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GENERAL-PURPOSE UNMANNED RESEARCH VESSEL USED FOR MEASUREMENT OF WATER DEPTHS IN RESERVOIRS AND THEIR DEPOSITS LAYOUT

BEZZAŁOGOWA UNIWERSALNA ZDALNIE STEROWANA PLATFORMA POMIAROWA SŁUŻĄCA DO BADAŃ NA ZBIORNIKACH WODNYCH

A b s t r a c t

Large artificial water reservoirs are one of the most valuable assets in flood protection. However, the overall volume of a reservoir can decrease over time. This happens mainly because of sediment accumulation, and that alluvia is "eating-up" an otherwise useful volume of water. It is therefore important to know the current volume of sediments accumulated in the reservoir. This way one is able to calculate the useful volume of the reservoir storage capacity, secondly, for assessment of future reservoir operation. The process of obtaining relevant data for this is normally partially automated but nevertheless, it is arduous, extremely time-consuming, and may be dangerous. To overcome those problems we have developed an unmanned vessel, which is able to perform the work much faster and easier. The vessel is a fully unmanned, integrated, nonetheless it is still under development (working prototype 1E), but it can be still easily used in its current state, albeit with some minor limitations.

Keywords: water reservoirs, sediment accumulation measurements, unmanned surface vehicles, echo sounder, anti-roll system for boats

S t r e s z c z e n i e

Duże sztuczne zbiorniki wodne są jednym z najważniejszych ogniw w systemie ochrony przeciwpowodziowej. Całkowita objętość zbiornika nie jest wartością stałą i zmniejsza się w miarę jego eksploatacji. Jako główny czynnik można tu wyróżnić gromadzenie się osadów nanoszonych przez rzekę. Proces pozyskiwania danych do oceny zalądowania zbiornika jest częściowo zautomatyzowany, mimo wszystko jest to zadanie trudne i czasochłonne. Opracowane przez autorów pływające urządzenie pomiarowe sprawia, że pomiary wykonuje się o wiele łatwiej i szybciej. Jest to urządzenie bezzałogowe, zdalnie sterowane i w pełni zautomatyzowane. Prototyp będący w fazie udoskonalania może być z niewielkimi ograniczeniami wykorzystywany do wykonywania pomiarów na zbiornikach wodnych.

Słowa kluczowe: zbiorniki retencyjne, pomiary zalądowiania, bezzałogowe urządzenie pomiarowe, echosonda, system eliminacji wpływu falowania

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1. Introduction

Large artificial water reservoirs are one of the most valuable assets in flood protection. Their value cannot be overestimated. They offer the cheapest and most effective tool against floods – water retention. They can significantly lower flood flow volumes in rivers, thus giving anti-flood protection to areas downstream. The other tools – like dikes, small "dry" reservoirs and polders are important as well, but nothing is equivalent to vast water retention reservoirs – concerning overall impact and the relative cost [see 1]. However, the overall volume of a reservoir can decrease in time. This happens mainly because of sediment accumulation, and that alluvia is "eating-up" useful volume of stored water. That is a rather slow process, which may speed up considerably during flood events. The yellow curve in the centre is a swollen Vistula River entering the reservoir, the water is firstly contained within the old flood protection dikes (see Photo 1 below).

It is very important to know the current volume of sediments accumulated in the reservoir, firstly to be able to calculate useful volume of the reservoir storage capacity (which is needed to plan flood protection and other purposes) and secondly for assessment of future reservoir operation. Sediment input into a large water retention reservoir (like Goczałkowice reservoir pictured above, with approx. 118 mln m^3 of nominal capacity [see 2]) can go into the several thousands of cubic meters annually.

Fig. 1. Aerial photo of flood water entering Goczałkowice reservoir in May 2010 (source: ZiZoZap Project)

Another, though related issue is the changing of riverbeds due to sediment accumulation and erosion. That can lead to dramatic changes in river cross-section geometry, thus alternating its hydraulics and making flood events much more likely and severe. Knowledge of the actual geometry of the river beds, especially for river segments inside towns and cities, is also very important for flood protection and planning [see 3].

2. Present measurement practice

Typically the measurements of the layout of bed of water reservoir are performed using the devive called the “echosounder” mounted on a boat. (like “UŚKA” pictured below). The device emits sound into the water and measures the time between emission and echo reception, thus allowing for distance calculation. It is attached to a boat and together with a GPS receiver (only for plane, or for XY, location) is used to record actual water depth at a given position. In order to complete a meaningful research, however, a lot of measurement points are required (hundreds of thousands or even more for medium-sized water reservoirs). The process is usually partially automated but nevertheless, it is arduous, extremely time-consuming and may be dangerous.

Fig. 2. Research vessel “UŚKA” used for measurements in Goczałkowice reservoir (source: ZiZoZap Project)

3. Our Invention

To overcome the above mentioned problems we have developed an unmanned surface water vessel (called UPP-1E), which is capable of doing that work much easier and faster. The vessel is a fully integrated device, consisting of following subsystems (see schematics in Fig. 1):

- Measuring subsystem: high-class echosounder consisting of the central unit (signal reception and formatting) and dual frequency heads (transducers). This device is a NaviSound 215 of Teledyne-Reson.
- GPS receiver – Garmin 18x unit. The signal from this unit is directly fed into the central unit of the echosounder for combining with the depth data and then transmitted further – into the central computer.
- Steering/propulsion and control system. Consisting of the central computer (with provisions for expanding into redundant double system in the future), and the switchboards (including associated firmware), electric motor and propeller. The power supply for all the systems is provided by a set of high energy density batteries (5 items, 12VDC) allowing for at least 6 hours of continuous operation. Communication with the shore station comes

through a GSM-based modem, allowing for almost clear and stable signal coverage throughout most of Europe.
- Auxiliary systems. As for now it is a surveillance/hazard avoidance camera, mounted on a small mast on the fore part of the boat (see Fig. 4). Adding a forward looking, short distance hazard avoidance radar is planned in the near future (funds allowing).

The use of two measurements frequencies allows us to perform two tasks simultaneously: the first frequency (200 kHz) is used for first-contact measurement, which is typically understood as "real lake bed" depth. This sound frequency reflects off first obstacles near the lake bed, sand, stones or vegetation. The other frequency (50 Hz) is a penetrating one, and can be used for direct deposit layer width determination. This must be carefully calibrated before any meaningful results can be presented.

A simple schematics of the system is presented on Fig. 3, below:

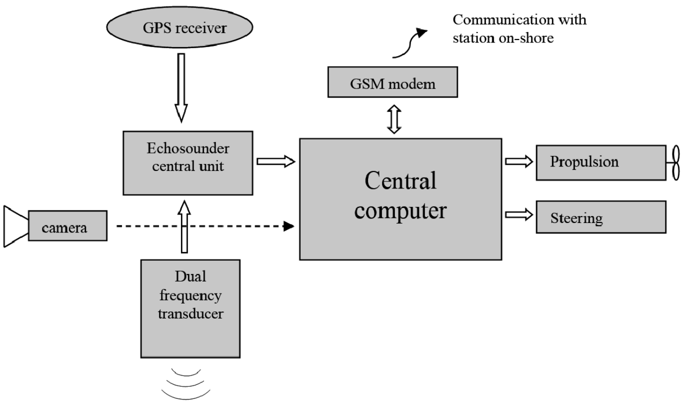

Fig. 3. Base schematics of the UPP-1E vessel. The UPP-1E vessel is pictured below

Fig. 4. General view of UPP-1E vessel (source Delta Prototypes)

Fig. 5. Steering mechanism

Fig. 6. Propeller, diameter 9 cm

Fig. 7. Control software screen shot

Fig. 8. Batteries compartment

In the Fig. 3 the whole vessel can be seen. It is 200 cm long (not counting the rudder) and 80 cm wide (including impact dampeners – grey tube around the hull). Its projected draft shall be no more then 10 cm. The echo sounder compartment is located between the camera and the tall mast. (First white cover). The other compartment is for batteries and propulsion (see Fig .7).

The Fig. 4 shows the details of the steering mechanism. A removable rudder will be utilized to allow for rapid replacement in case of expected rapid wear-and-tear.

In the next, (Photo 5), the propeller is shown just under the main hull. It is going to be the most exposed part of the entire vehicle. We expect it to be replaced fairly often (more then 6 times in a season). Currently a 9 cm diameter is being used. After the initial trials we may change it for a larger one.

In the last picture (Fig. 7) the batteries compartment can be seen. As for now only five units are used (for testing purposes). For a final use there is space provided for 15 more. Our aim is to be able to perform at least 8 hours of continuous operation. The maximum speed of the vessel is to be about 2 m per second, but for nominal measurement conditions it shall be no more then approx. 1 m per second (as the echo sounder gives up to 5 pings a second, it should be more then enough for most applications).

The UPP-1E vessel is meant to be able to replace the large boats (like UŚKA above) as bathymetric (depth measurements) platforms. Our vessel shall be much cheaper to procure, easier to maintain and able to perform much more research, even in adverse conditions. There shall be no crew on water, much longer measurement passes are possible, the draft will be minimal.

There is, however, a problem with boat stability. Larger vessels as a rule offer a much more stable platform against waves then smaller ones. It is a difficult problem for echo sounder measurements. If the sound beam emitted from the transducer is skewed (as happens when a wave rolls a boat) the resulting water depth value is incorrect – much higher (30% or even more then the "true" value).

The UŚKA vessel is 8 meters long, 2.5 meters wide with draft of 40 cm. It is possible to record bathymetric measurements (using a stabilized transducer firmly attached to its side) for up to approx. 20 cm of wave heights. Achieving the same with a much smaller boat is a challenge. To overcome that we are proposing a three-part solution:

1) Software. Using a white noise statistical function some impact of high wave can be eliminated during post processing of the obtained data.
2) Passive wave dampening. This will be done by using two additional hulls, attached to the sides of the main one, forming a trimaran configuration. The auxiliary hulls will be much smaller, but nevertheless shall offer some stabilization.
3) Active wave dampening. A device (under development) to actively dampen the rolling of the boat.

The anti-roll system – active and passive, integrated with steering and propulsion system is currently under development and in preparation for obtaining a Patent protection.

The entire system (even in its current configuration) is meant to be as rugged as possible. We are currently testing it to see what can be improved for the product to be able to work in the most adverse conditions. Trying to assess the progress of this new technology National Aeronautics and Space Administration (NASA) Technology Readiness Level can be utilized. Using this scale UPP-1E vessel in its current shape is on the TRL 6 – "Prototype demonstration in relevant environment" (see [4]).

The vessel is still under development (working prototype 1E), but it can easily be used in its current state, albeit with some limitations (mostly concerning surface wave impact dampening, man-machine interface and firmware issues). After it is completed it can be a game-changer for the industry.

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