Mechanical design and development aspects of a small AUV – Maya

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Small AUVS are increasingly appearing in different marine application areas particularly in oceanography, naval applications of mine reconnaissance, and as effective tools for monitoring the coastal environment. This is not surprising as AUV technology has benefited from advances in control systems, local area networks, high performance micro-controllers and high capacity batteries, and new technologies that are resulting in smaller size sensor payloads for marine applications.

This paper addresses the mechanical design aspects of a small Autonomous Underwater Vehicle [AUV] called Maya, now nearing development at the National Institute of Oceanography in Goa, India; see Figure 1. Part of the development effort was done in the scope of an on-going Indian-Portuguese collaboration programme that aims to build and test the joint operation of two AUVs for marine science applications.

At the conceptual stage of this project, we decided that the design specifications had to meet several inter-related requirements. Namely, a safe AUV which was to be small in length, low in weight, modular in construction, capable of large mission endurance, application specific with suitable miniature payloads in the nose volume, easy to use,

Figure 1 The Maya AUV.

and low in cost. To a large extent, the present design has met these criteria removing the perception that AUVs are difficult and complex platforms to use. Our design description is patterned along the following lines:

AUV Hull

The main hull is machined from an aluminium cylinder which has two removable O-ring-fitted end caps. The hull volume accommodates a downward looking Doppler Velocity Log (DVL), batteries, one attitude and heading reference unit (with rate gyros), one digital depth cell, high performance embedded controllers, and shaft seals integrated with digital servo motors that are used for the deflection of the control surfaces.

The front nose section is removable and is used to accommodate mission-specific sensors. The nose cone is a low drag slender ellipsoid unlike the torpedo shaped nose of most small AUVS (e.g Remus, Gavia). The rear cone follows a classical Myring profile (see Fig. 2). The measured drag coefficient is ~ 0.310 at a velocity of 1.5m/s. The payloads that have been integrated in the Maya hull include a miniature CTD sensor, a Dissolved Oxygen (DO) sensor, and a single wavelength fluorometer to measure chlorophyll. See Table 1 for the main particulars of the AUV.

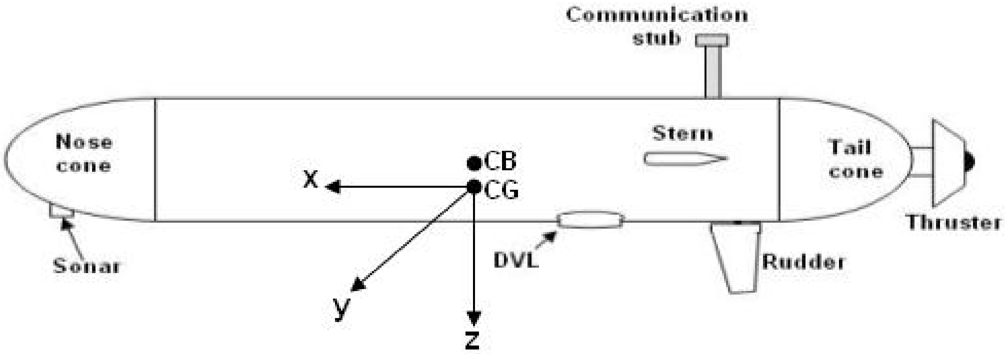

Figure 2. Side view of the MAYA AUV

Vehicle Parameter	*Value*
Total Length	1.8 m
Diameter	0.234 m
Shape	Slender Ellipsoid
Hull	Aluminum- 6082
Nose and Rear Cone	Acetal homopolymer
Depth range	200 m
Propulsion	Single electric DC brushless motor
Nominal speed	1.5 m/s
Endurance	~ 6 hrs
Power source	Lithium Polymer cells
RF Communications	2.4 GHz, 115kbaud
Scientific Payloads	CTD, Oxygen Optode, Radiometers, Camera, Fluorometer

Table 1. Main particulars of the Maya AUV

Control foils and shaft seals

The control foils consist of a pair of stern planes and a single rudder. The shape profiles of these foils follow a standard NACA 0015 section with an aspect ratio of 2.79 and a leading edge angle of 10.6 degrees. The NACA section being symmetrical it is easy to machine, has a zero lift force at zero angle of attack, and possesses a good torsional rigidity with a high thickness to chord ratio. Following standard practice, the shaft of the actuator motor is embedded at a distance equal to a quarter of the foil root chord.

A shaft seal is needed to seal the connection of the actuator motor to the control foil. This involves a seal that permits a shaft to protrude through the hull wall and connect to the foil. Two versions of the shaft seal are described in the paper namely a design based on dynamic O-ring seals and another that uses rotary face seals composed of tungsten carbide and graphite in dynamic contact with each other.

Hydrostatics of the vehicle

The net positive buoyancy of the AUV after trimming was about 500 grams. The AUV hull was enclosed in a foam jacket to provide this buoyancy. The separation between the center of gravity and the center of buoyancy was approximately 6 mm. This was smaller than initially planned, but it could not be increased since the best possible arrangement of components within the hull had already been chosen. Static stability tests of pitch and roll were conducted with the vehicle at rest, and the resulting data shows that the AUV was able to reach a stable equilibrium within 10 seconds.

Energy and propulsion for the vehicle

The choice of power source for the AUV was Lithium Polymer cells that offer a high energy to weight ratio of 182 Wh/kg. The AUV is powered by one battery bank dedicated to the electronics (24V/18Ah) and another bank for the thruster (96V/ 9Ah) . The total power bill of the AUV was approximately 125 W. This results in a minimum endurance of 6 hours.

The vehicle propulsion was achieved with a single brushless DC motor capable of delivering a maximum thrust of 4kgf at a bus voltage of 96V. At this operating point, the vehicle cruise at an average speed of 1.5 m/s. The paper will describe tests performed on the thruster so as to achieve a tradeoff between lower power consumption, battery volume, and thrust.

Safety aspects built into the vehicle

Safety on the AUV is of prime importance, and this will be discussed in the paper from three viewpoints namely

1) Power safety which monitors the bus voltage on a network node, and redirects the AUV towards home coordinates if the power level falls below a minimum threshold level

2) Software safety ensures that the AUV thruster is powered off if the vehicle crosses a programmed depth or exceeds a set pitch angle

3) Mechanical safety that drops a weight should electronic methods fail. The last method has not been implemented as yet, but will be incorporated in the near future.

Conclusions

The design of a small AUV has been described, and the development is nearing completion. Our original specifications have been broadly met. The AUV is currently under trials in the field. The final paper will detail the most relevant aspects of vehicle design and manufacturing and will discuss issues that warrant further research and development.