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# Fish Catching Unmanned Underwater Vehicle

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**Abstract:**
Unmanned Underwater Vehicle(UUV) are powerful and complex systems which are capable of performing underwater (shallow and deep sea) tasks like bathymetry calculation, detection of faults in oil pipelines, collection of deep sea water samples, counting of fish and even complex tasks like collecting data which aids in understanding global warming. This paper presents the design and development of Unmanned Underwater Vehicle for fish catching. The design and development as well as rationale behind the design of various systems such as the Control systems, mechanical design, embedded and power systems, vision and acoustics location estimation system which form the integral part of Fish catching UUV has been discussed in the paper. The advantage of nozzle effect has been used to trap fish in the net. The region of the nozzle along the inner side of the fish trap has a gradually decreasing area, which tends to drop in pressure of the fluid. Thus, the fluid velocity increases as a result of nozzle effect, and fish are caught easily without any add-on requirements for catching of fish. The CAD modelling was used for designing. The UUV navigates over the sea surface and, at certain fixed points, dives vertically to obtain a profile of a water column. In this paper, we also developed an efficient method for buoyancy control to achieve effective results and also describe about the adaptive control algorithm.

**Keywords:** UUV, Fish Trap, Nozzle, Tethered Port, Live Feed Camera, Blue-Green Light.

## I. INTRODUCTION

Unmanned underwater vehicles (UUV), usually called underwater drones, are the vehicles that are able to operate underwater without a human occupant. These vehicles may be divided into two categories, remotely operated underwater vehicles (ROVs), which are controlled by a distant human operator, and autonomous underwater vehicles (AUVs), which operate without human intervention. Thus, a UUV is a robotic device that is driven through the water by a propulsion system, and maneuverable in three dimensions. Sensors on board the UUV sample the ocean as the UUV moves through it, providing the ability to make both spatial and time series measurements. Sensor data collected by a UUV is automatically, geospatially and temporally referenced and normally of superior quality. Multiple vehicle surveys increase productivity, can insure adequate temporal and spatial sampling, and provide a means of investigating the coherence of the ocean in time and space. The operation comes with its own challenges explained in [3]. Unmanned underwater vehicle falls into mobile robotics sector and are of brilliant importance to the present world military and commercial requirements. The need to find an edge over others in military research induces the invention of UUVs. This paper gives a glimpse on Unmanned Underwater Vehicles and its applications. The application of this vehicle has increased in recent years, such as cable or pipeline tracking and deep ocean exploration. So it is better to make these UUVs smaller and flexible as much as possible so that it can go to smaller region easily. And if we need higher speedds in water then a streamline body is required. Fishing is the activity of trying to catch fish. Fish are normally caught in the wild. Techniques for catching fish include hand- gathering, spearing, and netting, angling and trapping. Fishing may include catching aquatic animals other than fish, such as moll scans, cephalopods, crustaceans, and echinoderms. The term is not normally applied to catching farmed fish or aquatic mammals, such as whales where the term whaling is more appropriate. Thus, the paper describes an alternative to such conventionally used methods of fishing.

## II. METHODOLOGY

### i. DESIGN

An ROV or a UUV works majorly underwater and hence is subjected to hydraulic pressure during its operation. Hence the design and material should be such that it can maintain structural integrity and retain functionality in the environment and under the given conditions. Hence for the project, a composite material is proposed for the parts in addition to stainless steel components in regions that experience larger forces. Since the means of controlling the UUV is with the aid of a tethered port, the UUV is designed with positive buoyancy, as it can surface in case the port is cut by any means, causing a loss of communication. The buoyancy calculations are shown below. The distinctive feature of a fluid is buoyancy. Any object immersed in a fluid like water, experiences an upward force called buoyant force. The use of the principle of buoyancy is seen in various applications like submarines, boats and similar vehicles. In the current project, considering all components of the UUV, the net downward force due to their respective masses was found to be 80 kg on the whole (includes hub, fish trap, electronics, fixtures, thrusters, etc.).

Downward force = $\mathbf{F_1} = m_1 g = \mathbf{784.8N}$

The mass of water displaced due to the volume of the UUV is 81.5kg. The force corresponding to this mass of water is the upward buoyant force experienced by the UUV.

Upward force = $\mathbf{F_2} = m_2 g = \mathbf{799.515N}$

The net force on the UUV is **14.715N** upwards, hence showing that the UUV is positively buoyant. And this small positive buoyancy is being exploiting in the project. Details of design and material of individual components shall be explained in the following section. The UUV is proposed to work under a maximum depth of 1500m from the surface in still or slow flowing water. Hence by the pressure equation of fluid statics we have

**P = ρgh** = $1000 kgm^{-3} \times 9.81 ms^{-2} \times 1500m = 14.715 \times 10^6$ Pa

≈ **15MPa** ........(1)

Based on Equation (1), we can conclude that most materials have their yield strengths well above the value while even having a Factor of Safety of around 4 to 5. Two materials have been chosen for the construction for their inertness in the marine environment and their excellent strength to weight ratio. They are Glass fiber and Stainless Steel. Though Carbon fiber is a good alternative, the cost makes it non-economical. Table with the properties of E-glass fiber is provided below [1] in Table I and Table II.

**Table I**

| Properties (Units) | Maximum Value | Minimum Value |
|---|---|---|
| Density ($kgm^{-3}$) | 2.6 | 2.55 |
| Bulk Modulus (GPa) | 43 | 50 |
| Compressive Strength (MPa) | 4000 | 5000 |
| Ductility | 0.026 | 0.028 |
| Elastic Limit (MPa) | 2750 | 2875 |
| Endurance Limit (MPa) | 2970 | 3110 |
| Fracture Toughness ($MPa.m^{1/2}$) | 0.5 | 1 |
| Hardness (MPa) | 3000 | 6000 |
| Modulus of Rupture (MPa) | 3300 | 3450 |
| Poisson's ratio | 0.21 | 0.23 |
| Shear Modulus (GPa) | 30 | 36 |
| Tensile Strength (MPa) | 1950 | 2050 |
| Young's Modulus (GPa) | 72 | 85 |
| Glass Temperature (K) | 820 | 850 |
| Maximum service temperature (K) | 620 | 630 |
| Specific heat (J/kgK) | 800 | 805 |
| Thermal Conductivity (W/mK) | 1.2 | 1.35 |
| Thermal Expansion ($\times 10^6$/K) | 4.9 | 5.1 |

**Table II**

| Environmental Condition | Resistance (1 = poor; 5 = excellent) |
|---|---|
| | |
| Flammability | 5 |
| Fresh water | 5 |
| Organic Solvent | 5 |
| Oxidation at 500 ℃ | 5 |
| Sea Water | 5 |
| Strong Acid | 5 |
| Strong Alkalis | 4 |
| Wear | 5 |
| Weak Acid | 5 |
| Weak Alkalis | 5 |

## ii. INDIVIDUAL COMPONENTS

### 1) HUB

This is the component that contains all the electronics that aid in maneuvering the UUV, as shown in figure 1. It is a cylindrical shell made of Glass fiber epoxy composite. It also has links that connect the thrusters and the fish trap to the hub. The design is such that it can withstand the Hoop's stress due to the hydrostatic pressure. The hub also houses the tethered port and GPS system, used as a means of communication when the UUV surfaces, which are encased in an acrylic box to prevent damage by the water. The front end of the hub is fitted with an acrylic cover where the camera is attached with a two axes gimbal for surveillance and live feed. The gap between the acrylic case and the hub has a rubber gasket that seals the space and makes a water tight seal. The fasteners are screws made of stainless steel. A costlier variant is the copper bronze screw but the stainless-steel screw is considered adequate for the project. Since the hub experiences large amounts of Hoop's stress as well as compressive stress, the thickness of the Hub has to be designed so that it can withstand these stresses [2]. The minimum required to withstand the external pressure, calculated in equation (1), is given by the following equation.

$$Minimum\ thickness = \frac{External\ pressure \times Radius\ of\ the\ component}{2 \times Yield\ stress\ of\ the\ material}$$

$$t = \frac{(15 \times 10^6)Pa(.18)m}{(2)(1.95)GPa} = 6.923 \times 10^{-4} m$$

Since the designed thickness is 5mm, which is more than the minimum thickness, the hub can easily withstand the external pressure without failure. Considering the factor of safety as 5 to accommodate the failures due to fatigue, the thickness was found to be 3.46mm. The final design of 5mm was implemented, as the fabrication of the hub becomes tedious due to the very thin section. Also, there is material inhomogeneity as various materials like glass fiber, glass and stainless steel are used, which needs larger thickness. The similar procedure is followed for all such components.

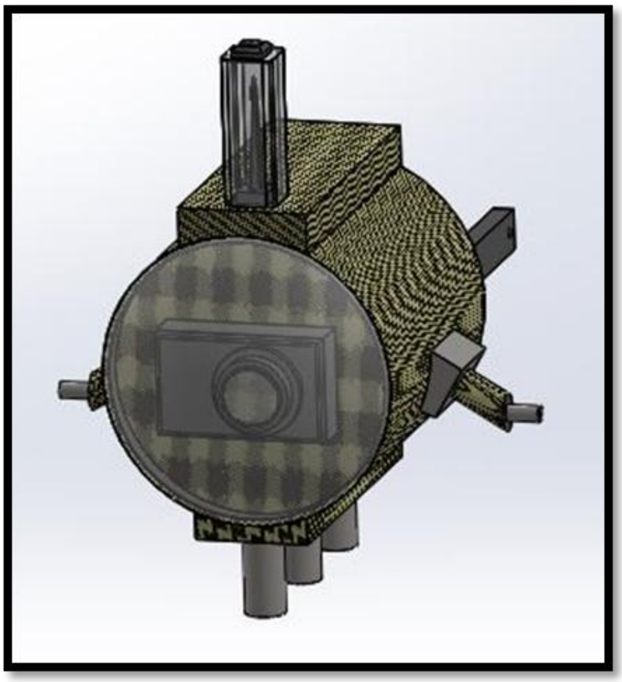

**Figure 1**

### 2) THRUSTERS

Thrusters are the mode of movement for UUVs. The UUV consists of 3 thrusters for accommodating all possible movements. The design of the thrusters is as shown in figure 2. It consists of a motor attached with a propeller. The propeller is designed such that it has a very large pitch for large flow rates, hence it could propagate very quickly at even considerably low speeds. The casing of the thrusters is made such that the fluid can flow out, and in turn propel the UUV in the desired direction. The capacity of the motor is about 150 lph (liters per hour). The propellers are made from polymer composites. The windings and wirings are insulated to prevent shorting in the water environment. The mountings are pivoted to the links on the hub for changing the direction of the UUV.

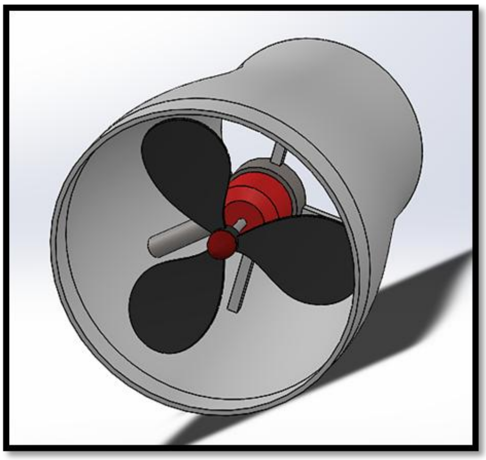

**Figure 2**

### 3) GIMBAL AND LINK MOVEMENTS

The gimbal is the mechanism that aids the movement of the thruster in preferably one axis: pitch. The links connecting the thrusters to the hub are also pivoted joints. Both these mechanisms are servo controlled using electrically controlled metal gear heavy duty servos. The servos are controlled through a control board that controls them to move the UUV in the desired direction. The two thrusters can independently pivot about the links from the hub as shown in the figure 3. The servos can pivot the thrusters to about 90° in clockwise and counterclockwise directions about the links (figure 3). Thus, the pitch movement and also the forward motion can be controlled using the controller board, placed inside the hull.

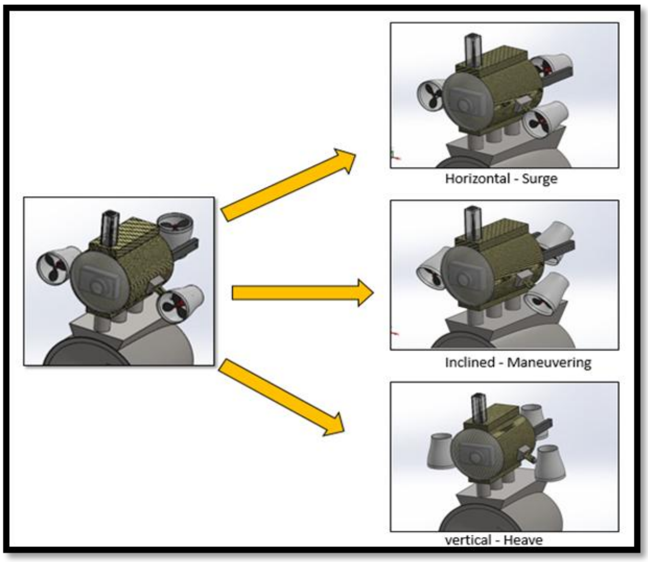


**Figure 3**

### 4) FISH TRAP

This is the main component of the UUV that traps the fish. A very simple and effective way has been designed for capturing the fish as shown in figure 4. Inspiration for the design is partially drawn from the method of fish basket trap. A similar idea is used but with a nozzle. The nozzle due to its constant reduction in area along its length, experiences a drop-in pressure and an appreciable increment in the fluid velocity. The increased velocity prevents the fish from swimming back into the water and forces them into a net attached to the end of the nozzle. Thus, fish are caught in the net. An additional feature that can be added is a counter. Since the UUV has its maximum payload constraints, excess fish can cause the UUV to sink and make it unstable. Hence a counter can be implemented at the throat of the nozzle which can count the number of fish caught and once a predetermined number of fish are caught it can be surfaced by the operator. An IR sensor has been used for this purpose. The emitter is placed at the top surface of the throat and the receiver is placed at the bottom surface of the throat region and thus any obstruction near the throat confirms zero input to the receiver of the IR circuit and thus the counter is incremented every time the process happens and the same is stored in the memory.

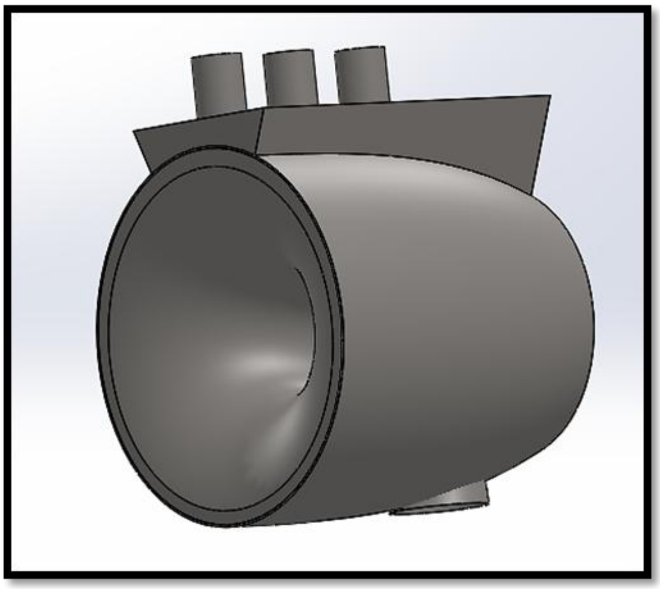

**Figure 4**

## III. OPERATION

### i. UUV MOVEMENT

The UUV is initially left on the surface of the water. The UUV is designed such that it has inherent small positive buoyancy. Hence the UUV floats without any external aid. A tethered port, maximum of a kilometer long, acts as a continuous source of power, control and communication. Details of a tethered port controlled ROV can be seen in [4]. The operator at the surface assesses the surroundings of the UUV by means of the live feed provided by the camera placed in front of the hub. The details on control of a UUV can be seen in [2]. The thrusters are placed nose down for heave movement along 'z' axis so that the UUV can dive overcoming its positive buoyancy. The thrust cup aids the effective transfer of fluid thus propelling the UUV to larger depths. Surge is the movement of the UUV along the X axis (longitudinal axis of the hub) and is achieved by pivoting the thrusters as shown. Yaw is another important movement that aids the UUV to rotate about its Z axis to take turns. This is achieved by increasing the speed of one motors and reducing the speed of the other. The rotation occurs in the direction opposite to that of the motor with higher speed. The UUV has three degrees of freedom which are highlighted in figure 5. A pressure sensor provides the depth of the UUV.

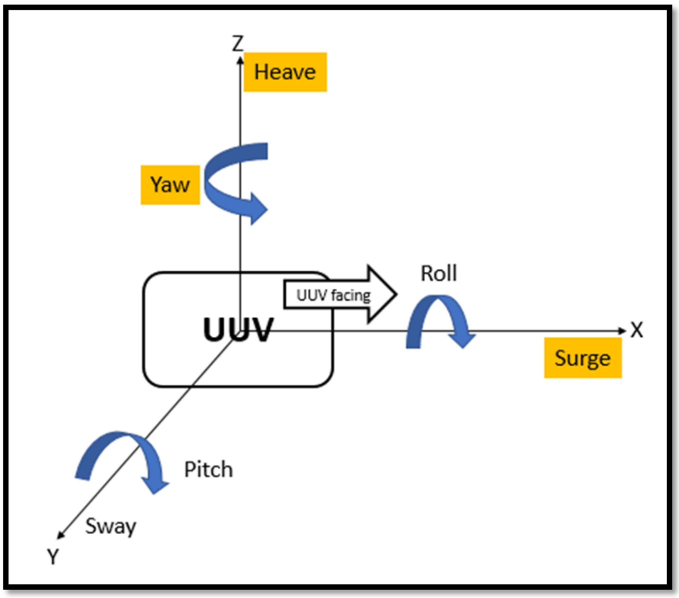


**Figure 5**

### ii. FISH TRAPPING

The UUV, as mentioned in the earlier section, uses the nozzle effect to capture fish. [5] and [6] mentions that fish are attracted to blue-green light and mercury vapor lamp. This is used in all modern fishing techniques. The same principle has been incorporated in this project. The light source is an LED placed inside the acrylic case next to the camera. This is highly effective in the dark. This further facilitates the fish catching process making it a little more efficient. Nozzles are meant to increase velocity of fluid while reducing the pressure. The pressure drop is calculated using the Bernoulli's principle. The length of the nozzle from inlet to throat is such that the rise in velocity is sufficient to propel the fish into the net. The throat length is kept long enough to maintain the pressure difference till the fish reach the net. The severe drop in pressure prevents backflow of water and hence fish cannot return to the free waters. The performance of the nozzle can be studied based on two important fluid mechanics principles

**1) Continuity equation:**

Mass flow rate at inlet = Mass flow rate at outlet

$$\frac{dm}{dt} = \rho A v$$

Applying this equation at the entry and throat of the nozzle, the velocity of the fluid at the throat can be determined.

$(\rho A \varpi)_1 = (\rho A \varpi)_2$ ........(Density remains constant)

$\pi \cdot (0.3)^2 \cdot 1 = \pi \cdot (0.1)^2 \cdot v$

(considering relative velocity of water to be $1ms^{-1}$)

$\mathbf{v_2 = 9ms^{-1}}$

**2) Bernoulli's principle:**

Using the velocity obtained, the pressure drop across the nozzle can be calculated using Bernoulli's principle.

$\mathbf{(P + \frac{1}{2}\rho v^2)_1 = (P + \frac{1}{2}\rho v^2)_2 = constant}$ **……** $\mathbf{(z_1 = z_2)}$

$[(15MPa) + \frac{1}{2}(10^3 kgm^{-3})(1ms^{-1})^2]$

$= [P_2 + \frac{1}{2}(10^3 kgm^{-3})(9ms^{-1})^2]$

$\mathbf{P_2 = 14.96MPa}$

Therefore, the pressure drop is

$\mathbf{P_1 - P_2 = \Delta P = 0.04MPa = 40kPa}$

The calculations have been performed considering a slow UUV moving at $1ms^{-1}$, but the velocity at the exit of the nozzle and the pressure drop increases as the velocity of the UUV increases. The net is fixed to the end of the nozzle by means of a lock pin joint. The net is made from nylon fiber. The drag due to the net is initially neglected, but once the fish get trapped, drag increases. Thus, the motors for the thrusters are chosen such that their thrust is high enough to overcome the maximum drag force. The thrusters are aligned in a direction that will facilitate the movement of the UUV in the direction of least resistance by the operator. The weight due to the fish shifts the center of gravity and center of buoyancy slightly and this is adjusted adequately by moving the thrusters. The complete assembly of the UUV is shown in figure 6.

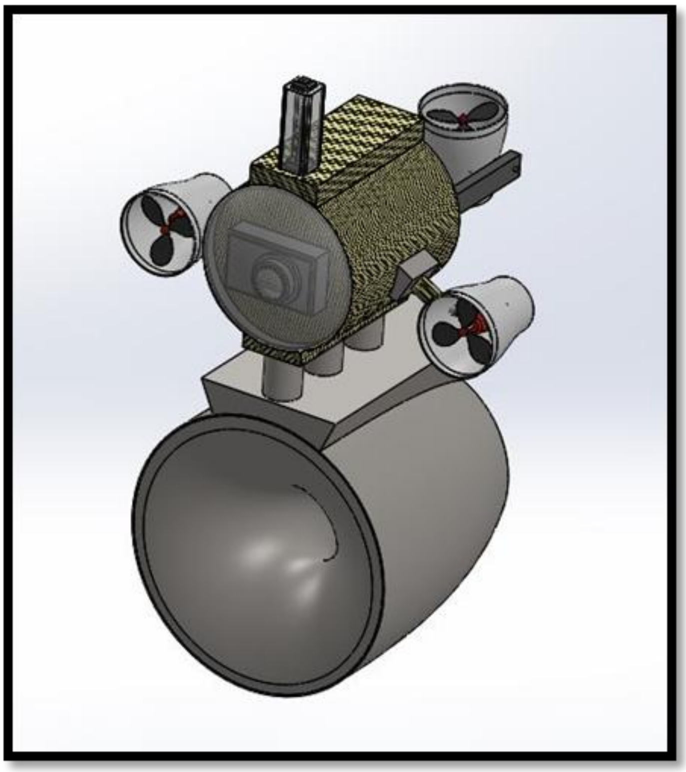

**Figure 6**

## IV. COMMUNICATION

Since GPS or any satellite controlled location devices are ineffective at large depths from the sea level, their use is not possible, but approaching the method of using LF (low frequency) or VLF (very low frequency) radio waves as in actual scenario, the length of antennae becomes impractical. Hence the feasible alternative for communication is the use of tethered port. Initially once the UUV is placed on the surface of the water; it floats due to its inherent positive buoyancy. The operator then increases the speed of the thrusters to heave the UUV below the surface of the water. Once below the water surface, the only means of control, communication and source of camera live feed is the tethered port. The operator maneuvers the UUV using the live feed and alters the speed and orientation by varying the speeds and angle of the thrusters. In cases when the tethered port is cut or a loss of communication between the operator and the UUV occurs, an auxiliary power source is incorporated in the UUV. On losing contact with the operator, the net is detached from the trap by pulling out the lock pin. This system is servo controlled and all accessories are placed inside the casing of the fish trap. The power source is a 2200mAh 3 cell Li-Po battery. Once the net is detached the UUV due to the positive buoyancy surfaces. On surfacing, a GPS sensor also operated on the auxiliary power source sends its position via an antenna to the operator by means of which it can be recovered. The schematic of the communication process in case of failure of tethered port is given in the figure 7 below. It shows the consecutive stages of communication

i) The position of the UUV during underwater fish catching operation where no GPS is available

ii) The final position when the UUV has surfaced after failure of tethered port and uses GPS to ascertain its position and report the same to the operator

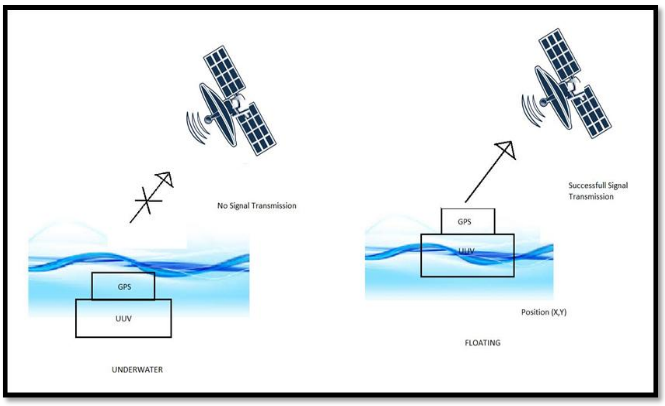


**Figure 7**

## V. CONCLUSIONS

The UUV is supposed to work underwater in a very hostile condition such as in saline or freshwater environment. It also has to work at pressures of up to 150 bars. Still it must be able to carry certain amount of fish. The success of the mission lies in the effectiveness of the nozzle in guiding the fish into the net. Thus, an effective nozzle reduces mission time and the power requirement. An ANSYS simulation of the nozzle has been done to see its effectiveness. The results can be seen in figure 8, describing the meshing, figure 9 depicting the stresses acting on the nozzle and figure 10, depicting the strain at various positions on the nozzle.

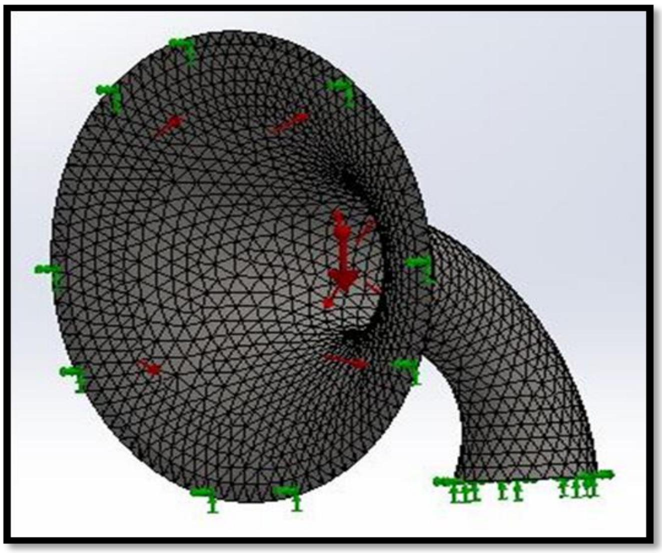

**Figure 8**

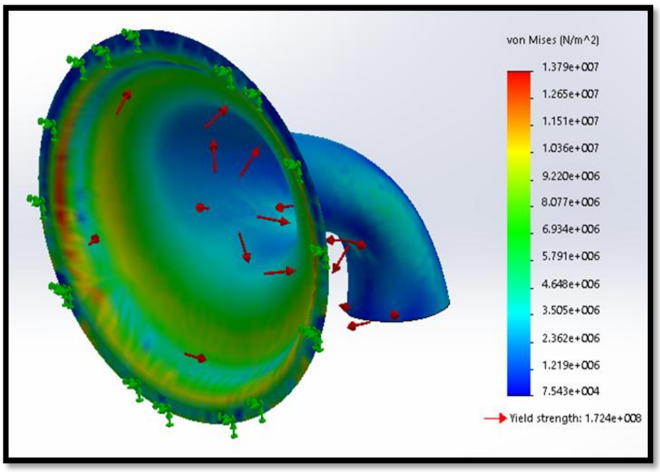


**Figure 9**

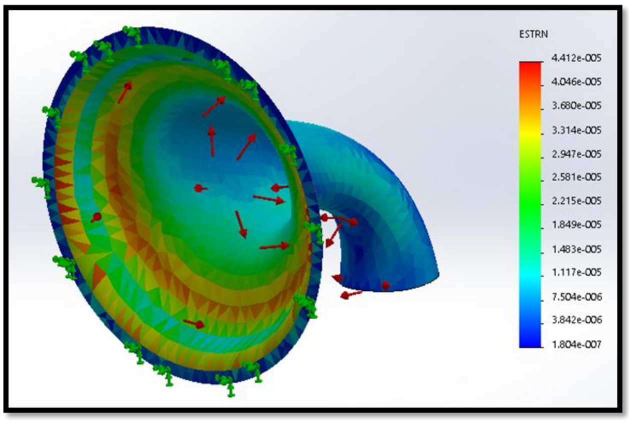


**Figure 10**

## VI. FUTURE WORK

- Designing the hull body in such a way so as to dissipate the heat effectively and proper thermal analysis of the hull can be done in order to make the electronic components in the hull work efficiently. Thus, the performance of the UUV can be enhanced.
- The nozzle design can be optimized to get the best performance possible and the analysis of the nozzle effect can be done by advanced CFD tools. The Modelling and simulation can also be done using MATLAB® software and this contributes to our major part of the future work.
- Though economy is a major criterion in any project, strength to weight ratio becomes critical in higher applications such as deep-sea explorations. This brings the inevitable use of composite counter parts such as carbon-fiber, aramid-fiber and 3D printed components. This can be a research project by itself.
- The project could be developed to use SONAR for detecting the fish. Also, an even more advanced and efficient method could be implemented by using image processing technique. Here the images captured by the camera can be analyzed by the onboard computer to determine the type of fish and the position of maximum fish density effectively. The advantage of this system lies in its low-weight, lesser need for system integration and easier application.
- The project has projected a fish catching UUV that is controlled by an operator via a tethered cable. A development would be to make a completely autonomous fish catching UUV that can navigate, catch fish and also surface without any human intervention. That would reduce the risk of operators in severe cases like calamities at sea.

## VII. ACKNOWLEDGMENTS

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