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Measurement System for Wind and Waves Characteristics Registration on the Silm Lake

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ABSTRACT: This paper describes the system for registration of waves and wind disturbance. Ultrasonic anemometer measures wind parameters. Capacitor sensor is used for measurement of wave height. The wave sensor changes its capacitance according to the immersion of the sensor in water. The measurement system is controlled by the microprocessor system, which collects data from the sensors and retransmit them to the computer via radio modem. The system is used for design and simulation of control systems for isomorphic ship models on the Silm Lake near Ilawa, Poland.

1 INTRODUCTION

During precise control of ship movements at small velocities and when dynamic positioning task is performed, disturbance has considerable impact at the control accuracy. Particular influence to the ship movements are during trials on isomorphic ship models which are used for captains training and also for control systems research in the Ship Handling Research and Training Centre at Silm Lake near Ilawa, Poland. Most of isomorphic ship models have been built in the 1:24 linear scale. According to the laws of mechanical similarity during trials on the lake time run $\sqrt{24} \approx 5$ times faster than during operations on the real ship. The same scale $1:\sqrt{24} \approx 1:5$ must be used for comparison of velocities in the real world and on isomorphic ship models. Therefore even small wind disturbance during tests affects ship model like quite strong wind and wave disturbance acts the real ship (Szalangiewicz 1996; Morawski 2007).

To take into consideration the external disturbance in the control process the appropriate mathematical model of wind and wave disturbance is required. The model enables a design of more precise control systems and also more sophisticated computer simulations can be done. This paper describes design of the measurement system, which is used for collecting wind and wave parameters on the Silm Lake. The registered data will be base for developement of mathematical models of disturbance on the lake.

2 MEASUREMENT SYSTEM DESIGN

The wind and waves measurement system diagram is given in figure 1. It consists of measurement sensors, which are installed on a dolphin fixed in the lake bottom in some distance form a lakeshore. The measurements are collected by a remote computer, which can be installed on a shore or on the ship model.

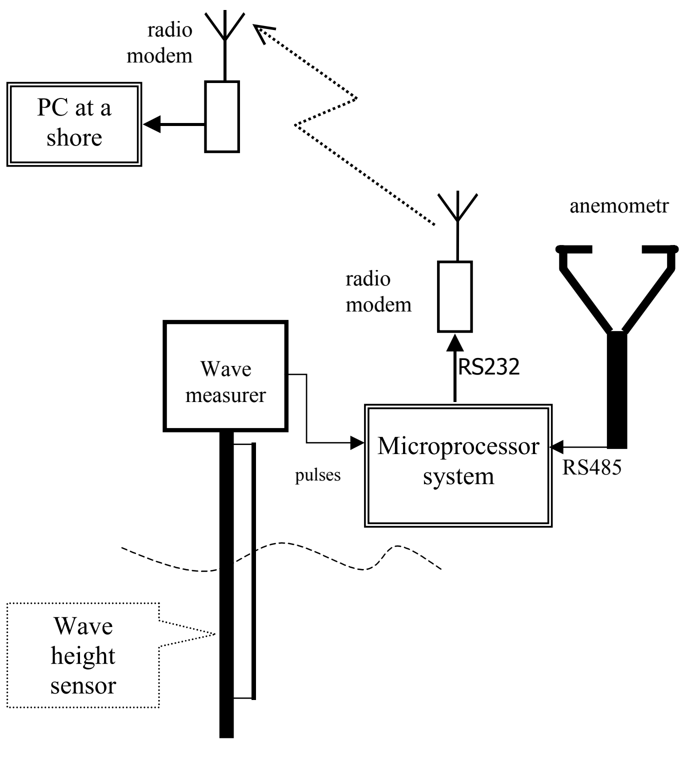

Fig. 1. Wind and waves measurement system.

2.1 *Anemometer*

The ultrasonic anemometer measures the time taken for an ultrasonic pulse to travel from one transducer to the opposite transducer and then compares it with the time taken for another pulse to travel in the opposite direction (Fig.2).

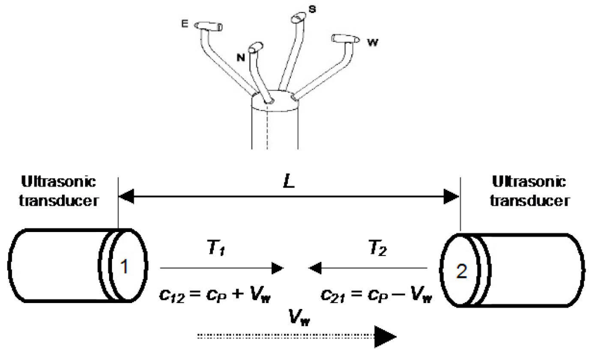

Fig. 2. Ultrasonic wind speed measurement

The speed c_{12} of the pulse travelling in the same direction as wind and opposite direction c_{21} are given by:

$$c_{12} = \frac{L}{T_1} = c + V_w \qquad c_{21} = \frac{L}{T_2} = c - V_w \tag{1}$$

where:

V_w – is a wind speed component, which is parallel to the 1-2 line,

c – is a speed of the sound in the air (it depends on air temperature),

L – is a distance between both transducers.

If both times T_1 and T_2 are known, it is possible to calculate wind speed V_w and speed of the sound in the air c:

$$V_w = \frac{L(T_2 - T_1)}{2T_1T_2} \qquad c = \frac{L(T_2 + T_1)}{2T_1T_2} \tag{2}$$

Gill Instruments' WindObserver II has been used for the wind measurements. It has two pairs of ultrasonic transducers, which are used for calculation of two perpendicular components of the wind speed. Both components can be easy converted to the polar co-ordinates i.e. wind speed and direction. Both coordinates are calculated with 2% accuracy. The data are transmitted 10 times per second in the NMEA 0183 format through RS422 interface to the microprocessor system (WindObserverII User Manual).

2.2 *Wave height measurer*

Electronic part of the wave measurer (Fig.3) consists of:

- a sensor, which capacitance changes due to immersion of the sensor in a water
- a monostable oscillator, which forms pulses according to the capacitance of the sensor,
- a transmission module which receives data from anemometer and sends data to the PC on a shore,
- a microcontroller which controls an operation of the measurer.

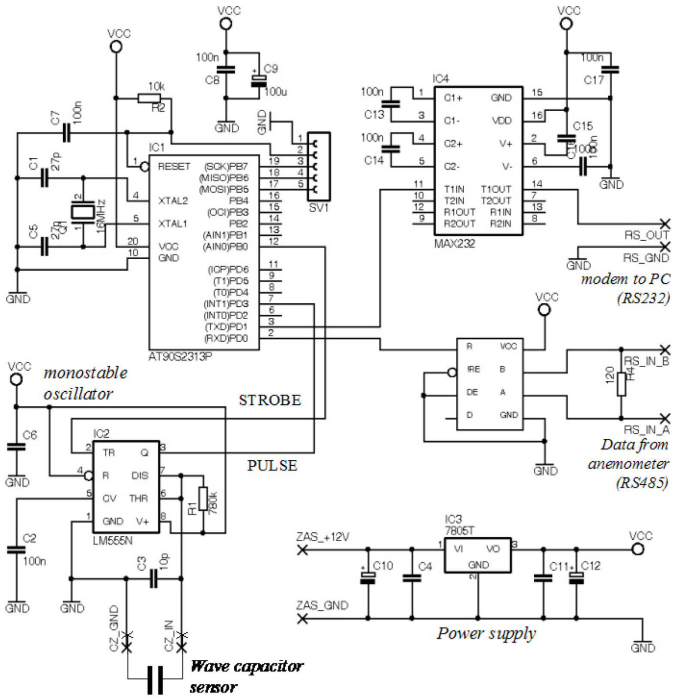

Fig. 3. Electronic circuit of wind and waves meter.

Capacitor sensor is used for measurement of wave height. It is formed by two electrodes (Fig.4). The flat bar is one of electrodes. The bar is also the element of mechanical structure of the sensor. Second electrode is composed by the thin copper wire with a teflon isolation coat. The wire is parallel to the bar. The permittivity of the air and the water are different, so the capacitance of the wave sensor depends on the wave level as it causes what part of the sensor is under the water.

The sensor immersion in the range 0-500mm corresponds to the capacitance variance from 40pF to 400pF. The capacitor is a part of the monostable oscillator composed by a popular LM555 chip (LM555 Data sheet). In this chip the time pulse width strictly depends on the connected capacitance. Pulse generation is strobbed by the microcontroller. The microcontroller also measures the pulse time width. The 32 partial measurements approximate final result. Measurement is available 10 times per second. Relationship between the pulse time width and the sensor immersion (the wave height) was determined by experiment. The damping of the electrodes by water mainly influences the measurement accuracy. Static error of wave height measurement is less then 1mm, but maximum dynamic error is bigger – it was estimated to 5mm.

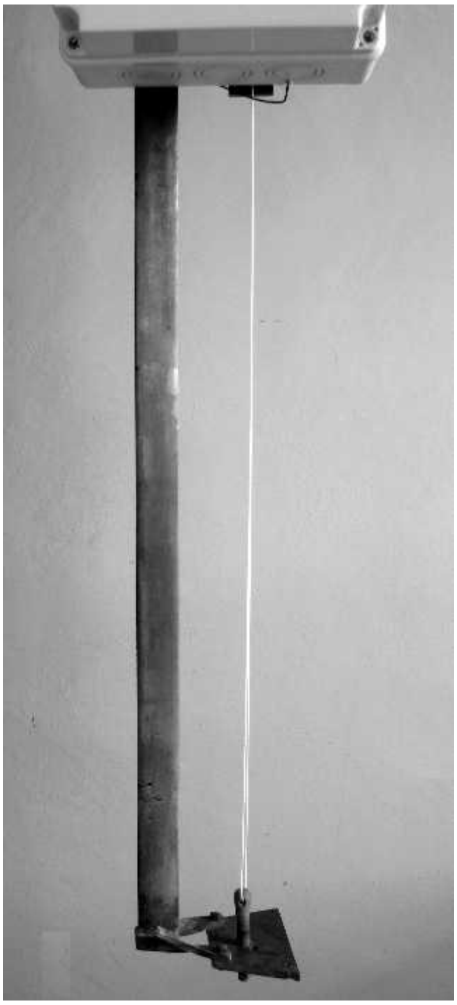

Fig. 4. Wave sensor – capacitor partially immersed in the water.

Additional microcontroller tasks are collecting of the data from the anemometer and then retransmittion of both the wave and wind parameters to a computer through radio modem. Transmission baud rate of the radio modem is limited to the 4800B. Because the measurements are available every 100ms (10Hz), and the NMEA format of data received from anemometer causes long time of transmission (70ms), and moreover 32 measurements of wave height are performed in parallel, therefore the microcontroller program has been quite difficult to write. Transmission of the data to the shore reduces power requirements for the measurement system, so the weight of the equipment installed on the lake is lower, therefore even thin dolphins, far away from a shore could be used for the measurer fixing.

3 CONCLUSION

Examples of the wind and waves parameters was recorded on the lake and given in the figure 5.

The described measurement system enables registration of wind and waves parameters and finally it will be possible to construct of appropriate mathematical models of wind and waves disturbance which appears on the Silm Lake during trials on isomorphic ship models.

Data are transmitted by radio modem, so the sensors are light enough to be mounted even on the thin beacon fixed to the lakebed. Another advantage of the measurer is small power consumption, therefore battery supply can be used to register data for many hours. The slow baudrate has been selected for transmission, it caused some problems in software design, but finally the cheap radio modem can be used, moreover an influence of the disturbances is reduced and the distance range covers nearly whole lake.

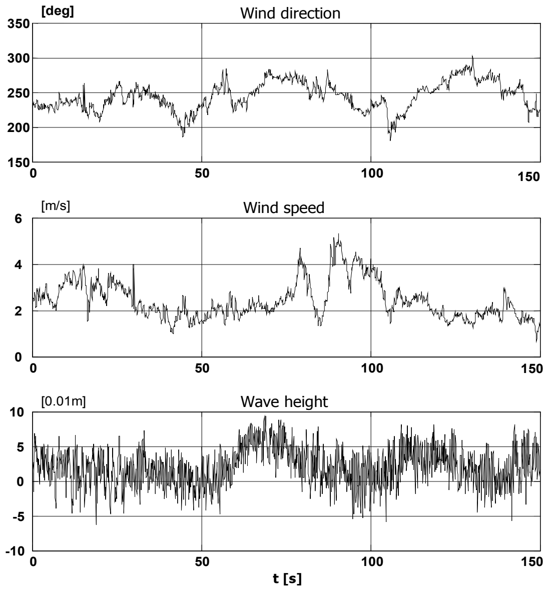

Fig. 5. Direction and speed of wind and level of wave recorded on Silm lake.

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