Design Mathematical Modeling and Analysis of Underwater Glider

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Abstract: ***To know the underwater behavior of the glider dynamics needs mathematical modeling, it requires the knowledge of hydrodynamic force coefficients of the glider body and Acceleration hydrodynamic force coefficients of underwater glider body. Hydrodynamic force coefficients of the body are to be determining by using slender body theory. Acceleration hydrodynamic coefficients of the underwater glider pressure hull are to be estimate by using Strip theory. Static stresses on the pressure hull when subjected to External hydrostatic pressure have to be calculating by using Ansys software.***

Keywords: Glider,Static analysis,buckling analysis,Ansys

1. Introduction

Underwater gliders constitute a new class of autonomous underwater vehicles (AUV). With wings and tail, they glide through the ocean, controlling their buoyancy and attitude using internal actuators. Gliders have many useful applications, notably in oceanographic sensing and data collection. In this application they are attractive because of their low cost, autonomy, and capability for long-range, extended-duration deployments. The last five years have seen the first ocean deployments of underwater gliders, and there is a need for improved understanding and modeling of their dynamics to further capitalize on the unique advantages of underwater gliders. This dissertation details the development of a model of the dynamics of underwater gliders. The model is then applied to analysis of glider dynamics, glider control.

1.1.Characteristics and Design

Underwater gliders are a class of Autonomous Underwater Vehicles (AUVs) that glide by controlling their buoyancy using internal tanks and pumps. Existing gliders have fixed external wings and tails and control their attitude by moving internal masses and using external control surfaces such as a rudder. Gliders travel from place to place by concatenating a series of upwards and downwards glide. Characteristic glider motions include upwards and downwards straight glides in a saw tooth pattern, turning, and gliding in a vertical spiral. Gliding flight is buoyancy driven, and does not use thrusters or propellers. Thus, gliders must change depth to glide.

They glide downwards and upwards in the ocean by controlling their buoyancy to make themselves negatively and positively buoyant. Gliders may also hold their position by gliding against the current, make themselves neutrally buoyant and drift with the current, or rest on the bottom. Through their use of buoyancy propulsion systems and low power designs, gliders are capable of long-range and high-endurance deployments. With careful design, buoyancy driven gliders are quiet and use little power. Housing vehicle actuators within the hull shields them from the hostile ocean environment and makes gliders more durable

1.2 Applications of Underwater Gliders

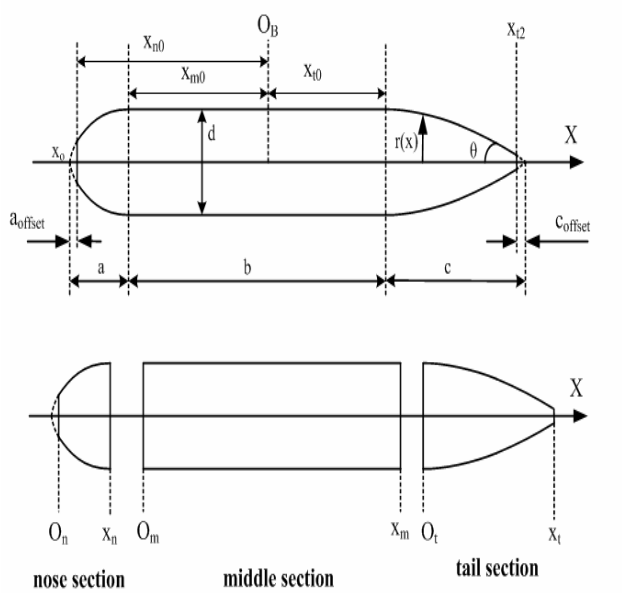
- Gliders have application in remote sensing for physical, chemical and biological oceanography.
- Other possible applications include use as communications gateways or navigation aids and military applications such as tactical oceanography and maritime reconnaissance.
- The first application of underwater gliders, and the inspiration for their design, has been Oceanographic data collection.
- They are mainly used for Inspection Purpose in Under Water.
- Collection of data at any one point in space and time is of much less scientific use than collection of data over large regions. Gliders offer a flexible and elegant platform to meet this need.
- Underwater gliders have a variety of advantages over existing methods of ocean sampling.
- Gliders also have application in a variety of military roles

1.3 Gliding underwater vehicles are characterized by four common features

- Buoyancy driven propulsion systems that use volume change to create vertical lift, and some sort of wing shape to convert that to forward motion.
- Saw tooth pattern of vertical motion.
- Relatively slow speeds.
- Long duration due to low power consumption for propulsion.
- The initial appeal of this vehicle type (besides the long duration of operation) is the saw tooth vertical motion pattern. This type of pattern is excellent for collecting ocean profile information, as it can sample the entire range of desired depths. The majority of gliding vehicle designs being tested today adopts the cylindrical body type that houses the buoyancy system, often adding long narrow wings to convert depth changes into forward motion

2. Methodology

The underwater vehicle discussed in this thesis adopts the Myring hull profile. This kind of hull shape provides more inner space for carrying equipments while keeping the streamlined characteristics outside when compared to the underwater vehicle shapes. This hull shape is axis symmetric and the specific profile is described by the equations of radius distribution along the main axis. The origin of these equations is set at the front point of the vehicle, the point x_0. The underwater vehicle adopting this kind of profile can be divided into 3 modules: the nose section, the middle section and the tail section



The equation of radius distribution along x axis for the nose section is:

$$R_n(x)=\frac{1}{2}d\left[1-\left(\frac{x-a_{offset}-a}{a}\right)^2\right]^{1/n}$$

The equation for the tail shape is:

$$R_t(x)=\frac{1}{2}d-\left[\frac{3d}{2c^2}-\frac{\tan\theta}{c}\right](x-l)^2+\left[\frac{d}{c^3}-\frac{\tan\theta}{c^2}\right](x-l_f)^3$$

Where $l_f=a+b-a_{offset}$

The middle section is a cylinder with constant radius

$$R_m(x)=\frac{d}{2}$$

Where x represents the x-axis position with its origin at point x_0 ; n is an exponential parameter which can be varied to give different body shapes. a ,b and c are the full lengths for the nose section, middle section and tail part respectively; a_{offset} and c_{offset} are the offset for the nose part and the tail part respectively; 2θ is the included angle at the tip of the tail; d is diameter of the middle part. By using MATLAB coding the hull profile of the under water glider is obtained from radius equations

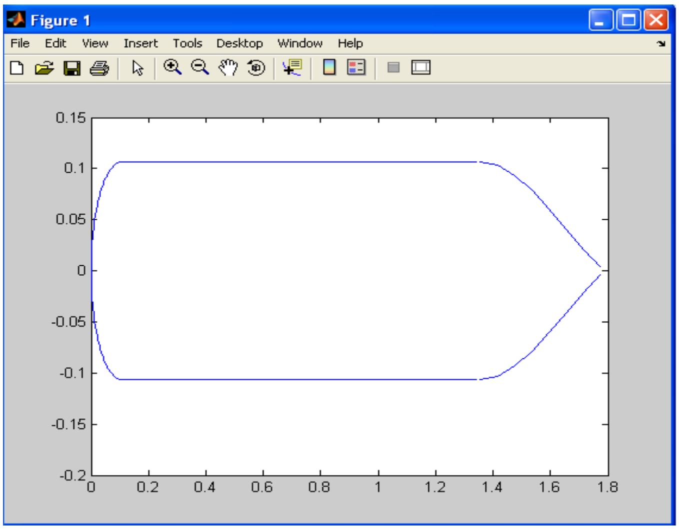


Figure1: Hull profile in MATLAB

3. Analysis using ANSYS

The ANSYS Main Menu contains all of the commands to create, mesh, apply loads, solve, and view results of the FE analysis. By using the coordinates generated from MATLAB, the Under water glider is designed in ANSYS.

3.1 Design Specifications

3.1.2 Shell details

(a)The entire length of the shell is 1789.2mm
(b)The outside diameter of the shell is 212.7mm
(c)External pressure of 100 bar acts on the shell

3.1.3 Stiffener details

(a)Number of ring stiffeners in the shell: 11
(b)Number of ring stiffeners in the tail: 3
(c)Cross section of the stiffeners: Rectangular
Stiffeners thickness of cylinder is 10 mm while stiffener depth is 20 mm
Stiffeners thickness of tail is10 mm while stiffener depth is 10 m

3.1.4 Specifications of Glider used in present Thesis:

- Weight: 52 k
- Hull Diameter: 21.27 cm
- Vehicle Length: 1.79 m
- Wing Span: 120 cm
- Depth Range: 200 – 1000 m
- Wing span: 0.974m
- Wing Root-Chord: 0.11m
- Wing Tip-Chord: 0.07m
- Wing Area: 0.131m^2
- Mach number:0.0005

3.2 Material Details

The material used for the analysis of the shell is Aluminium 6061-T6 alloy with properties given below
Young's modulus: 7.31 Gpa
Poisson's ratio: 0.33
Density: 2700kg/m^3

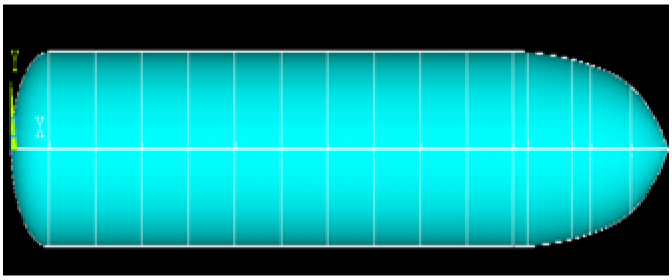


Figure2: Solid model of Glider in Ansys

3.3 Mesh Generation

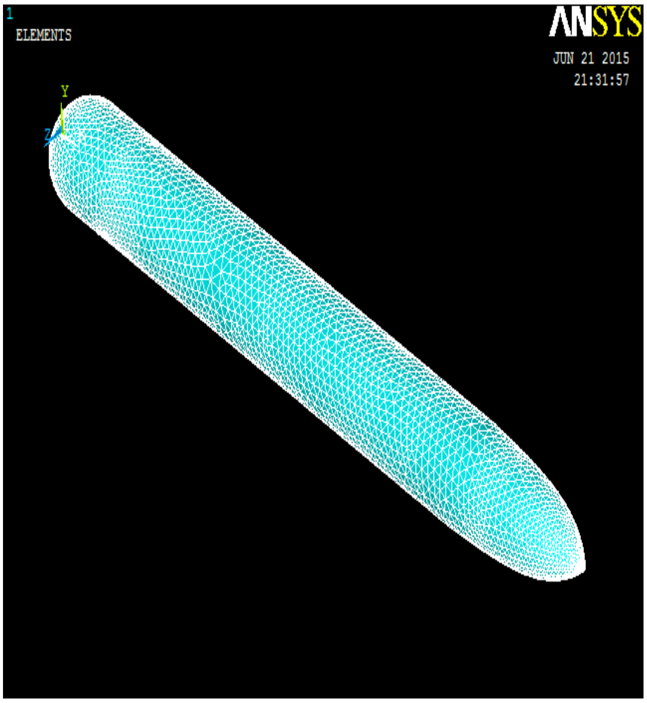


Figure 3: Quad mesh of Glider

4. Results and Discussion

The following type of analysis has been carried out on the under water glider

a) Static analysis

b) Buckling analysis

Table 1: Static analysis

S. No	Thickness (mm)	Wt (kg)	Max Stress (Mpa)	No. of stiffners
1.	8	26.5	131.37	14

From the table 1 the maximum stress the glider can withstand is 131.37 Mpa

Table 2: Buckling analysis

S. No	Thickness (mm)	Wt (kg)	Buckling factor	No.of stiffners
1.	8	26.5	6.865	14

From the table 2 the buckling factor of the glider after Buckling Analysis is 6.865

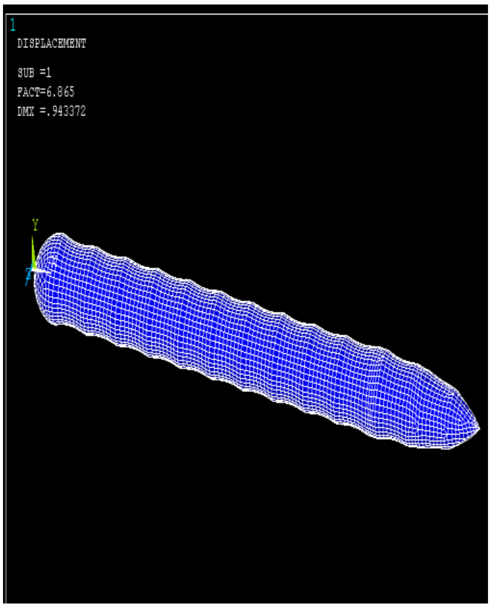


Figure 4: Deformed shape of under water glider

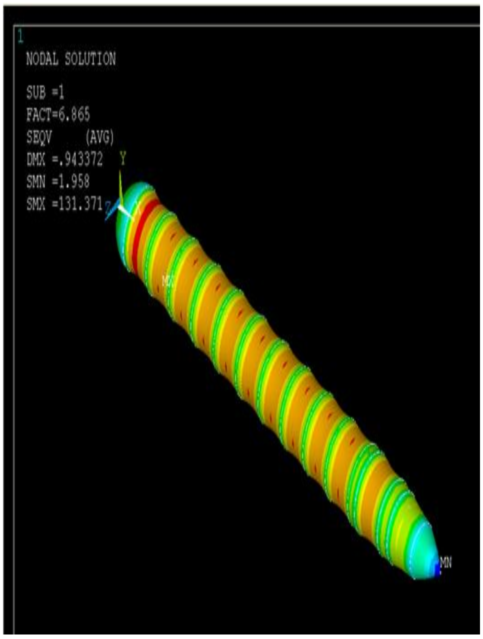


Figure6: Buckling analysis of under water glider

5. Conclusion

Acceleration of hydrodynamic coefficients of the underwater glider pressure hull are estimated by using Strip theory and Lambs inertia coefficients Strip Theory computes each coefficient as sum of coefficient of unit length slices by using empirical formulae given by Newman. The Lambs inertia coefficients for the vehicle are computed by assuming the total body as an ellipsoid. K1,K2 and K3 obtained from the calculations are used for computing the coefficients .Hydrodynamic coefficients of underwater glider body obtained by using strip theory and Lamb's inertia coefficent are found to be in close agreement.

Static stresses on the pressure hull when subjected to 10 Mpa External hydrostatic pressure were computed by using ansys structural software . Maximum Vonmoses stress was 140 Mpa which is much below than allowable stress of the aluminium alloy Material (240 Mpa -0.2% proof strength)

Maximum deformation was 0.8 which is considered safe. Buckling factor for the pressure hull was 6.8 with 10 Mpa External pressure which is considered very safe from design considerations

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Author Profile

Degaala Shravya sree received Bachelor's Degree in Aeronautical Engineering from Marri Laxma Reddy Institute of Technology in 2012. I am interested in Mathematical modeling and Analysis of structures