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A New Approach to Underwater Gliders Modelling

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Abstract

The article describes the importance of underwater gliders. Although the underwater gliders (UGs) are autonomous underwater vehicles (AUVs), they still have a different propulsion system. That is, these underwater gliders use propulsion with variable buoyancy compared to propellers or thrusters. The presented model consists of body, wings, rudder, antenna, stern and nose. Moreover, this model is made of aluminum alloy 6061. With the help of the finite element method (FEM), the shear and octahedral stresses of an underwater glider are determined. In addition, with the help of the computational fluid dynamics (CFD), the velocity is determined. Launching and retrieving such an underwater glider from the sea is easy under normal temperature conditions. The underwater glider (UG) can also move slowly (ex. 0.21 m/s) only up and down through the sea.

Keywords: Alloy, Aluminium, Stress, Body, Wings

1. Introduction

Underwater gliders are autonomous vehicles that are developing maritime research today because they make it possible to monitor the state of the sea (ex. Black Sea) in real time [1].

The underwater gliders (UGs) are equipped with sensors capable of obtaining information about physicochemical parameters in seawater. Anyway, the underwater gliders (UGs) are able to collect data on: conductivity, temperature, depth, chlorophyll and oxygen through their sensors over long periods, as shown in Fig 1.

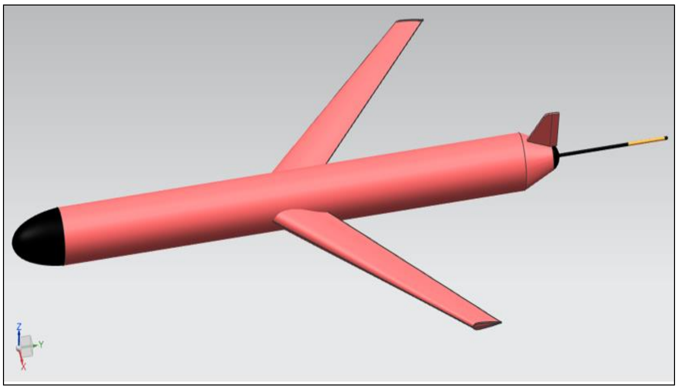

Fig 1: Underwater glider

The underwater gliders (UGs) can be easily launched in: oceans, seas or lakes, as presented in Fig 2.

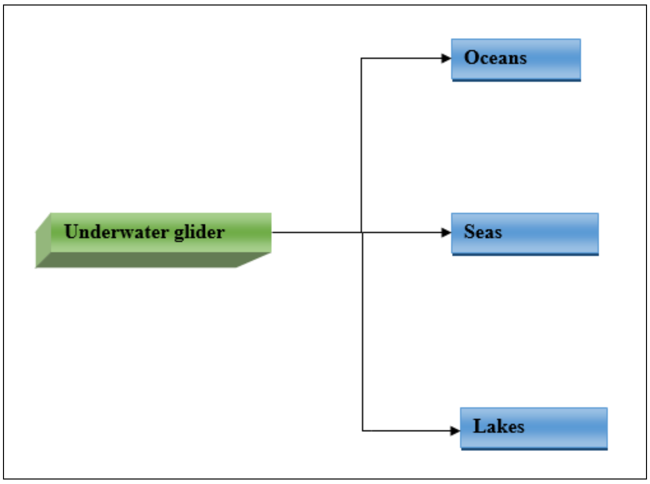

Fig 2: Launch areas of an underwater glider

The model of underwater glide (UG) has the following characteristics, as shown in Table 1.

Table 1: Characteristics of an underwater glider

Parameters	Value
Length	1.58 m
Diameter	0.20 m
Wing area	0.60 m^2
Weight	45 kg
Rudder length	0.17 m
Rudder wigth	0.08 m
Speed	0.21... 0.24 m/s
Maximum depth	330 m

2. Studies of underwater gliders

An underwater glider is considered a type of autonomous underwater vehicle (AUV) which uses variable buoyancy. Moreover, underwater gliders use a monitoring system that works continuously even in extreme conditions [2].

Furthermore, the underwater gliders can explore the sea without the need for a motor or propeller and consume very little energy. Another great advantage of underwater gliders is the fact that they do not pollute the marine environment. Such that at a certain depth the glider switches to positive buoyancy to climb backwards and forwards, and the cycle then repeats [3].

Namely, it has an upward movement (ascending) and a downward movement (diving), as shown in Fig 3 below.

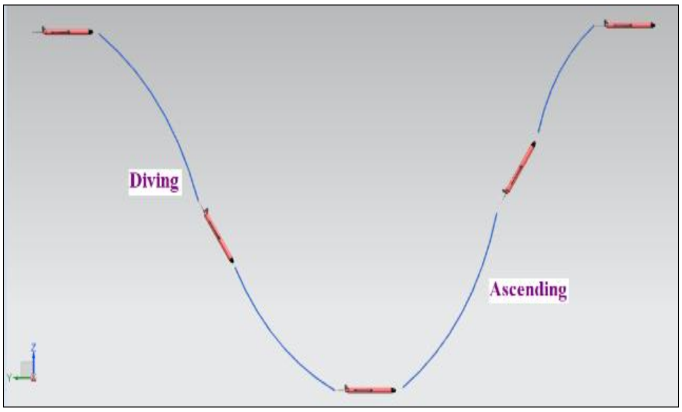

Fig 3: The movement of an underwater glider

It generally consists of the following components: body, wings, rudder, antenna, stern and nose, as in Fig 4 below.

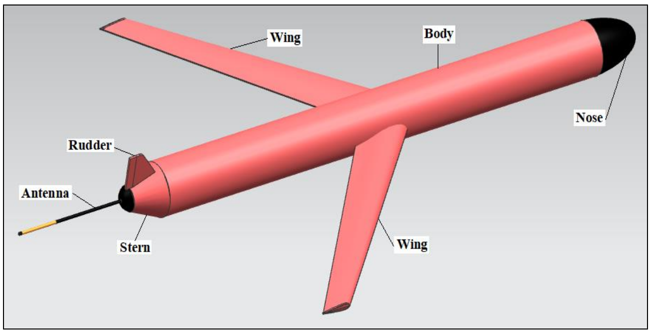

Fig 4: The components of an underwater glider

The external pressure for underwater glider was designed up to 2.35 MPa.

In our case, these components are made of aluminium alloy 6061[4].

The external pressure for underwater glider was designed up to 2.35 MPa.

In our case, these components are made of aluminium alloy 6061. Because underwater gliders benefit in the sea from the outstanding corrosion-resistant attributes and strength-to-weight ratio of 6061 aluminium [5].

Nevertheless, the material properties of 6061 aluminum alloy 6061 are show in Table 2.

Table 2: Characteristics of an underwater glider

Property	Value
Density	2700 kg/m^3
Melting point	923.15 K
Modulus of elasticity	$70 \cdot 10^9$ Pa
Thermal conductivity	166 W/m·K
Electrical resistivity	$0.04 \cdot 10^{-6}\ \Omega \cdot m$
Hardnes Brinell	95 HB

The main stresses acting on a glider are: tangential stresses and octahedral stresses.

The shear stresses are determined with the relationship of Zhuravskii[6]:

$$\tau = \frac{V \cdot Q}{I \cdot t} \tag{1}$$

Where:

τ – shear stress.
V – shear force.
I – second moment of area of the shape.
t – width of the shape.

In any case, the extreme values of the tangential stresses are shown in Fig 5 below:

Maximum value: $\tau_{min} = 3.95506 \cdot 10^{-6}$ MPa (2849 Element, 3408 Node).

Minimum value: $\tau_{max} = 12.5253$ MPa (5665 Element, 10480 Node).

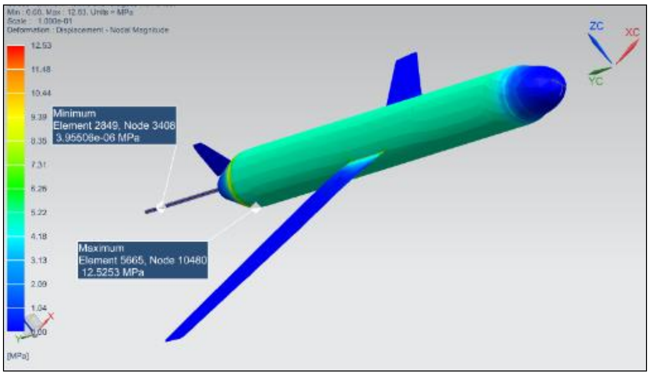

Fig 5: Shear stress (τ) → Underwater glider

All values of the tangential stresses in the nodes chosen by us are positive. The highest values are on the body of the underwater glider (max. 5.5 MPa), as shown in Fig 6 below.

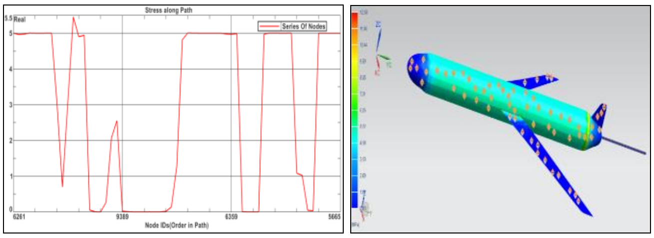

Fig 6: Diagram of shear stresses → Underwater glider

On the other hand, the octahedral normal stress can be written using the following expression[7]:

$$\sigma_{oct} = \frac{\sigma_1+\sigma_2+\sigma_3}{3} \qquad (2)$$

Where:

σ_{oct} – octahedral stress
σ_1 – normal stress in x direction
σ_2 – normal stress in y direction
σ_3– normal stress in z direction

However, the extreme values of the tangential stresses are shown in Fig 6 below:

- Maximum value: τ_{min} = $3.30842 \cdot 10^{-6}$ MPa (2849 Element, 3408 Node).
- Minimum value: τ_{max} = 10.5306 MPa (5665 Element, 10480 Node).

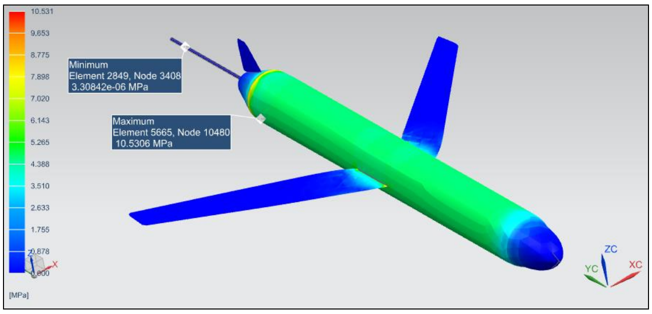

Fig 7: Octahedral stress (σ_{oct}) → Underwater glider

In our case, both the extreme values of the normal stresses and the octahedral stresses are in the same nodes (3408 and 10480) and the respective elements (2849 and 5665).

All values of the octahedral stresses in the nodes chosen by us are positive. The highest values are on the body of the underwater glider (max. 4.8 MPa), as shown in Fig 8 below.

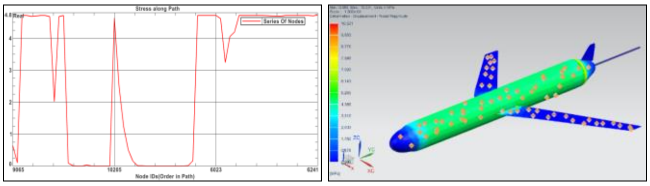

Fig 8: Diagram of octahedral stresses → Underwater glider

The velocity distributions acting on the glider are determined by CFD methods as in Fig 9.
In addition, the underwater glider (UG) is located approximately 1.3 m below surface of the water.

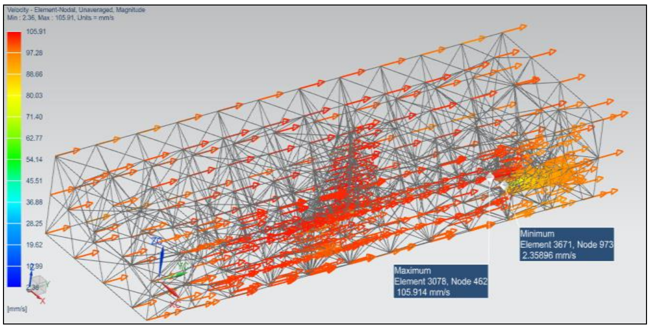

Fig 9: Velocity distributions → Underwater glider

Finally, the extreme values of the velocity distributions are shown in Fig 9 above:

- Maximum value: v_{min} = 2.35896 mm/s (3671 Element, 973 Node).
- Minimum value: v_{max} = 105.914 mm/s (3078 Element, 462 Node).

3. Acknowledgment

We greatly appreciate the contributions and technical advice received from Professor Stanca Costel PhD. at the Constanta Maritime University.

4. Conclusions

The underwater gliders are monitoring systems important to researchers and students because their main advantage is that they complete missions autonomously, with time durations (weeks or months).
Some advantages of an underwater gliders:

- High endurance (long-range roaming capability, long on-station time capability and round-trip patrol capability).
- Depth mission capability.
- Stealthy (quiet, small acoustic cross section and quasi-wakeless).
- Not pollute the marine environment.

In the future, these types of underwater systems will develop more depending on the mission that must achieve it successfully.

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