New designs of underwater vehicles from Underwater Technology Department,

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Abstrakt

New designs have been recently added to wide range of submersibles developed at Underwater Technology Department. After completion of KORAL AT ROV, an autonomous vehicle prototype, for Baltic Sea environment monitoring, is being currently developed. Paper describes operational requirements for the craft and its principal components. Vehicle control by remote means is not discarded however. This technology has been adopted for a sea mine destruction system with disposable low cost vehicle used for mine identification and destruction. Other interesting development is the newest version of diver towing vehicle. The vehicle is constantly improved and modified to different requirements regarding range and special equipment. The latest design is shortly described.

Introduction

For many years Department of Underwater Technology has been involved in design and development of various submersible crafts. They ranged from 35 kg diver towing vehicle to 1500 Mg nodule mining vehicle. Principal common problems associated with these projects are design methods and technologies that can be used. For this reason our efforts are always devoted to long term developments in these two areas. Therefore every single project is excellent source of a new facts and valuable data, improving our design tools and manufacturing abilities.

1. AUV for oceanographic studies of Baltic waters

This project, financed by Polish governmental Research Comity calls for a prototype able to perform according to assumptions listed below and is our third (but first practical) approach to AUV world. The subject is autonomous vehicle for Baltic Sea environment monitoring . This calls for 200 km range at 1m/s, significant payload and instrumentation volume as well as excellent navigation. The vehicle will follow programmed route in horizontal plane with vertical excursions in required points. While actual position of the vehicle is of great importance for navigation and oceanographic measurements, GPS satellite navigation equipment supplements standard navigation tools such as obstacle avoidance sonar, Doppler log and electronic compass. For GPS or DGPS position fixing the vehicle will be periodically surfaced. Motion system provided, gives the vehicle comparatively good maneuverability. The vehicle will be initially powered by gel type, lead-acid accumulator battery. To decrease development time and costs, of f the shelf components are widely utilized.. For the same reason high level Windows based programs are used to configure computer control system.

Mission task

Being significant source of pollution of Baltic Sea, Poland is heavily involved in its monitoring as well as investments devoted to protection of the environment. It means the need for periodical trips to selected points using various surface ships. While at location, oceanographic equipments are being lowered and required measurements performed. AUV mission task is identical. It is expected that introduction of the new technology will substantially reduce costs of monitoring and will make it whether independent.

Mission profile

The mission profile is comparatively simple. Vehicle is intended to be delivered by road and than launched from one of Polish ports located along Baltic south coast. After a launch, vehicle leaves the port controlled by radio means. While at sea, it descends and begins its trip along planed route. Normally it cruises at given speed and depth to first point were oceanographic measurements are to be done in vertical. Measurements are made twice - during ascent and descent. While at the surface, actual position is being measured using satellite (DGPS) navigation receiver. If a distance between vertical measurement points exceed allowable maximum, vehicle surfaces between these points and corrects its position using the same means. While at the depth again the vehicle cruises to next measurement point or recovery (destination) point which can be located at the same port or any other port at a range of 200km from the launch point.

The vehicle

At this early stage of the project and according to our design philosophy, no final external form has been decided yet. This is considered to be final step in design procedure. Initial step is evaluation of "payload". In the case considered, these are equipments used for acquisition and storage of oceanographic data. For this phase of design the following set of oceanographic instruments has been selected:

1. InterOcean Systems Inc. CTD/S4 - High Performance Digital CTD Instrument

with Dissolved Oxygen, Sound Velocity, Redox, pH, Turbidity meters..

2. Seas "TRITON", Ocean Technology Systems, Stockholm, Sweden, Hydrocarbon

detection device (it is exceptionally heavy and requires high power energy supply)

Resultant payload can be finally described as a list of the following parameters:

Volume:	400mm x 400mm x 1000mm
Negative buoyancy:	100kg
Power requirements:	24V/50VA (average)
Energy:	10000Wh

General arrangement

The vehicle is of highly modular design allowing easy modifications, maintenance and repairs. Further it means need for easy access, assembly and disassembly of modules and submodules with wide spread self diagnostic capabilities. To reduce construction and operating costs number of the vehicle subsystems are kept to reasonable minimum. Of course components available off the shelf are preferred choice.

At present, as seen on Fig 1., vehicle is composed of the following sections:

- Bow section containing navigation equipment
- Instrument section
- Battery section
- Propulsion section, stern

All above sections are designed to be neutrally buoyant. This allows selected sections to be removed or modified. The development phase is such a case, when instrument section is not really required.

Move system

The move system has been initially designed with a different ballasting and trimming subsystems, supplementing propulsion components. After detailed study this has been reduced to set of 6 electric propulsors arranged to meet motion requirements. Standard propulsors used in our systems can be seen on Fig 2 .They are build around well proven solution with permanent magnet synchronous motor powered by simple AC frequency inverter. The arrangement used in our underwater application gives full speed control without need for encoders and multiconductor cables. Industrial AC inverters are also much less expensive then normally used brushless DC servo controllers. The design has been recently modified to reduce complexity. At a penalty of slight diameter and weight increase, the planetary gear has been removed. Principal advantage of modified propulsor is increased reliability but noise generated has also been reduced.

Energy source

Powerful, simple, reliable and inexpensive source of energy is our target and we still wait for it. For the time being, we have adopted well known and proven lead-acid hermetically sealed accumulators. Their parameters are suitable for the vehicle prototype and it is assumed they can be easy replaced with more advanced source in near future. Although hermetically sealed and filled with gel electrolyte, lead-acid accumulators can be also a source of troubles and even danger to personnel and vehicle itself. As with other batteries hydrogen generation is most significant factor. We experienced hydrogen concentration build up and self ignition in diver towing vehicles. This initiated from our belief, supported by a manufacturer information, that batteries used are really hermetically sealed and does not discharge hydrogen when carefully charged. Later it was disclosed that actual rate of hydrogen generation during discharge period reaches 4 cubic centimeter per 1 Ah, per single cell. Not to mention charging condition. For limited volume of a battery compartment, dangerous level of hydrogen concentration can be reached very easily. Countermeasures available are numerous end well known. We has addopted low temperature catalizers.

With real accidents in mind it was however decided not to use these batteries in the prototype, before evaluation of real battery discharge in simulated conditions. To find volumes of hydrogen released operational condition were simulated. Battery composed of several cell was formed and placed in sealed container. Charge/discharge cycles were controlled by computer. For assumed battery loads, hydrogen concentration in compartment atmosphere is measured by means of polarographic sensor. This is suitable for concentration levels up to 2% (2000 ppm). For safety reasons permanent hydrogen level measurements will be provided in the prototype being built.

Cotrols and navigation

The vehicle control system is being designed as multiprocessor STE/VME bus system . with several CPU boards serving different tasks. Most critical are navigation and obstacle avoidance. From navigational point of view Baltic is comparatively easy. There are no tides and therefore strong currents. Main threat seems to be live and entangled fishing gears.

To give oceanographic equipments ability to work according to assumed parameters, they must be accurately located in water space. This accuracy was assumed as ± 50m at a range of 200 km. Generally actual position of the craft will be calculated using data from magnetic compass, pressure sensor and Doppler sonar. To correct actual position error, satellite navigation reference (DGPS) will be used. This however requires the vehicle to surface before the error becomes to high. For this purpose, GPS receiver antenna located at highest possible point of the craft has been provided. It is combined with serial radio transceiver. Argos transmitter for long range communication will be installed on operational vehicle.

As mentioned before, extensive fishing activity takes place at vehicle operating area, the vehicle can be easily entangled in nets of different type. To reduce the problem its route must be programmed to avoid all the existing sites were entangled fishing gears can be expected. Also active fishing gears can be avoided to some extent. This requires data regarding locations of fishing boats to be known before the vehicle is launched. We would also like to give the vehicle ability to detect and to avoid nets hanging or floating in water space. While detection and identification means available are not sufficient, performance tests of selected means has been initiated.

Structural members

While external shape is not defined yet, all vehicle components are assembled using central weight bearing frame. The latter being equipped with lifting points. For the development phase no external fairings are provided.

2. Diver towing Vehicle

Holonur Mark II

Our diver towing vehicle is quite old development now. It was started at 1990 when first prototype has been built. Its performance was not impressive so next model was developed soon. Some test vehicles were built as Mark II. They were further upgraded to obtain reliable underwater tool. They performance and reliability were proved in exploitation with exception for some problems with hydrogen build up (see remark above).

Mark II can be described as standard design with brushed DC motor supplied with low voltage lead acid accumulator batteries. Motor is switched on and off only and LED indicators inform a diver of battery condition. General arrangement of the vehicle can be seen on Fig. 2. The only navigational instrument is externally installed magnetic compass. The Mark II was also modified (extended) to accommodate a scanning sonar with waterproof 150mm LCD display.

Holonur Mark III

New requirements end technological developments resulted in totally new approach to vehicle propulsion. Principally new requirements call for longer range, higher speed, lower noise and improved reliability. To achieve this we have adopted well proven synchronous AC motor technology, previously used in Remotely Operated Vehicle KORAL AT. First prototype was built using permanent magnet AC motor with sinusoidal magnetic field. The motor assembly as shown on Fig 3. is similar to that used in CORAL AT and shown on Fig 2. Main differences are: lack of speed reduction planetary gear, slide bearings and oil pressure compensation. This solution offers higher reliability and substantial noise reduction, with slight increase in weight and motor diameter. To avoid operational problems servo inverter was used as motor drive, supplied with 144V lead acid battery. The hull dimensions were slightly increased to contain bigger battery provided. General arrangement was not changed to great extend, but new flux gate, self compensating compass with LCD display was added. Final changes of vehicle parameters are illustrated in Table 1.

Table 1. Mark III and Mark II diver towing vehicle technical data

	Mark III	Mark II
1. Nominal thrust	250 N	120 N
2. Maximum speed - 1 scuba diver	1.5 m/s	1 m/s
	1.4 - 3.5 hours	2 hours
5. Operating time at nominal thrust	11000 m	4500 m
6. Range (maximum)	550 VA	300 VA
2. Nominal battery power drain	144 V	24 V
3. Nominal battery voltage	2000 hours	800 hours
4. MTBF calculated	Yes	No
6. Continuous speed control	Flux gate	Magnetic
7. Compass	LCD, plain text	3 LEDs
8. Diagnostics		

Fig. 1 AUV main components

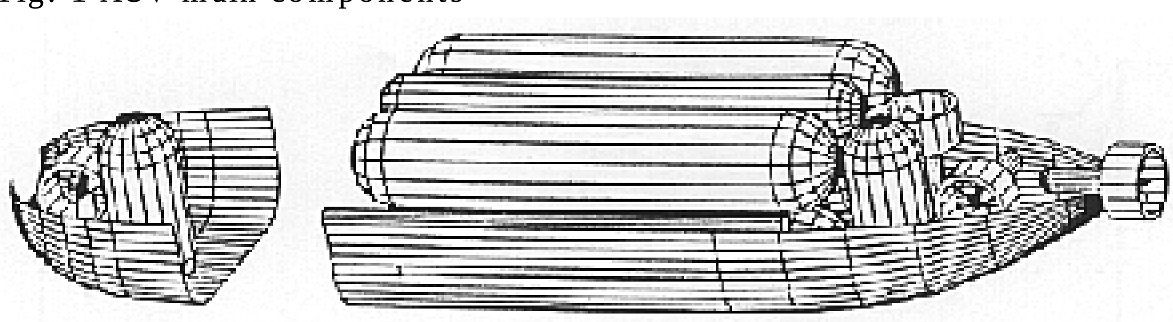

Fig. 2 Standard propulsor

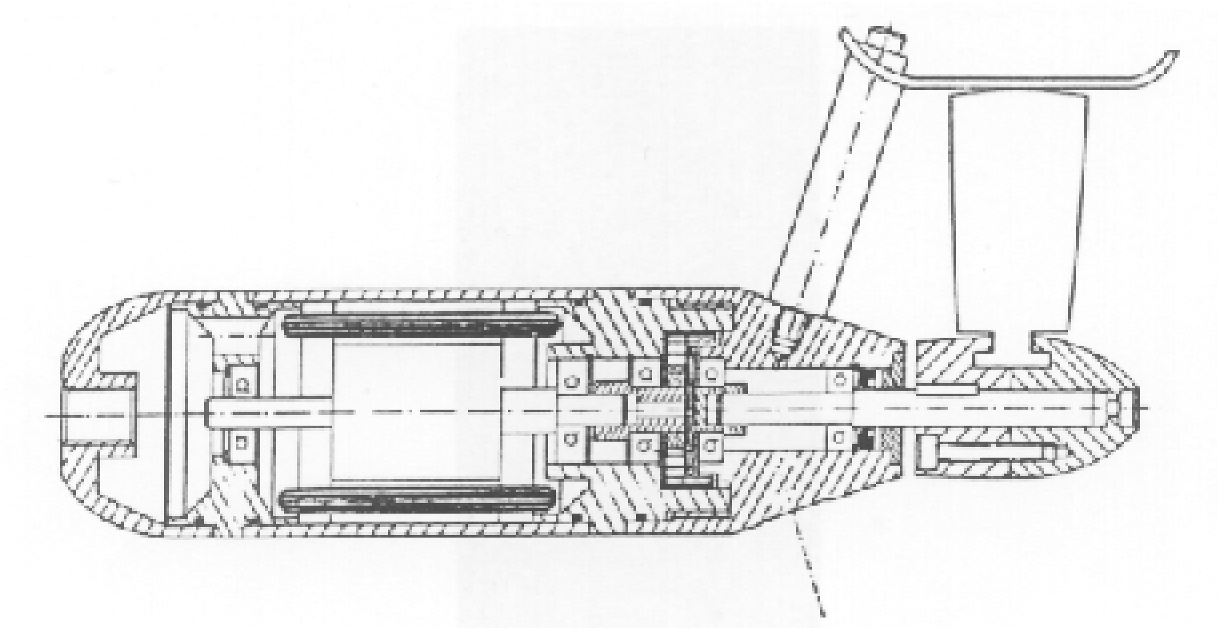

Fig. 3 Mark III motor assembly

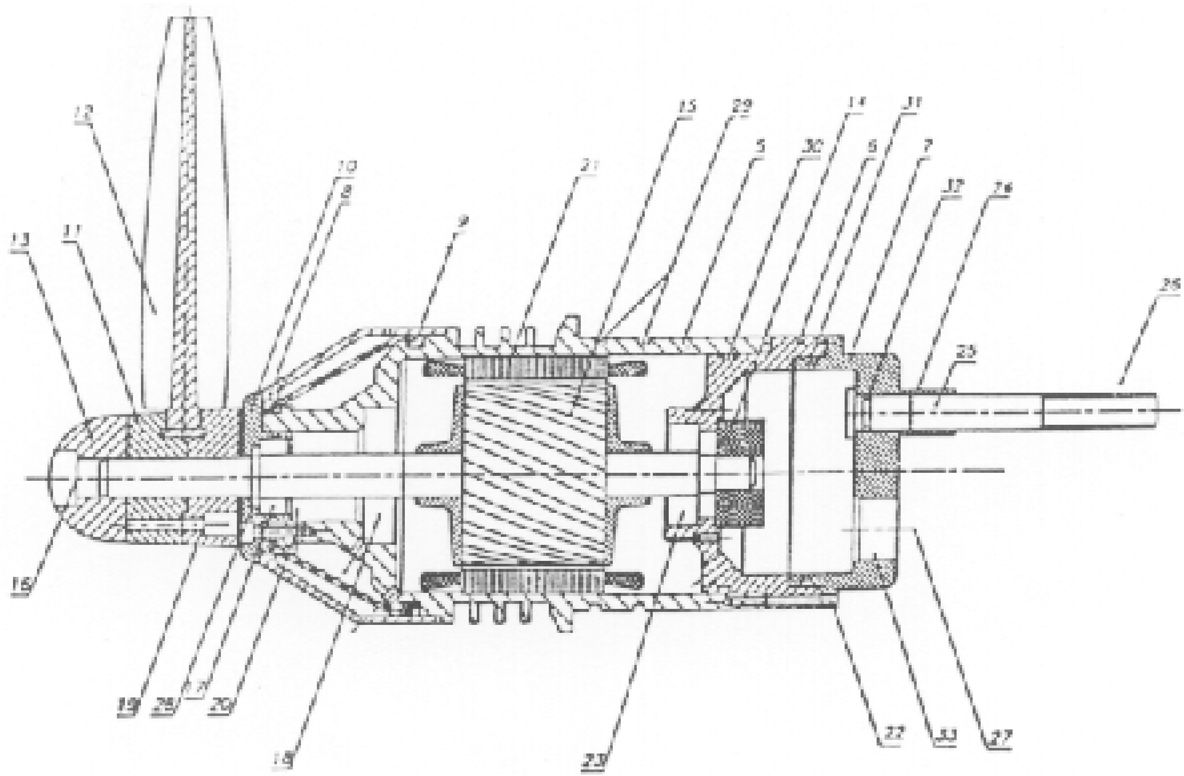

Fig. 4 Mark III cross sestion