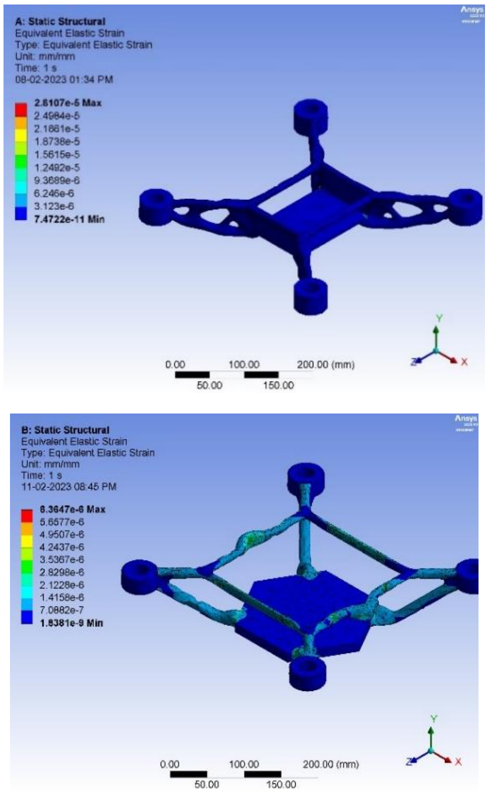


Fig 2: - Strain of drone A&B

The maximum of 2.8107e[-5] and 6.3647e[-6] Strain value occurs when the drone A&B undergoes a load condition of 3.5kg

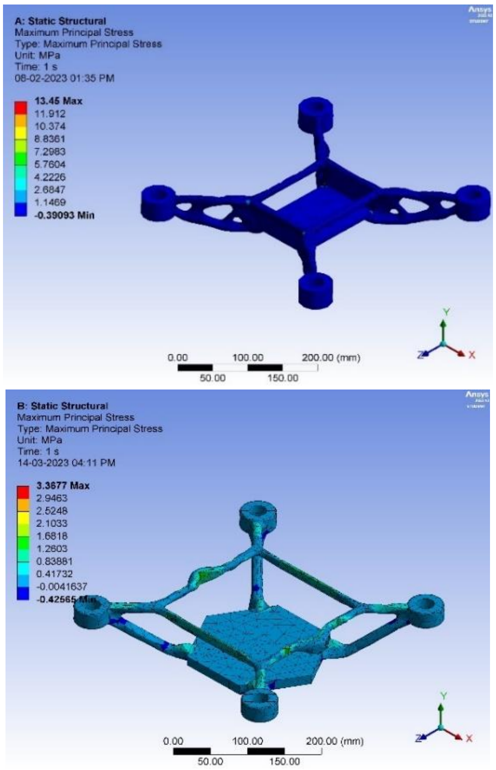


Fig 3. Stress of drone A&B

The maximum of 13.45 Mpa and 3.367 Mpa Stress value occurs when the drone A&B undergoes a load condition of 3.5kg

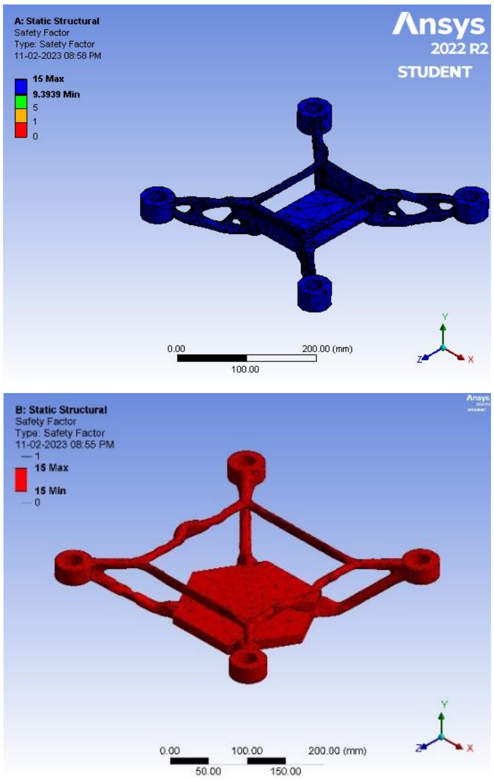


Fig 4. Safety factor of drone A&B

Analysed Results	Drone A load at 3.5 kg	Drone B load at 3.5 kg
Total Deformation (mm)	0.001508	0.000935
Stress Analysis	$2.8107e^{-5}$	$6.3647e^{-6}$
Strain Analysis (Mpa)	13.45	3.367
Safety Factor	0-15	15 (Failed)

Table 2. Comparison of the Analysed results

From the above analysed results table, drone B analysed under 3.5 kg payload conditions shows a factor of safety of 15, which is not satisfactory and by comparing the weights of the two designs, drone A is much lower than drone B. Since the topic is about low weight, drone A is taken and the rest of the analysis is done on drone A

Factor of safety is the ratio of ultimate stress to the working stress. It used to denote the additional strength of the component to the required strength for carrying that load

The drone A frame is analysed on the payload condition of 5kg and the results of the analysation is listed

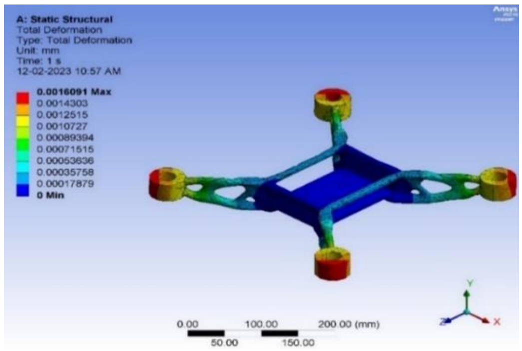


Fig 5. Total deformation drone A

The maximum of 0.0016091mm total deformation value occurs when the drone A undergoes a load condition of 5kg

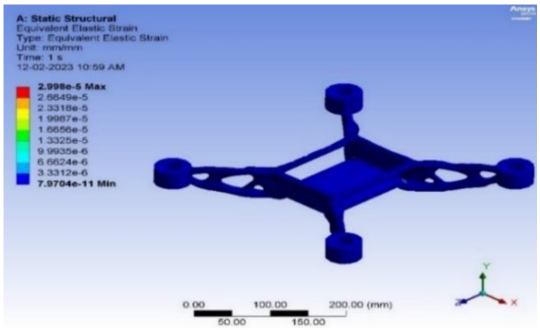


Fig 6. Stress of drone A

The maximum of $2.998e^{-5}$ Strain value occurs when the drone A undergoes a load condition of 5kg

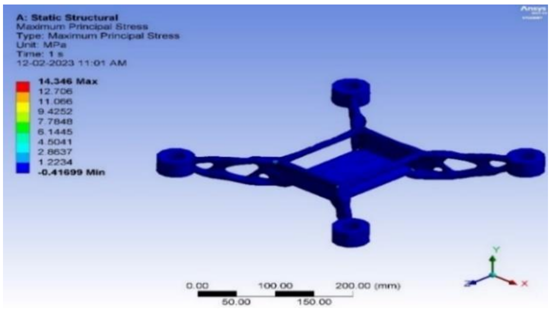


Fig 7. Strain of drone A

The maximum of 14.346 Mpa Stress value occurs when the drone A undergoes a load condition of 5kg

In additional cases, the drone A frame is analysed with a 10 kg payload condition to check whether it can withstand or not, the analysis results are presented.

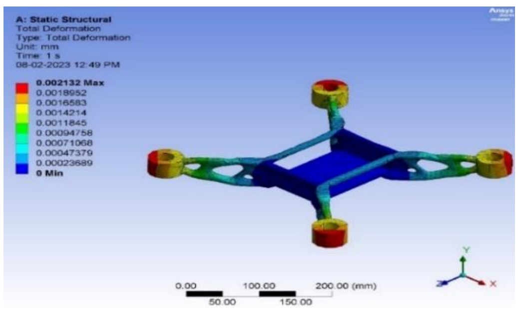


Fig 8. Total deformation of drone A

The maximum of 0.002132 mm total deformation value occurs when the drone A undergoes a load condition of 10kg

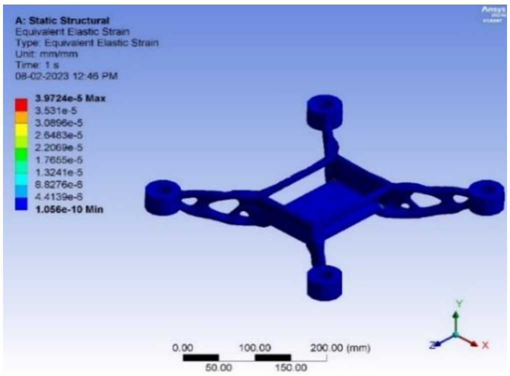


Fig 9. Strain of drone A

The maximum of 3.9724e^{-5} Strain value occurs when the drone A undergoes a load condition of 10kg

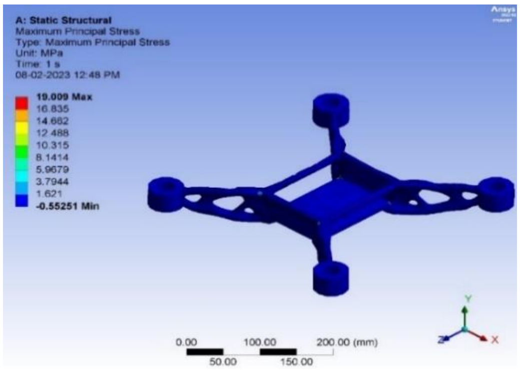


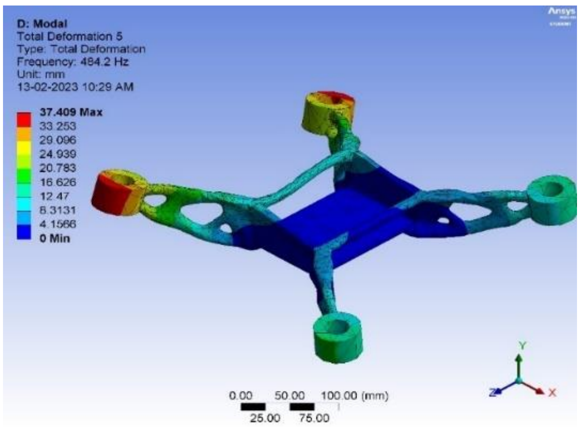
Fig 10. Stress of drone A

The maximum of 19 Mpa Stress value occurs when the drone A undergoes a load condition of 10kg

(Note: -The difference in weight is based on the drone's payload, not the components used in it. The analysis is to check whether the frame can support such a weight or not, so the component and its weight remain unchanged.)

5.2 Modal Analysis

The Modal Analysis is done for drone frame A due the result shown on the Structural Analysis



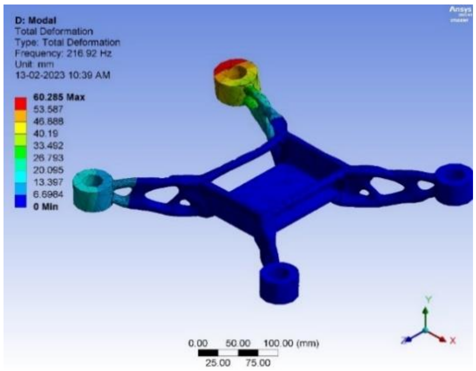


Fig 11. Minimum & Maximum frequency

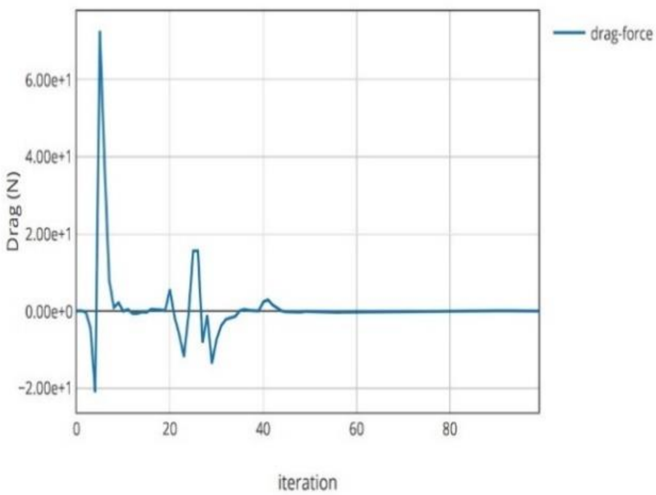
The minimum of 37.409 Hz and maximum of 60.285 Hz of frequency can be withstand by Drone frame A

5.3 CFD

This analysis shows the variation of velocity and pressure actions on the propeller and frame. Fluency analysis of drone A with wind speed of 10ms-1 (36 kmph) and turbulence speed of 5% are given as input condition and lift force, drag force and their coefficients are found.

When the drone is at hover condition at a speed of 10 ms^{-1} the drag force of maximum 6e^{+1}N is created due to wind velocity acting on the drone at the particular speed

When the drone is at hover condition at a speed of 10 ms^{-1} the lift force of maximum 2e^{+1}N is created due to wind load acting on the drone at the particular speed



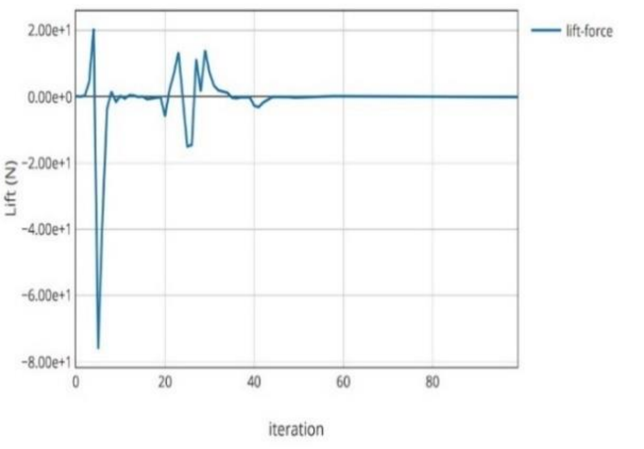
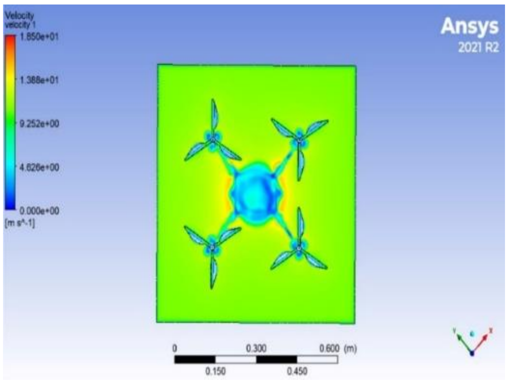
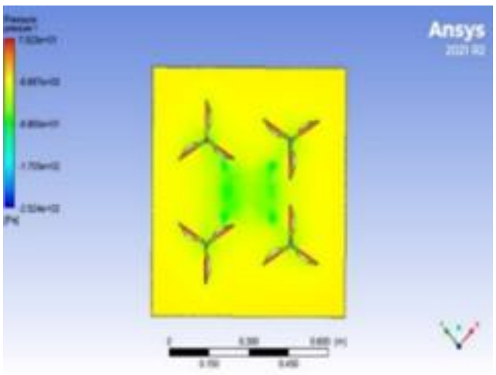
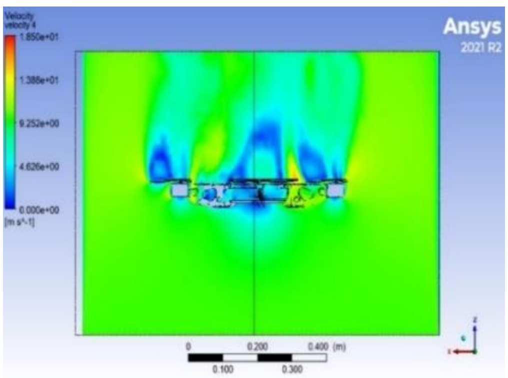


Fig 12. Drag and Lift force of the drone

The contour planes are created to display the effect of velocity and pressure affecting on the drone areas at a speed of $10ms^{-1}$ and for the clear understanding the results are listed







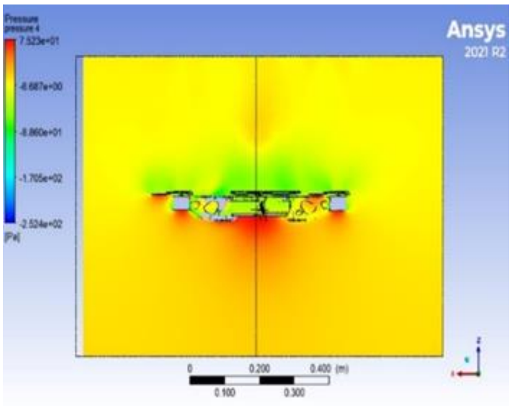


Fig 13. Velocity and pressured occurred on the frame & propeller

The Fig 13 shows the maximum velocity of $1.85e^{+1}$ ms^{-1} and pressure of $7.52e^{+1}$ Pa is occurred on the drone frame as well as to the propeller at the speed of $10ms^{-1}$

6. RESULT ANALYSIS

The 2 selected optimum designs are analysed for stress-strain and deformation. 2 designs were selected based on drone A&B weight and suitable design provided by generative design. Drone B was rejected due to the safety factor exceeding the limits required for a normal drone. The model is analysed for drone A to check the maximum frequency. Then wind speed of 10ms-1 (36 kmph) and turbulence speed of 5% input condition goes to CFD.

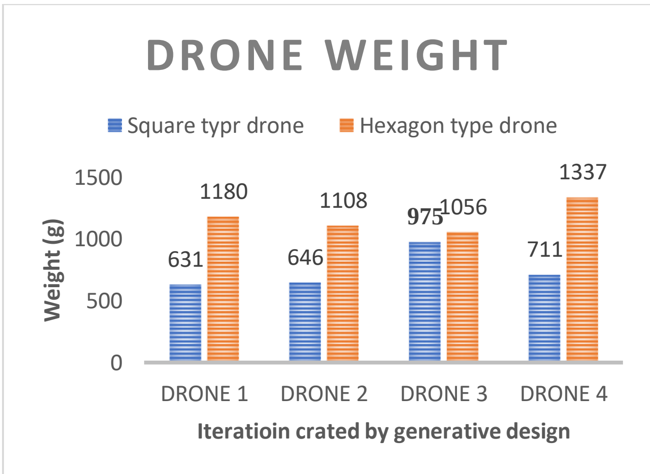


Fig 14. Weight chart of different iterated design

The above chart shows the weight of the different iteration of the two designs, from that data two designs is chosen by considering the weight as well as the design

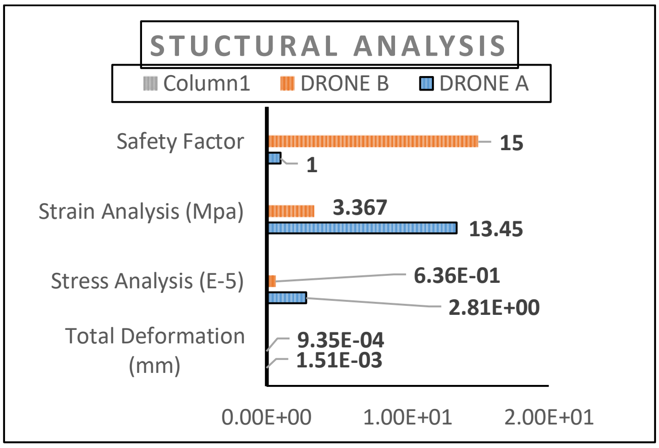


Fig 15. Comparison Chart of the Analysed results

From the above chart, the drone design is optimized to a single drone by the analysed result

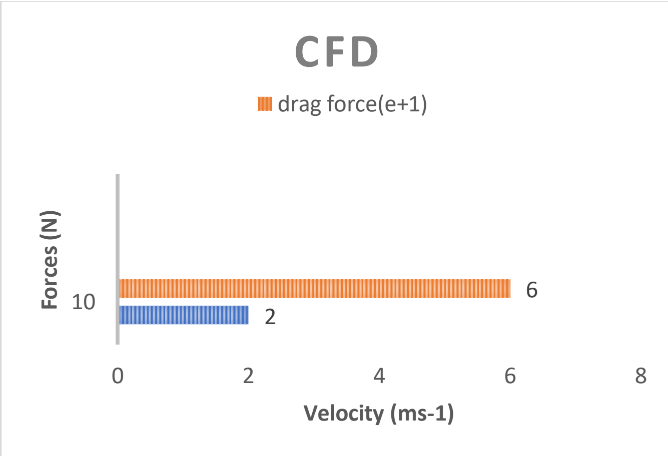


Fig 16. lift and drag force of Drone A

7. CONCLUSION

Drone delivery is the technology of the future and this technology should be low cost with better delivery time. Involvement of drones in delivery will be huge in future, but delivery drones have some issues like flight time, energy consumption, weight control, distance to cover, which need to be identified and fixed as the basic problem Based on weight management, this paper reduces weight by introducing two design models in the generative design, where material is removed from non-required areas and material is added to the load-bearing area ,So with this the strength remains the same, but the weight is reduced. Both models are tested to withstand the real-time environment and load condition used for delivery. The analytical data result shows that the drone developed using the Generative design can withstand the weight, and the result developed by CFD shows the lift force drag force, pressure-velocity generated on the surface by the given wind speed and this conclude that the selected drone can withstand the situation with the minimum weight created by the design, so the use of this drone in the future can increase the flight time and distance covered and can be used at a lower cost. Avoiding wasted materials during drone manufacturing

8. REFERENCE

1) Balint Leon Seregi and Peter Ficzere “Weight Reduction of a Drone Using Generative Design”. Hungarian Journal of Industry and Chemistry Vol. 49(2) Pp. 19–22 (2021)

2) Sakshi Sharma, Aayush Srivastava “Design and Analysis of Drone”, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 08 Issue: 04 | Apr 2021

3) Mohaneshwar S, Karthik R M, Rahul Batapagari, Ninganna Gangappa Bani, Varun Kumar Reddy N “Design of Delivery Drone” 2021 JETIR July 2021, Volume 8, Issue 7

4) Konstantinos Christodoulou, Michail Vozinidis, Asterios Karanatsios, Efstathios Karipidis, Fotios Katsanevakis, Zinon Vlahostergios “Aerodynamic Analysis of a Quadcopter Drone Propeller with the Use of Computational Fluid Dynamics”, The Italian Association of Chemical Engineering VOL. 76, 2019

5) K. Sowjanya, S. Suresh, “Structural Analysis of UAV”, International Journal of Computer Trends and Technology (IJCTT), Vol.4 Issue 7–July 2013.

6) Gabriel M. Hoffmann, Haomiao Huang, Steven L. Waslander, “Quadrotor Helicopter Flight Dynamics and Control: Theory and Experiment” AIAA

7) Kush Soni, Gaurang Vara, Ishit Sheth, Harshil Patel, “Design and Analysis of Drone System for ISIE ESVC”, International Journal of Applied Engineering Research ISSN 0973-4562 Vol-13, Number 10 (2018) pp. 8572-8576”.

8) Michael Leichtfried, Christoph Kaltenriner, Annette Mossel, “Hannes Kaufmann Autonomous Flight using a Smartphone as On-Board” ACM 978-1-4503-2106, MoMM2013, 2-4 December 2013

9) J. Cohen, "Drone Spy Plane Helps Fight California Fires," Science Journal, vol. 318, no. 5851, p. 727, 2007

10) Neeraj Singh, R.S. Bharj, Kamal Kumar, “Optimum Design and Experimental Analysis of Drone System for BAJA”, International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264) Vol. 5, No. 3, December 17.

11) Yeong S. P. and Dol S. S., 2016, Aerodynamic Optimization of Micro Aerial Vehicle. Journal of

Applied Fluid Mechanics, Volume 9, No. 5, 2111-2121

12) D. C. L. Kristen Boon, "Warrant Requirement and Suspicion less Drone Searches," in the Domestic Use of Unmanned Aerial Vehicles, USA, Oxford University Press, 2014, p. 228.

13) Kutty, H.A., Rajendran P., “3D CFD Simulation and Experimental Validation of Small APC Slow Flyer Propeller Blade”. Aerospace, 4(1), 10

14) Sarghini F., De Vivo A., 2017, “Analysis of Preliminary Design Requirements of a Heavy Lift Multirotor Drone for Agricultural Use.” Chemical Engineering Transactions, Volume 58

15) Vivek Singh Negi, Nayan Deshmukh, Amit Deshpande, “Design and Analysis of Drone system”, International Journal of Advance Engineering and Research Development Vol-4(11), November - 2017”.

16) Barth, T.J., Jespersen, D.C., 1989, the Design and Application of Upwind Schemes on Unstructured Meshes. In Proceedings of the 27th Aerospace Sciences Meeting, Reno, NV, USA, 9–12

17) Mattingly & Heiser & Daley, “Constraint Analysis for electric powered Mini Aerial Vehicle”, Aircraft Engine

18) Mohammadmahdi Khamsi “Design and Analysis of an Unmanned Aerial Vehicle Capable of Carrying the Camera” Department of Mechanics, University of Guilan, Iran

19) Konstantinos Christodoulou, Michail Vozinidis, Asterios Karanatsios, Efstathios Karipidis, Fotios Katsanevakis, Zinon Vlahostergios “Aerodynamic Analysis of a Quadcopter Drone Propeller with the Use of Computational Fluid Dynamics” Democritus University of Thrace, Xanthi, Greece VOL. 76, 2019

20) Anderson K, Gaston KJ (2013). Lightweight unmanned aerial vehicles will revolutionize spatial ecology. Frontiers in Ecology and the Environment. 2013; 11:138–146