Conceptual Design and Numerical analysis of an Unmanned Amphibious Vehicle

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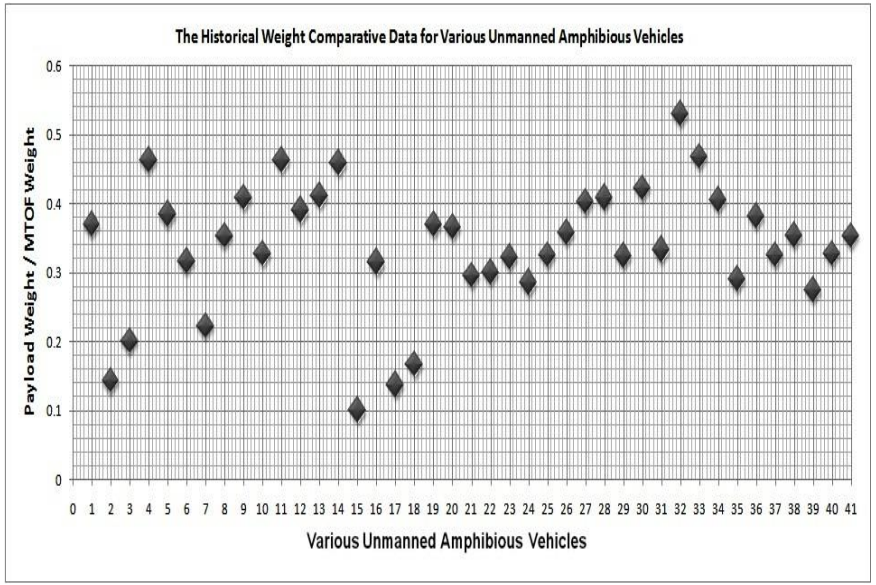
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Introduction

- Designed an Unmanned Amphibious vehicle inspired from Flying fish.
- Flying fish has the capability of gliding in the air for more than 200 m.
- The biological design of the Flying fish is quite impressive which allows the fish to swim and fly efficiently.
- An attempt is made to use this bioinspired design of this fish to conceptually design an Unmanned Amphibious Vehicle (UAV).
- Keeping the payload for surveillance as a key parameter, the UAV with retractable wings is designed to have the capability to swim and fly.
- Reduction of surface area in the UAV`s transition in the media from water to air is desirable, hence the **retractable wing design is chosen**.

Design Process involved in this UAV's construction



Historical Relationship of UAV

- The specifications of nearly fifty UAVs were collected and thereby the historical relationship was formed.
- Based on Flying fish, the length and wingspan of the UAV was attained, which provided the path for Reverse Engineering relayed construction.

Conventional Approach implemented on UAV

$$\frac{W_{Pl}}{W_O} = 0.337456986$$

$$V_{H-Tail} = \frac{S_{H-Tail} * l_{H-Tail}}{S_w * \overline{C_{Wing}}}$$

$$l_{HT} = \sqrt{\frac{2 * (V_{H-Tail} * S_w * \overline{C_{Wing}})}{\pi (R_1 + R_2)}}$$

$$V_{V-Tail} = \frac{l_{V-Tail} * S_{V-Tail}}{b_{wing} * S_{wing}}$$

$$T = 0.5 * \rho * \pi * r^2 * [(V_e)^2 - (V_o)^2]$$

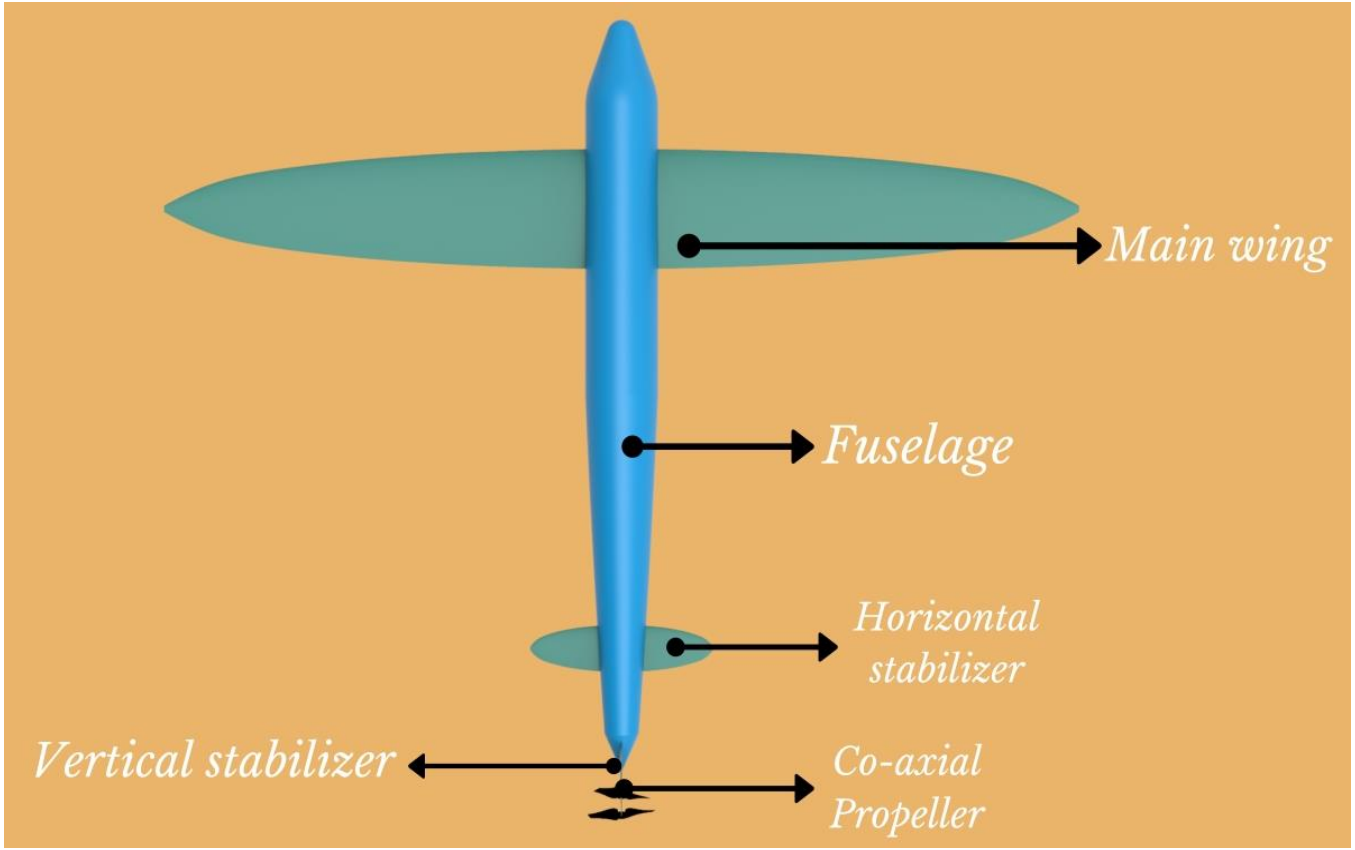
$$(T)\text{Static Thrust (oz)} = P\,(in) * D^3\,(in^3) * RPM^2 * 10^{-10}$$

- Length of the UAV is obtained as 45.72 cm.
- Wingspan of the UAV is obtained as 57.15 cm.
- The elliptical shape is used in wing and horizontal tail of this UAV, which is influenced from Flying fish.
- The maximum wing chord length is estimated as 7.28 cm.
- Vertical Tail is constructed based on tapered shape.

Design data of UAV

- The distance between AC [Aerodynamic Centre] of Horizontal Tail and the AC of Wing is estimated as 27.823 cm.
- The distance between AC of Vertical Tail and the AC of Wing is estimated as 34.29 cm.
- The co-axial propeller based propulsive system is implemented in this UAV's design, which can able to provide high stability with low consumption of geometrical area.
- For all the aerodynamic profiles, The airfoil "NACA 2408" is selected as best than others based on low co-efficient of drag value.

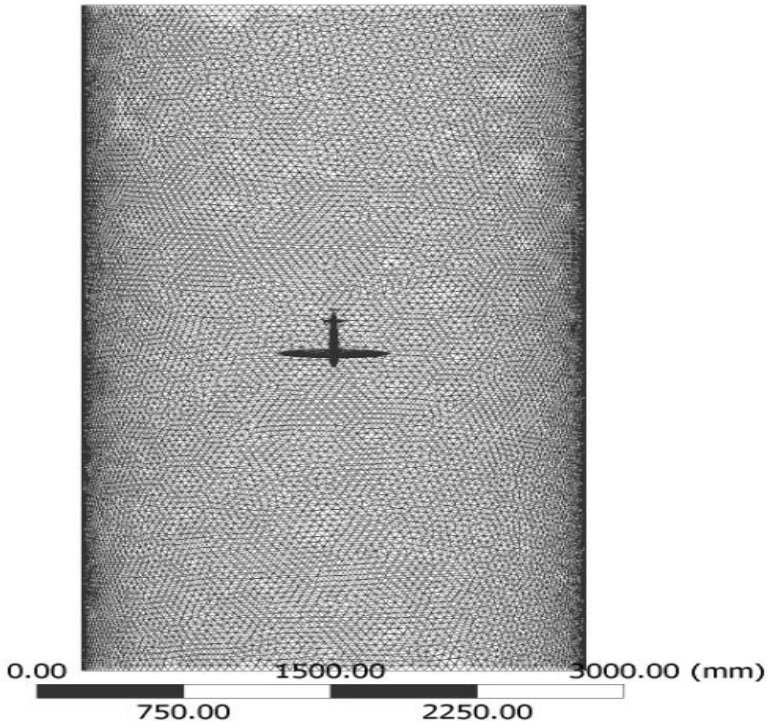
Conceptual Design of UAV



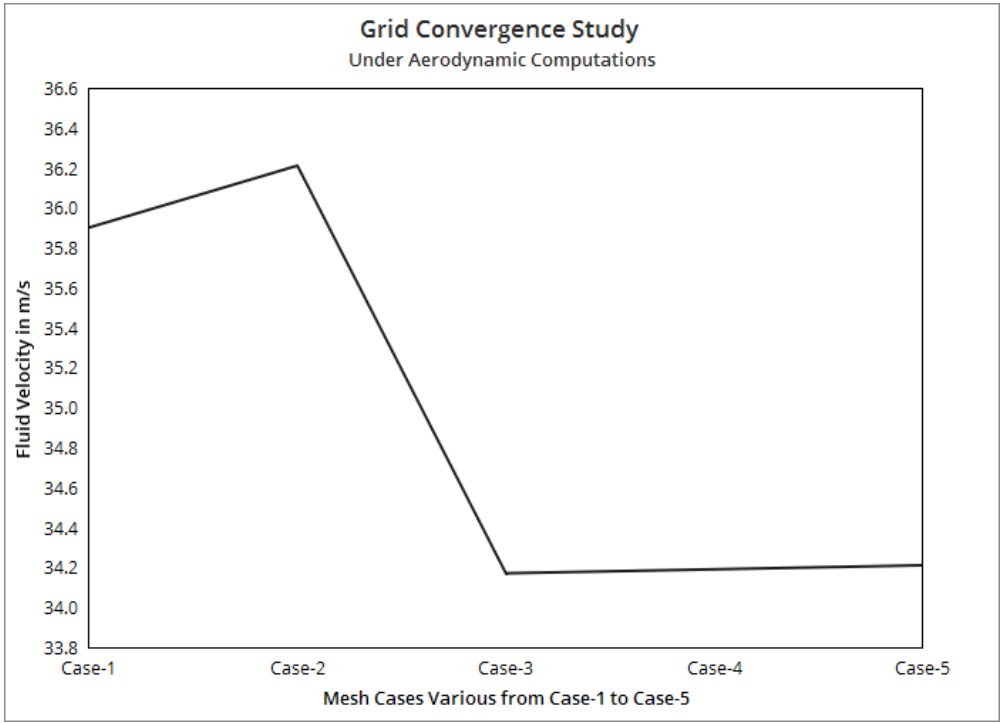
Methodology Used – CFD, FSI

- The preliminary design of the UAV is analyzed for a different flight and swimming conditions.
- SST k-omega turbulence model captures the physics much better than any other turbulence model for the real-time conditions.
- The effect of the fluid on the surface is imposed on the UAV using Fluid Structure Interaction (FSI).
- FSI analyses are computed for the range of desirable flight and swimming conditions.
- From the detailed analyses, the selection of appropriate light-weight materials for the design is made.
- Propeller is placed at the tail of the UAV to avoid any disturbance in surveillance and allow the wings to retract without any issues.

Grid Convergence Study

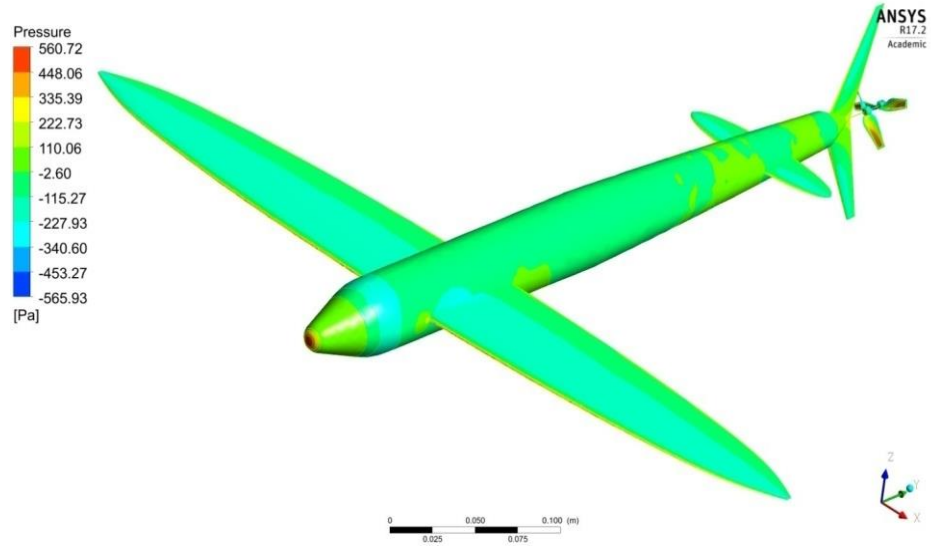


Discretized Structure – Fine cum Face Mesh

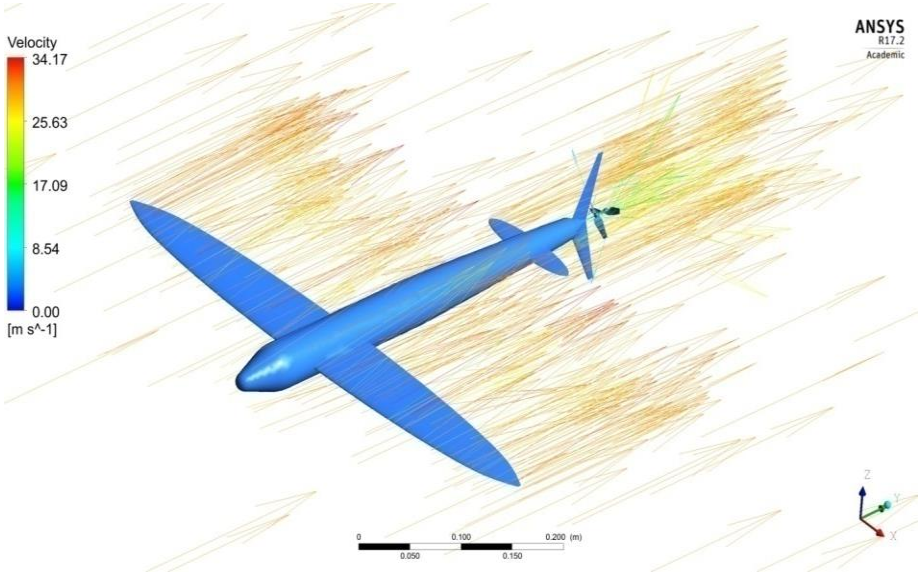


Grid Convergence Test on UAV under CFD Aerodynamic conditions

Results and Discussions – Aerodynamics

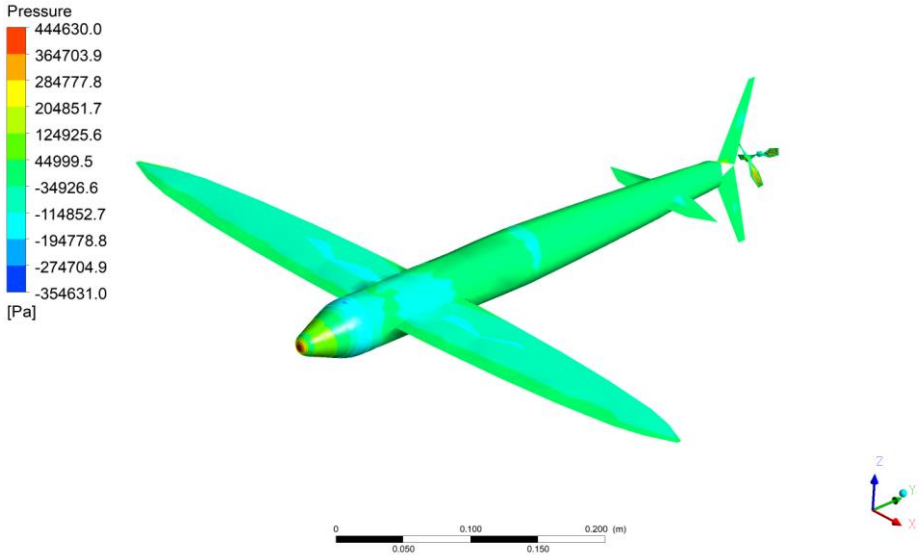


Pressure variations on UAV

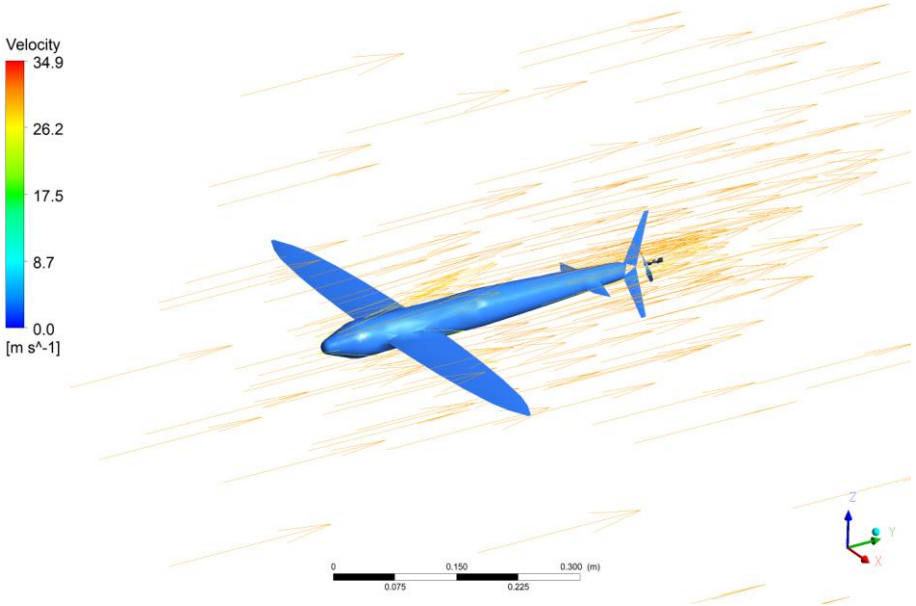


Velocity distributions over an UAV

Results and Discussions – Hydrodynamics

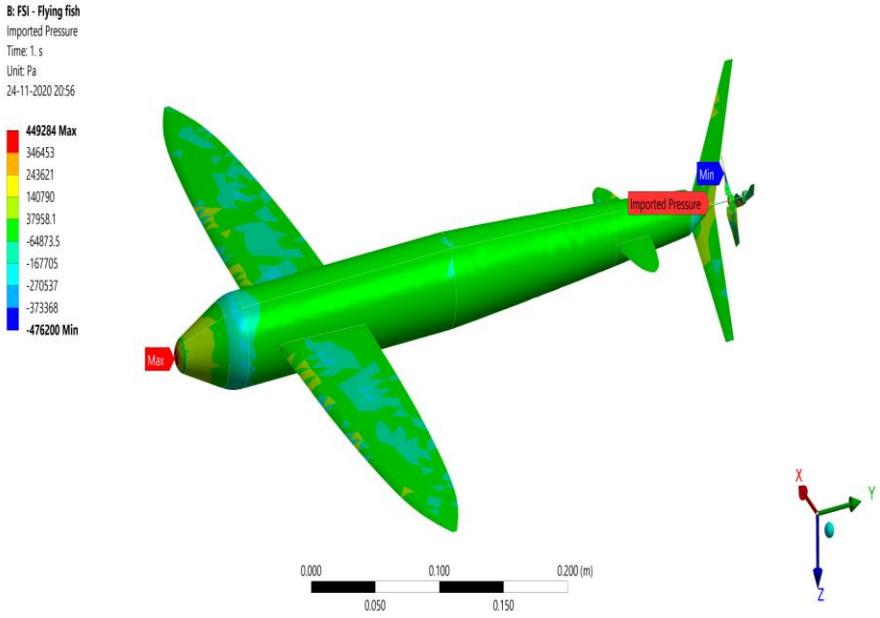


Hydro-Pressure variations

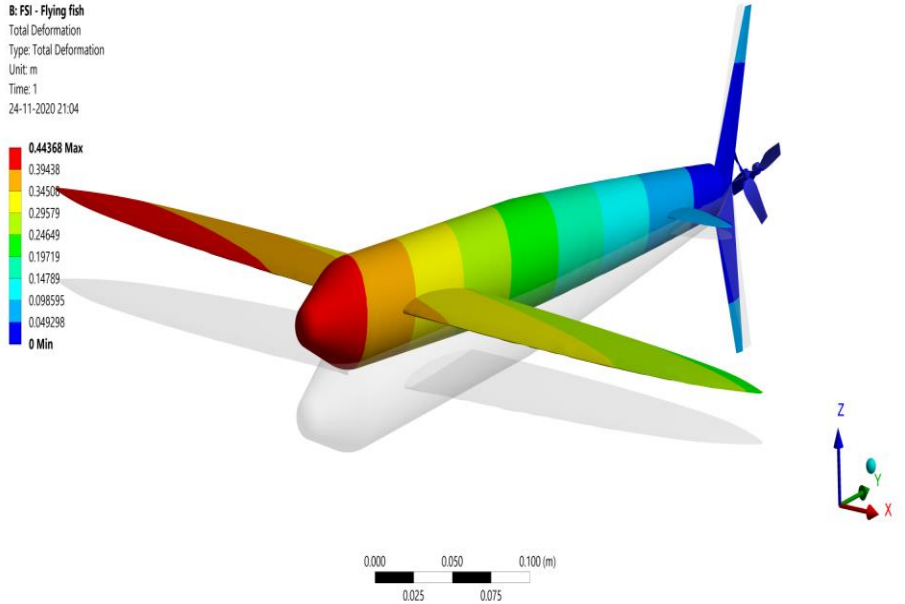


Hydro-Fluid Velocity distributions

Results and Discussions – FSI

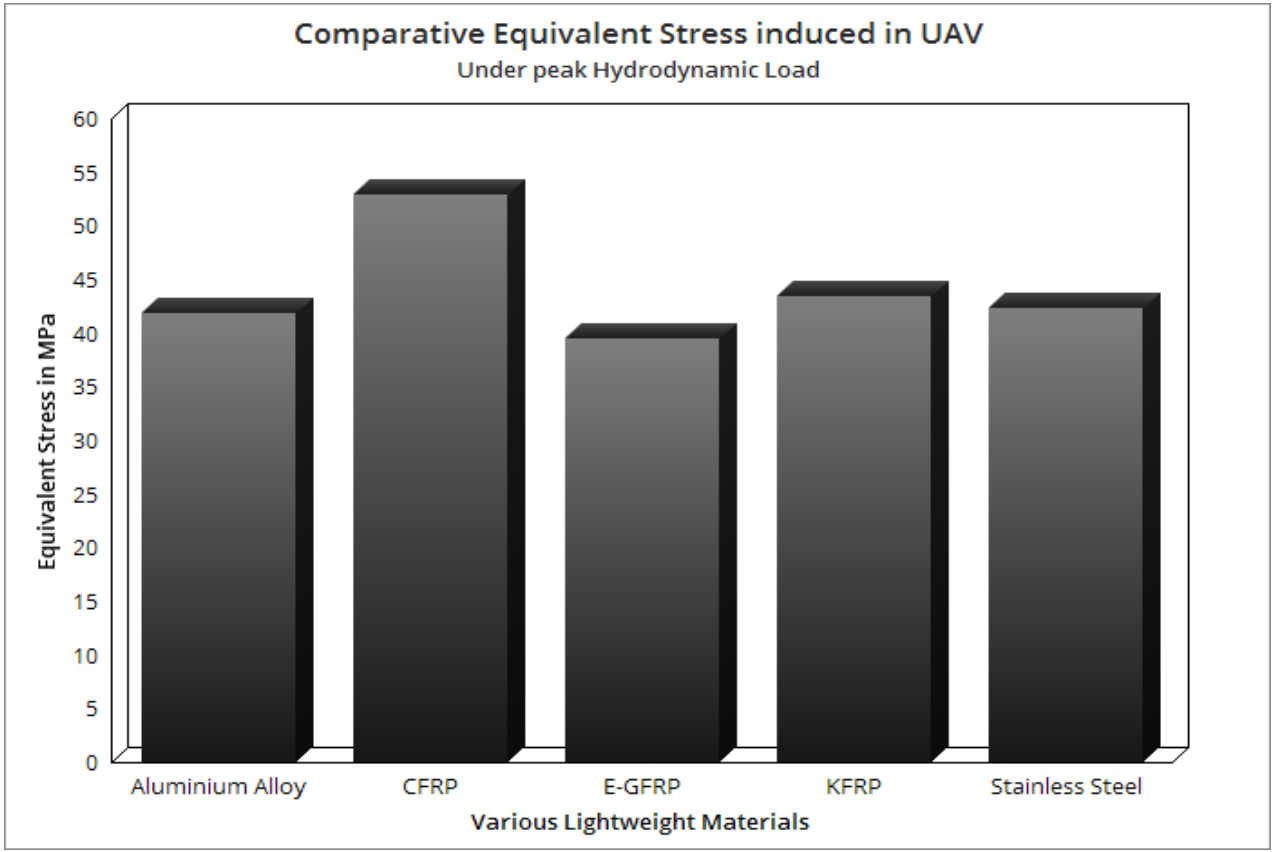


Aerodynamic load transferred into UAV's surface for FSI



Deformed structure of Aluminium alloy based UAV

Results and Discussions – FSI Overall



Conclusions

- With influence of nature and its flexible designs, this work constructed an advanced Unmanned Amphibious Vehicle to execute removal of ravage at the surface of the Ocean.
- With the help of advanced modelling tool, i.e., CATIA, the conceptual design of UAV is modelled and the same could be acted as computational model for both CFD and FSI analyses.
- The grid convergence test is computed on UAV under common aerodynamic boundary conditions for six different mesh cases. The optimized mesh case is selected from the convergence test and the same is used for all the remaining complicated simulations.
- The eddy formation over the UAV and stagnation pressure regions are primarily focused factors, which doesn't affect the performance of this unique UAV.
- After the null affect, the FSI analyses are carried out on UAV under hydrodynamic loading conditions for five different cum advanced lightweight materials. At last, the perfect material to defend the hydro pressure is predicted, which is Epoxy-E-Glass-Fabric based composite.
- All the structural outcome factors are performed well in E-GFRP, especially the equivalent stress is 2343000 Pa lesser than Aluminium Alloy, 2791000 Pa is lesser than Stainless Steel, 13397000 Pa is lesser than Carbon Fiber based composite, and 3938000 Pa is lesser than Kevlar Fiber based composite.
- Apart from this equivalent stress effect, the weight is also one of best favour for E-GFRP, in which the **weight of E-GFRP is lesser 4.11 times than Stainless Steel** and **1.42 times lesser than Aluminium Alloy**.
- Therefore through this study, Epoxy-E-Glass-Fabric based composite material is shortlisted to work at both hydro and aerodynamics conditions because of its high load resisting capability.

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