‘‘DESIGN AND ANALYSIS OF UNDERWATER GLIDER”

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Abstract *:* Underwater gliders are a novel type of autonomous underwater vehicle that glide by controlling their buoyancy and attitude using internal actuators. The shape of underwater glider is an important factor in determining the hydrodynamic efficiency. Hydrodynamic characteristics and dynamic stability of the glider will investigate, to determine the optimal wing form. This work presents a nonlinear multi-body dynamic model for an underwater glider operating in an unsteady, nonuniform flow.
According to the specification, a mechanical structure of the underwater glider is designed. A 3D model of underwater glider is generating by CREO Software. CFD simulations are perform by using the commercial software ANSYS. Then, according to the simulation results design optimize for better performance and cost.

IndexTerms **– Underwater Glider, CFD analysis, Airfoil Profile, Drag force, Lift Force.**

I. Introduction

Underwater gliders are a type of underwater vehicle that transverses the oceans by shifting its buoyancy, during which its wings develop a component of the horizontal plane's downward motion, thus generating forward force. There are many types of underwater gliders with varying payload delivery capacity and operating depth.
An underwater glider is a type of autonomous subwater vehicle (AUV) that uses variable-buoyancy propulsion rather than conventional propellers or thrusters. It uses variable buoyancy in a similar manner to a profiling float, but unlike a float that can only move up and down, an underwater glider is fitted with hydrofoils (underwater wings) that allow it to glide forward as the throat goes down.

An underwater glider adjusts its buoyancy to go down from or up to the free surface that covers the appropriate observation distance. The lifting force generated by its wings generates the horizontal or forward motion.
During the gliding motion that captures the necessary data, the sensor observation device will be activated, and when the glider ascends to the ocean floor, the data collected will be transmitted to control centres or research vessels using satellite or other communication network.

The forward motion of the glider should be used to counter the head-on currents. Glider motion is governed by buoyancy control, pitch control and heading control. Buoyancy control can be achieved by controlling the mass flow rate of the pump in the injecting and ejecting fluid through a bladder or the frequency of the single stroke piston pumps in extending and retracting a piston in a cylinder.

II. LITERATURE REVIEW

1. Motion parameter optimization for gliding strategy analysis of Underwater gliders[1] :They have established an optimized mathematical model which includes the steady motion model, the gliding strategy model and the energy consumption model. Then, the motion parameters are optimized to increase the gliding range, considering different powers related to the gliding time and different gliding strates. The two gliding strata, CGSM and HGSM, are analyzed based on the optimization result.The Petrel-L experimental study validates the effectiveness of the methods proposed.
2. Dynamic modeling and motion analysis for a dual-buoyancy-driven full ocean depth glider [2] : This presents a dual-buoyancy-driven mechanism for Petrel-X, a full ocean depth glider, to simultaneously adjust its buoyancy and pitch angle. The proposed dynamic model is derived from the Newton-Euler formulation by integrating environmental parameter influences and changing the volume of glider displaced. The adaptive modification of the buoyancy and subsequent results in motion was investigated.
3. CFD approach to modelling ,hydrodynamic analysis and motion characteristics of laboratory underwater glider with experiment result [3]: In this study, they validate the experimental lift and drag characteristics of a glider from the literature using Computational fluid dynamics (CFD) approach. The effect of the differential buoyancy in terms of gliding angle, speed and angle of attack is evaluated. Laboratory glider model is developed from CFD 's asserted finished product. A two-mass variable buoyancy engine has been designed and implemented. The equations of motion for this two-mass engine have been obtained by modifying the single mass version of the equations described in the literature.
4. Shape optimization of blended-wing-body underwater glider by using gliding range as the optimization target [4]: In this paper, a shape optimization of BWBUG with 5 most sensitive shape design variables was established by using maximum gliding range as the optimization target instead of Lift to Drag ratio. The maximum gliding range is more suitable as the optimization target of BWBUG's shape optimization, because the maximum gliding range can well balance the weight between volume and hydrodynamic performance.

5. Effect of wing form on the hydrodynamic characteristics and dynamic stability of an underwater glider [5]: The effect of wing shape on an underwater glider's hydrodynamic characteristic and dynamic stability was investigated in this analysis, based on numerical and experimental tests. These findings may be useful for new design for improved maneuverability and surface control for underwater glider with wings and operating conditions similar to shape glider
6. Design and analysis of folding propulsion mechanism for hybrid-driven underwater gliders [6]: A foldable propeller is constructed for a hybrid-driven underwater glider, which can be completely closed when the glider is operating in a gliding mode driven by buoyancy. CFD analysis reveals that such design reduces the hydrodynamic drag substantially compared to unfoldable device.
7. Dynamics of underwater gliders in current [7]: Results of numerical simulations for the dynamic model were compared with results for simpler models that are commonly used for control design and analysis. First, using the example case of a horizontal flow field with a vertical gradient, we compared the full dynamic model with a simplified dynamic model that omits flow gradient effects. Open-loop simulations show dramatically different results but closed-loop simulations, in which vehicle attitude is regulated through feedback, demonstrate that feedback control can compensate for errors in the simpler model, provided that there is sufficient control authority to dominate the omitted flow gradient effects.

III. DESIGN AND ANALYSIS OF WING OF UNDERWATER GLIDER

As per literature review and discussion with thesis guide, airfoil profile selected for underwater glider Airfoil Profile: NACA 0016.Higher lift to drag (L / D) ratio is desirable for a glider. A comparative study has been carried out using CFD for a NACA0016 symmetrical wing profile.

The 3-dimensional model of the wing having airfoil profile NACA 0016 is generated by Creo. The model is imported in ANSYS 2018 Workbench in Design Modeler to assign the domain of analysis.

For getting the solution of wing at different Angle of Attack (AOA), the simulation software **ANSYS CFD fluent** is used. The boundary conditions applied for the simulation

Boundary Conditions:

Mathematical Model: k-ω SST (Shear – Stress Transport)
Inlet:Velocity inlet at 0.5 m/s

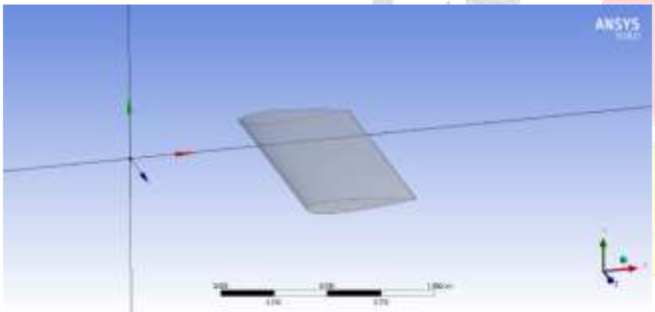

Fig.1 Wing import in Ansys Software

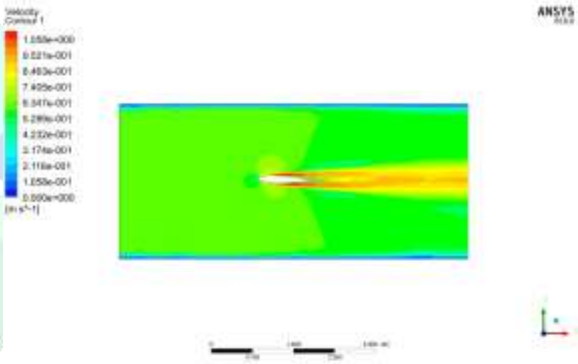

Fig.2 Velocity contour with Zero Degree Angle of Attack

IV. DESIGN AND ANALYSIS OF UNDERWATER GLIDER

4.1 DESIGN AND ANALYSIS OF UNDERWATER GLIDER WITH WING ZERO DEGREE(GLIDER 1)

In above section, the focus is only on the wing of the Underwater Glider and not on the combined effect of the underwater glider's body and the wings. So, in this section, the focus is on Underwater glider's and wings both combined. In this study, CFD analysis of underwater glider with wings are carried out. By the comparison of the result of these simulations, the optimum condition for Underwater Glider can be achieved.
The 3-dimensional model of Under Water Glider is generated in creo software then it is imported in ansys workbench.For getting the solution of under water glider different Angle of Attack (AOA), the simulation software ANSYS CFD Fluent used. The boundary conditions applied for the simulation are as follows. We will get lift force and Drag force as the result. Mathematical Model: k-ω SST (Shear – Stress Transport)
Velocity are set as 0.1 ,0.2, 0.3, 0.4 ,0.5
The different velocity and pressure contour were obtained for different Angle of Attack (AOA) like -4 ,-8,0,4,8 are applied. pressure contour are shown in figure 4

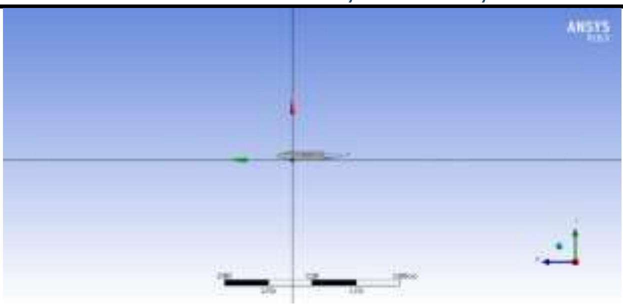

Fig.3 Underwater Glider with 0° Angle of Attack

Fig.4 pressure contour

Fig.5Wing NACA0016 with 0° Angle of Attack

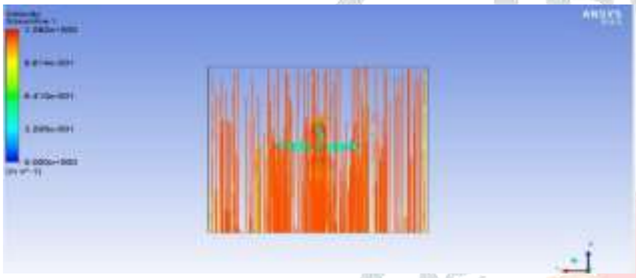

Fig.6 Velocity Streamline For Underwater Glider

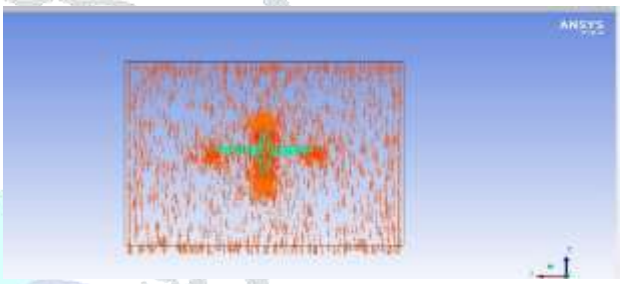

Fig.7 Velocity vectors for Underwater glider

velocity	AOA	L/D
0.1	8	6.85
0.2	8	7.94
0.3	8	11.5
0.4	8	12
0.5	8	12.3

Table 4.2 different velocity of glider at same Angle of Attack

A.O.A	L/D
-8	-10.067
-4	-8.761
0	5.077
4	8.781
8	10.103

Table 2. L/D ratio at different Angle Of Attack with constant velocity 0.5 m/s

L=Lift Force
D=Drag Force
A.O.A= Angle of Attack

4.2 Design and analysis of glider with Wing at 45 Degree (Glider 2)

The 3-dimensional model of Under Water Glider is generated in creo software then it is imported in ansys workbench Given angle of 45 degree to the glider's wing
For the computational solution, the mesh details of the mesh and the meshed domain is shown below.

Mesh Details:

Type:	Tetrahedral Mesh
Mesh algorithm:	Patch Confirming Method

For getting the solution of under water glider different Angle of Attack (AOA), the simulation software **ANSYS CFD Fluent** used. The boundary conditions applied for the simulation are as follows. We will get lift force and Drag force as the result.
Mathematical Model: k-ω SST (Shear – Stress Transport)
Outlet: Pressure outlet at 0 absolute pressure
Velocity are set as 0.1 ,0.2, 0.3, 0.4 ,0.5.The different velocity and pressure contour were obtained for different Angle of Attack (AOA) like -4 ,-8,0,4,8 are applied.

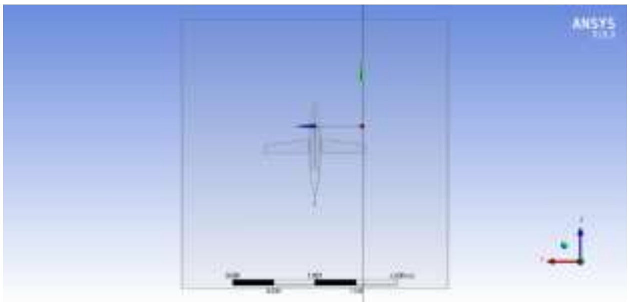

FIG.8 3D MODEL OF UNDERWATER GLIDER WING AT 45 DEGREE

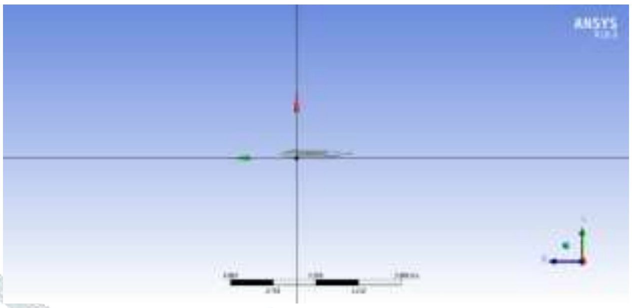

FIG. 9 *3D MODEL OF UNDERWATER GLIDER* WITH 0° ANGLE OF ATTACK

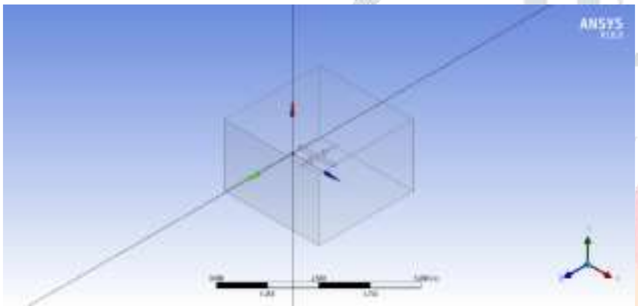

FIG.10 APPLIED DOMAIN

FIG.11 APPLIED MESHING

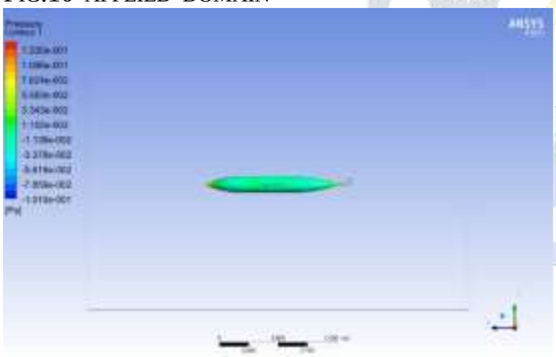

FIG.12 PRESSURE CONTOUR

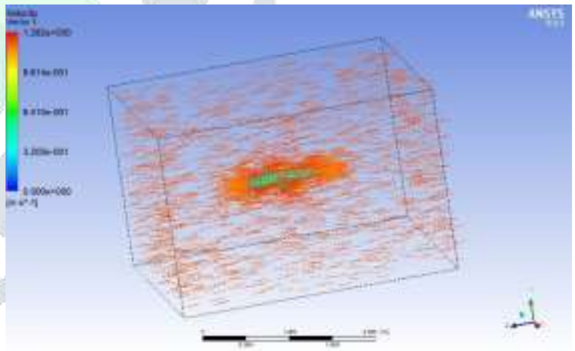

FIG.13 VECTOR FOR UNDERWATER GLIDER

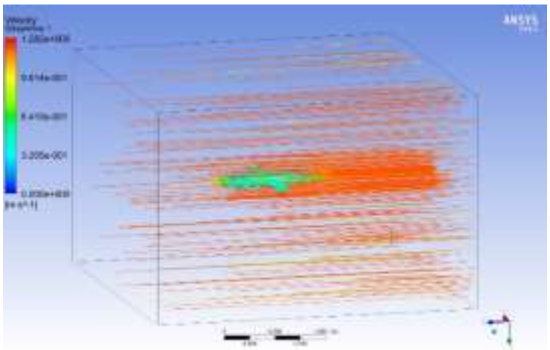

FIG .14 VELOCITY STREAMLINE

Velocity	AOA	L/D
0.1	8	7.31
0.2	8	10.7
0.3	8	11.6
0.4	8	12.1
0.5	8	12.4

Table 3 Different velocity of glider at same Angle of Attack for Underwater Glider

A	L/D
-8	-11.7
-4	-8.727
0	-5.156
4	8.727
8	11.7

Table 4 L/D Ratio at Different Angle of Attack for Underwater Glider with same velocity 5m/s

4.3 Comparison of Results and Discussion

AoA (degree)	L/D (Glider 1)	L/D (GLIDER 2)	Percentage diff- 1&2
-8	-10.067	-11.7	10.23
-4	-8.761	-8.727	-0.388
0	5.077	5.156	1.525
4	8.781	8.727	-0.618
8	10.103	10.798	6.430

V. CONCLUSION

The findings of study show that rise in lifting forces is higher than the resistance force with increased drift angle and speed Glider with different angle at wing is give more L/D ratio so it is more efficient.

Here result show that L/D ratio is increasing as tee angle of attack increases.It is maximum at A.O.A at 8. L/D ratio is 12.3 at velocity 0.5 m/s. NACA0016 symmetric wing profile is more suited for better motion performance of underwater gliders than the previous wing profiles.

The outcome of this will be useful for the design of future underwater glider that is required to fulfil a given mission type.

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