HYDRO-ACOUSTIC MONITORING OF WATER ENVIRONMENT

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ABSTRACT

The report deals with issues of the organization and implementation of the hydro-acoustic monitoring of natural and technogenic anomalies in water environment. The methods for the increase of the reliability of the obtaining information and evaluation of the sea bottom upper sedimentary layer composition, and also the water environment ecological condition in real time mode are described, the results of the completed shootings are illustrated.

Keywords: water environment, hydro-acoustic monitoring, natural and technogenic anomalies, ecological condition

I. INTRODUCTION

At present, the Earth water resources studies and the rapid development of the sea petroleum production lead to the development and improvement of the appropriate infrastructure for the effective implementation of a greater volume of works directly in the water density, especially with regards to the thorough study of the sea bottom. The shots of the sea-bottom sites, the revealing of the technogenic constructions and communications at these sites, geological anomalies detection, the definition of the bottom grounds parameters and of the sedimentary layers structure, providing of navigation safety, etc are the concern of this research.

All these tasks become of special significance in such water reservoirs as The Caspian Sea, The Mexican Golf, The Northern Sea, because their shelf-zones are rich in the semi-submersible extractive platforms and underwater communications. The fulfillment of all the tasks listed above makes the way for the development, creation and exploitation of the mobile remote information complex for the monitoring of the natural and technogenic anomalies in the water environment. The hydro-acoustic method is most effective for the water environment remote sensing [1]. That's why the hydro-acoustic devices have been world-wide adopted for the water density and sea-bottom studies.

The requirements for the devices include receiving of maximum information within minimal time frame and energy expenses, sufficiently high resolving capacity, stable picture of the sea bottom and underwater objects with minimal geometric distortion, saving and operative translation of the obtained data through communication links.

II. BODY OF THE TEXT

Taking into account the above listed demands, the following were used as the basis for the creation of monitoring technical aids: the experience of the development, the principles of construction and the data we obtained at the time of the field observation with the hydro-acoustic information-and-computing complex (HAICC) made by us. HAICC consists of a side-looking sonar (SLS) and a profilograph [2]. The SLS makes it possible to study the sea bottom surface with the objects located on it, to estimate their geological dimensions, reciprocal positions and current state, to detect underwater anomalies. The profilograph provides the information on the sea bottom upper sedimentary layer composition and structure. The SLS and the profilograph consist of the underwater and board modules, connected via tow-cable. The underwater modules can be placed either on one tow fish which combines the functions of the transmitter and receiver for both SLS and the profilograph, or on two individual tow-fishes. The generalized flow-chart of HAICC structure is given on fig.1. The board module of both SLS and prophilograph includes a transmitter and the receiver-converter section. The transmitter consists of the launching impulse generator and control block. The receiver is made of the receiving device and control block on the computer basis. The underwater module contains a tow-fish with the hydro-acoustic antennas, an antenna amplifier, a tow-cable. The immersion is provided by means of a lowering unit on one of the ship boards in order to increase maneuverability in the hard-to-get places full of underwater communications. It allows to change an angle of axis tilt in the directional diagram of the antenna and provides for the high resolution while shootings.

The complex allows to get the image of the bottom site, which is being explored, at the arbitrary altitude of the tow-fish above the bottom level due to the tracing the altitude and the forming of the appropriate control parameters of the system (impulse package frequency, its duration, power, filter band width, etc.).

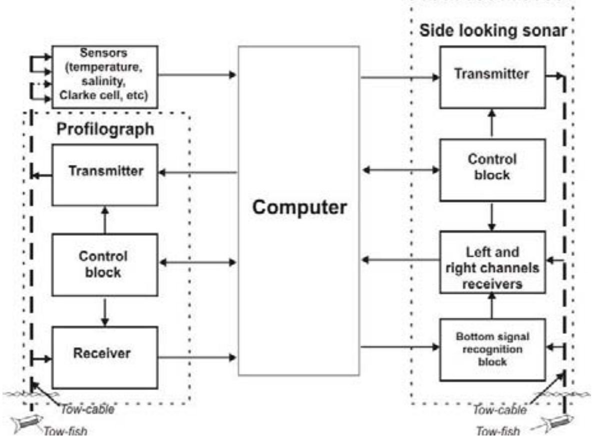

Fig.1. The flow-chart of HAICC

The complex allows to correct the geometrical distortions peculiar to the sonar images because of positional relationship of the hydro-acoustic antenna and the reflective surface as well as the irregular towage of antennas, bottom inclination and the other factors influencing the formation process of the hydro-acoustic image. The complex also realizes the correction of amplitude distortions which appear due to the echo-signals intensity weakening as a result of the enlargement of the acoustic wave front as well as the sound absorption in the water, the irregularity of the directional diagram and the change of the acoustic beam sliding angle in the view zone of the sonar. The complex saves the digitized data, accompanied by the annotation, on hard disk and CD, which allows to accomplish the further processing and transferring the data via communication channel [2].

In this case the frequency of launching impulses is defined as

$$f_{з} \le \frac{c\sin\alpha_{\min}}{2h}, \quad (1)$$

the filter band width, **Δf**:

$$\Delta f = \frac{cN\sin\alpha_{\min}}{4h(1-\sin\alpha_{\min})}, \quad (2)$$

the duration of launching impulse, $\boldsymbol{\tau_{з}}$:

$$\tau_{з} = \frac{4h}{cN\sin\alpha_{\min}}, \quad (3)$$

the antenna output voltage, $\overline{U}$:

$$\overline{U}^2 = k_U^2 \frac{J_0\sin^4\alpha_{\min}}{h^4} m_s, \quad (4)$$

the intensity of backscatter in reception point, $\mathbf{I_S}$:

$$I_S = \frac{P_A D V m_S S}{4\pi R^4 e^{2\beta R}}. \quad (5)$$

where **c** is the sound speed in water, $\boldsymbol{\alpha_{\min}}$ – the sliding angle of acoustic beam reflected from the most distant point within the range of the vision zone, **N** – the number of impulses in one cycle, $\mathbf{k_U}$ – the sensitivity of the antenna on voltage, $\mathbf{J_0}$ – the intensity of the antenna emitting at single distance, $\mathbf{m_s}$ - the coefficient of the bottom backscatter, **R** – slope distance to reflecting site, **S** – sectional area of site, **β** - in-water absorption factor, $\mathbf{U_{П}}$ – noise voltage in the antenna output, **M** – the sensitivity of the antenna in the reception mode, **D** – the directional diagram of the antenna, **V** – the concentration factor of the antenna, **ε** – signal-noise ratio.

To obtain the preliminary information on the structure and composition of the upper sedimentary layer of the bottom right at the time of the monitoring, it is necessary to develop the classification of the sediments sorting them in multiple groups according to certain qualitative characteristic (in this case – to density), to get the mathematical expression for the dependence of this characteristic on the water environment parameters, settled particles as well as the echo-signal level. Then, after measuring the values of the necessary characteristics at the preliminary stage of the monitoring and the value of echo-signal in the course of monitoring, it becomes possible to attribute the sediments in the point of the exploration to the certain group [3].

When modeling the equation for expression of the density dependence (y) from the measured parameters ($x_1,\ldots, x_m$), an algorithm of optimization of the model complexity using the least squares method with bordering [4], the idea of what consist in a stepwise refinement of the parameter estimations with application of a recurrent calculation of inverse matrix elements in the estimation process. At that, exclusion of arguments out of the model being built was carried out based on the multiple correlation coefficient [3].

To find the equation were choosed **T** (temperature of environment), $\mathbf{U_S}$ (settling velocity), η (dynamic viscosity), $\mathbf{I_S}$ (the intensity of backscatter), ψ (thermal capacity coefficient), ρ (sediment's density). The processing of this data gave the following mathematical dependence:

$$\rho = 3.6 \times 10^3 - 6.4\,\mathbf{T} - 2.3 \times 10^2\,\eta - 9.7 \times 10\,\mathbf{I_S} \quad (6)$$

It is significant that settling velocity and thermal capacity were excluded from model as spurious. The solution of equation allows to determine the group basing on developed classification given in [3] depending on ρ. Ibid, are given initial data for equation calculation obtained at the time of field observations.

The high quality of obtained model is illustrated on fig.2 where is presented the comparison of the bottom upper sedimentary layer density experimental values and corresponding to them modeling results

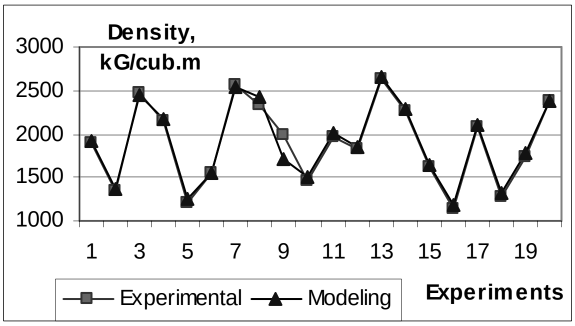

Fig.2. The result of modeling

While analyzing the obtained equation it is possible to make a conclusion: to have the same dimensions of both left and right parts of equation, the numerical efficients must have their own dimensions. This may occur because of not all the factors affecting to processes of sedimentation and sediments consolidation were taken into consideration. That’s why an exploration at place is necessary to reveal of other factors. After more accurate definition the given equation can be used for the preliminary estimation of the composition of bottom upper sedimentary layer in real time mode.

Processing the hydro-acoustic images the correction of profilograph’s input signals geometrical and amplitude distortions is carrying out. Amplitude distortions arise from different absorption of signals reflected from different layers. Therefore the brightness of different layers of image is not proportional to real values of these layers’ reflectivity coefficients. Geometrical distortions arise from different speeds of wave propagation in different layers. As a result, on the image is observed the nonlinearity in positional relationship of echo-signals from different bottom layers. The echograms of profilograph before and after use of the correcting program is given on fig.3.

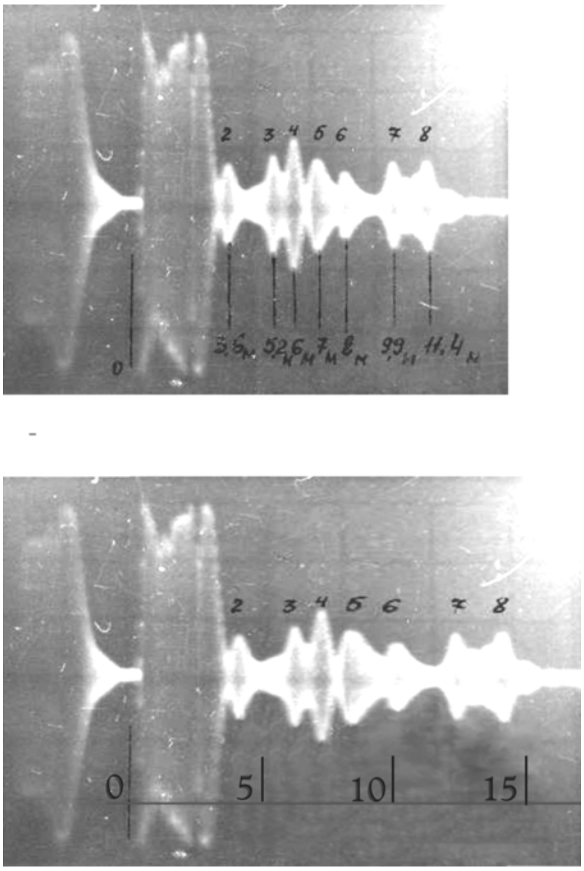

Fig.3. The echograms of profilograph before and after use of the correcting program

While decoding the receiving images, the fractal method is using. This allows to represent the bottom relief surface with minimal number of approximating triangles [5] and to select the natural and technogenic anomalies. The ecological state of water environment is estimating using the Clarke cell which is part of complex, by value of dissolved oxygen concentration and by oxygen demand rate.

III. CONCLUSION

The analyzing HAICC was approved experimentally in the area of the Caspian Sea to the south of the Absheron peninsula as well in the Kura river. On the fig.4 are given the echograms obtained during the monitoring on “Bahar” oilfield area. The obtained results affirm that an arranging of a monitoring using HAICC, including SLS and profilograph, allows to provide the obtaining of reliable information about natural and technogenic anomalies in a water environment.

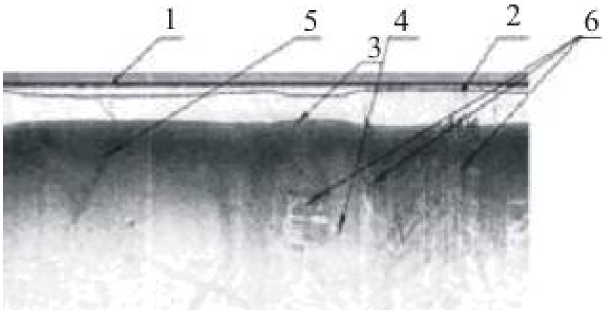

Fig.4. Shooting’s fragment. 1 – launching impulse; 2 – reflection from water surface; 3 – reflection from bottom; 4 – pipelines; 5 – hydrocarbons leaks; 6 – platforms

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