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DEVICES AND METHODS FOR DETERMINING THE DRIVING PERFORMANCE OF AMPHIBIOUS VEHICLE USED IN THE TESTS ON WATER

The article presents an analysis of the methods and equipment used for determining the speed of amphibious vehicle moving through the water in the tests. An analysis of existing methods for determining the speed of amphibious vehicle, their advantages and disadvantages submitted in this article. Material presented in this article make it possible to define the goals and objectives of the study to improve the methods for determining the driving performance of amphibious vehicle.

Keywords: *amphibious vehicle, aerodynamic testing, hydrodynamic testing,* experienced pool, *full-scale experiment, model, moving speed, measuring instruments.*

Statement of the Problem

Currently in the most developed countries of the world there is a significant increase in interest in the creation of amphibious vehicle (AV) various purposes as evidenced by a significant number of publications in print and online resources [1-9]. These include passenger cars floating (Fig. 1) [1] and transporters of various purpose (Fig. 2) [3], buses (Fig. 3), [3] the floating agricultural machinery (Fig. 4) [2], the rescue and a special technique (Fig. 5-7) [3].

Figure 1 – Floating ZAZ 968 modified by P. Kishchenko Ukraine

Over the past 40 years in the world have implemented more than 60 projects amphibians that often created on the basis of a stock car companies BMW, VW, Jeep, Citroen-DS, Lamborghini-Kauntach, WHA, GAZ, ZAZ, LUAZ etc. which greatly reduced their cost.

Providing the necessary qualities navigable AV - complex scientific and technical task.

The problems of running qualities AV in different years were engaged: N. I. Gruzdiev, N.S. Vetchinkin; P. Stepanov; P. V. Aksenov, Y. A. Kononovich; L.G. Barkhudarov, V. V. Kiselevsky; Y. L. Vorobiev, A. I. Veretennikov, A. V. Nefedov; A. V. Kryzhny, V. T. Bugaev and other authors.

Figure 2 – Amphibious vehicle for the transport of valuables GAZ 3934 "SIAM"

Figure 3 – Amphibious bus River Ride Hungary

Figure 4 – Floating machine for cutting reeds the company Ösmo Bandservice AB Sweden

Figure 5 – Track Gators Fast Track Amphibian Austria

Figure 6 – Rescue vehicle ZIL 4906 Blue Bird Russia

Figure 7 – Floating Crane Company Transport Russia

It was conducted a considerable amount of various tests using the AV and instrumentation equipment. To ensure measurement performance driving characteristics on the water AV authors proposed a number of methods and techniques.

Measurement methods, instruments and equipment used depends on the conditions of observation, the task and the required accuracy of measurement of the speed of movement on the water AV.

The main part

Determination of the driving performance of AV is made usually:

1) the calculation methods;

2) by testing models of the AV with the subsequent recalculation of the results on the natural object;

3) by full-scale trials.

Analysis of the calculation methods for determining the running qualities AV [6] shows that they do not provide the required accuracy of calculations.

Model tests to determine the speed of the movement of the AV can be:

- with direct water flow around the machine housing;
- with reversed flow.

In the first case experiments are carried out in the experimental pool (Fig. 8) or using a self-propelled models.

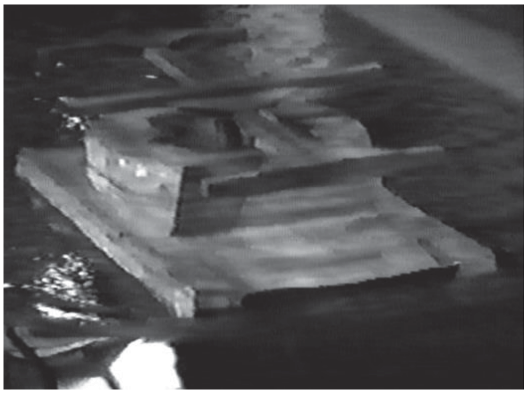

Figure 8 – The test model cars floating in the experimental pool of ONMU (author's archives)

In the second case the tests are carried out in the hydraulic tray or in an aerodynamic tunnel (Fig. 9).

Model tests are much cheaper full-scale tests. They can be repeated many times under stable environmental conditions. This contributes to their wide dissemination in scientific and engineering practice.

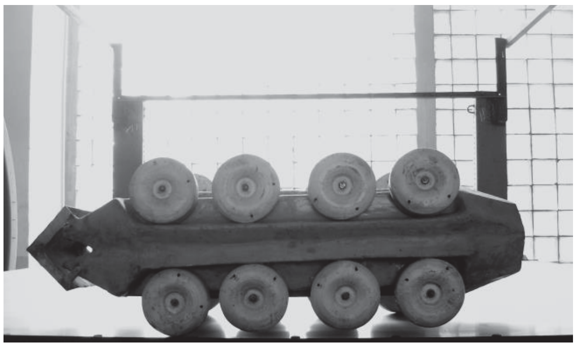

Figure 9 – The model prepared for aerodynamic testing (author's archives)

Despite the considerable experience gained in carrying out model tests their results are not as accurate as the results of full-scale tests. This is due to the need to translate the results of experiments on the nature. This leads to measurement errors. Another error appears because of the inaccuracy of manufacturing model for the experience. The action of water on the model leads to deformities and an error of the model geometry.

Therefore at present the most accurate data can only be obtained by conducting full-scale experiment.

In the work of Aksenov P.V., Kononovich Y.A. [5] to determine the speed of the AV in the sea trials authors suggested to use fixed objects as a sighting point, and note the time which vehicle taken for passage between them (Fig. 10).

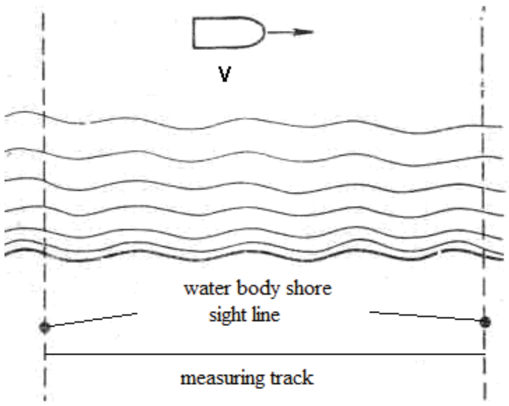

Figure 10 – Measuring the speed of the AV at the time of passage of lines of sight [5]

To increase the accuracy of reference for this process, it is recommended implement the movement of vehicles as close as possible to the shore because a large distance from the shore leads to an increase the possible measurement error, leading marks must be sufficiently removed from each other (at least 50 m) place for speed measuring should be hidden from wind and waves. Also, the authors proposed measure speed of the AV by using flow wheel, which is fasten to machine by a flexible cable (Fig. 11).

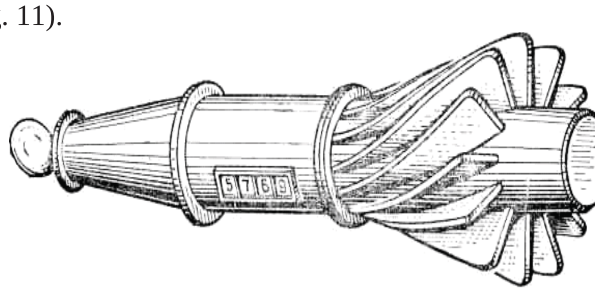

Figure 11 – Flow wheel [5]

The use of flow wheel lets not rigidly keep the observation locality. However, change of fluid flow, which caused by the work of vehicles propulsor, has a great influence on the accuracy of the result. Furthermore, to read results from flow wheel it is necessary to extract it out of water.

To improve the accuracy of the speed of the A.V. on the water by Aksenov P.V. was developed multi-purpose device (Fig. 12). Its working principle is based on the unwinding dimensional wire attached to the PM. It drives the revolution counter. This defines the path traversed by the machine for some time. The disadvantages of this device are: stretch wire, uneven movement of the revolution counter, the need to rewind and cleaning dimensional wire from contamination after the experiment.

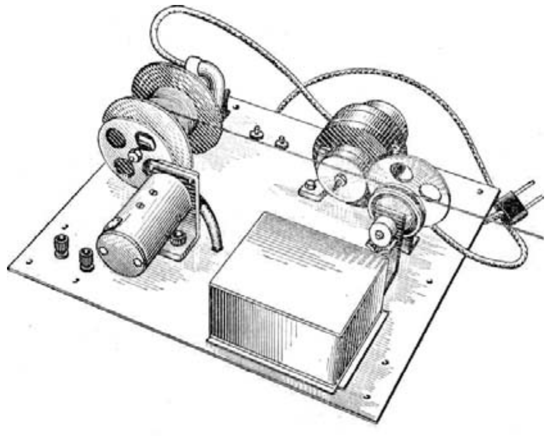

Figure 12 – Universal device for determining the speed of the AV [5]

In the work of Stepanov A.P., Davydova N.G. [4] to improve the accuracy result measurements has been proposed to increase the length of the sea trials AV and the number of points of sighting. This has enabled the measurement of speed for steady motion and accuracy when machine passing the markers (Fig. 13).

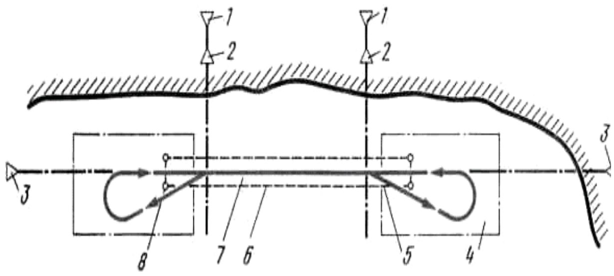

Figure 13 – Layout area of the sea trials of the AV [4]

To control the position of the AV on the water Stepanov A. P. proposed to establish on the vehicle a large-scale rail with markers in the horizontal plane of the vehicle (Fig. 14).

For the recording of the results of observations Plastinin E.I. had proposed to use the method of back bearing. This method allows to determine the coordinates of the position of the machine, from which is produced photographing. To do this before the test begins clearly distinguishable signs establish on the shore in the corners of the square (Fig. 15).

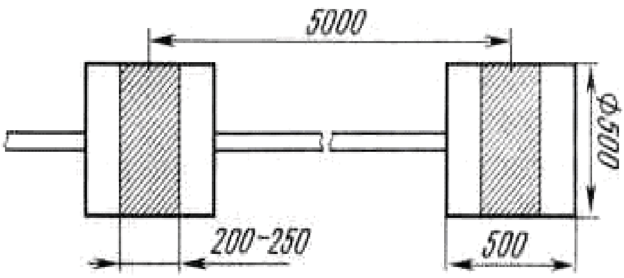

Figure 14 – The large-scale rail with markers [4]

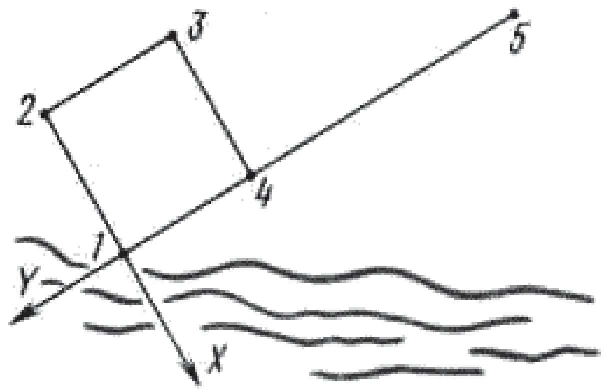

Figure 15 – For referencing square (by Plastinin E.I.) [4]
1-4 – set point racks, 5 – pre-recording point
x y - axis of a square

To determine the speed of the AV can be used photogrammetric methods of measurement, in which the pictures are taken at the shore. In this case the apparent dimensional rail mounted on the AV (Fig. 16).

The coordinates of the point M which determines the position of the AV is calculated using the following formulas:

- when shooting a single camera:

$$X_M = x_{m1} L / l ; \qquad (1)$$

$$Y_M = fL / l ; \qquad (2)$$

$$Z_M = z_{ml} L / l , \qquad (3)$$

- in stereo photography:

$$X_M = \frac{b x_{m1}}{x_{m1} - x_{m2}} ; \qquad (4)$$

$$Y_M = \frac{bf}{x_{m1} - x_{m2}} ; \qquad (5)$$

$$Z_M = \frac{b z_{ml}}{x_{m1} - x_{m2}} , \qquad (6)$$

where x_{m1}, x_{m2} - values of the measured coordinates of image of the point M on the first and second images; *L*, l - accordingly the length scale rail on the AV and the length of the image slats in the first picture; *f* - focal distance; z_{m1} - value of the measured coordinate of the image of the point *M* on the left image; *b* - photo base.

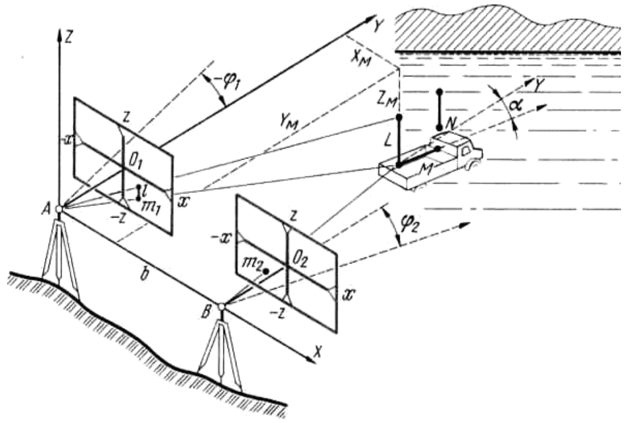

Figure 16 – Stereogrammic shooting tests AV [4].
M – position AV

Proposed method [4] allows defining as the spatial and angular coordinates of the AV in particular the heading angle.

When shooting single snapshots

$$\alpha = (-1)^k \arcsin \frac{X_M - X_N}{d} \pm \pi k , \qquad (7)$$

where *k* – an integer, *d* – the distance between points *M* and *N*.

Estimation of accuracy of the spatial coordinates by concerned methods allowed obtaining depending errors of calculation of coordinates, which are presented in graphical form on Fig. 17.

Unfortunately, the use of these methods for fixing the moving object does not allow for monitoring of changes in speed of movement of AV throughout measurement site, what may reduce the accuracy of determining machine speed.

The results of full-scale tests of the AV PTS-2 on the Dniester liman are presented in [6].

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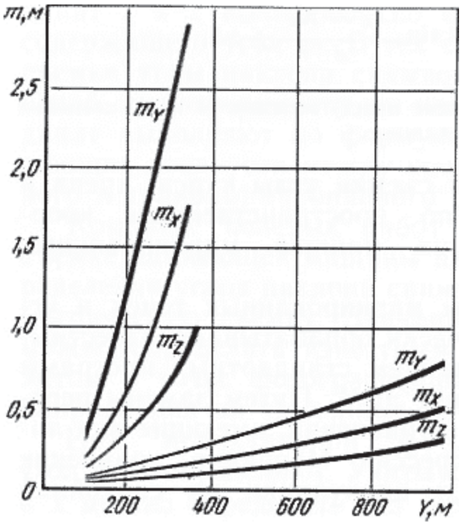

Figure 17 – Rating errors in determining the coordinates of the AV using photogrammetric methods [4]

For the full-scale testing was chosen plot navigation channel (B. Dnestr liman) (Fig. 18).

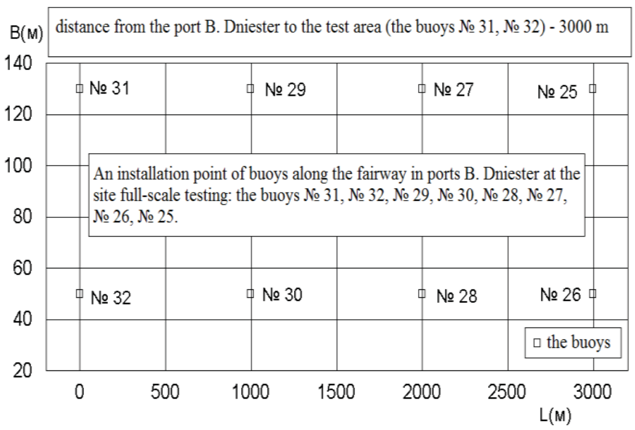

Figure 18 - The scheme of the site plan for testing floating machine

The length of the plot was 1 km; water depth over 5 m. To measure the depth was used electronic depth gauge kit KRVP with a measurement error of 5%.

Profiles of the bottom section are plotted from results of measurements of depths (Fig. 19).

Speed of movement of the AV was determined with the use of flow wheel GR-21M from the reconnaissance assets kit of water barriers CRP. The calibration curve of flow wheel GR-21M is shown in Figure 20.

Number of revolutions of the machine engine crankshaft (min^{-1}) was recorded by the tenured tachometer. The trajectory of the AV, its speed and circulation were determined by high-precision rangefinder KTD-1 (quantum topographic rangefinder). Measurements were taken from the shore. During carrying out of experiments was conducted videography. Specifications of the applied equipment are in the table.

Table - Specifications of measuring equipment

Specifications of measuring equipment			
type	measured parameters	measure ment limits	Max Δ
ЦГА-4	The angle of heel and trim	±30^o	±05^o
ГР-21М	The linear speed of the software, m/s	008÷5	±4÷8%
ГПК-59	heading angle	360^o	±05^o
ТЭ-4В	The speed of rotation of the engine crankshaft, min^{-1}	0÷ 5000	±50
КТД-1	The distance to the car, m	500÷ 1500	±01
videography	Behavior machine, m	0÷1	±005

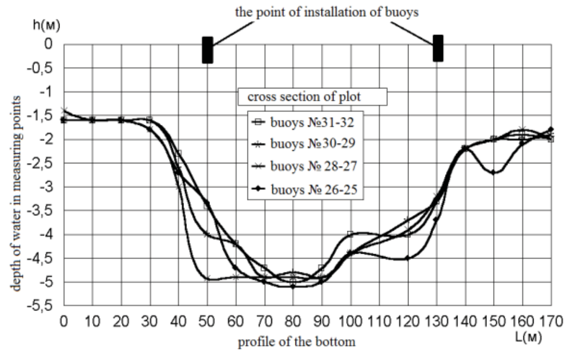

Figure 19 - The bottom profile of the test area (m)

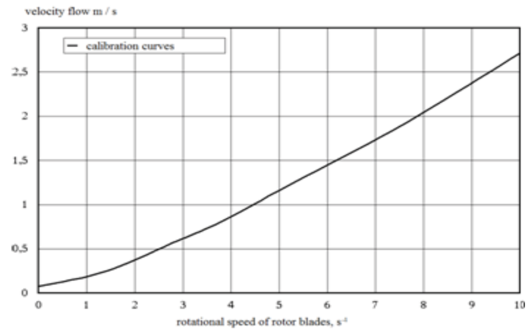

Figure 20 - The calibration curve turntbles GR-21M

The conclusions

The analysis of the literature allowed the following conclusions:

- existing methods for determining the driving performance AV were developed over 10 years ago;

- methods require their development;

- improvement of methods for determining of the driving performance AV is possible due to the

- wide use of digital measuring instruments and equipment;

- it is necessary to use modern instruments

Doppler to determine the range and speed of movement;

- to ensure the experiments to use gyroscopic sensors and GPS navigation devices;

- need to be widely to apply digital video recording of the experiments progress.

Application of the proposed instruments and devices will greatly improve the accuracy of measuring the characteristics of the AV driving performance, will significantly reduce the cost of the experiments that will promote the wide dissemination

of improved methods of measuring the characteristics of driving performance AV.

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ПРИБОРЫ И МЕТОДЫ ОПРЕДЕЛЕНИЯ ХОДОВЫХ КАЧЕСТВ ПЛАВАЮЩИХ МАШИН, ПРИМЕНЯЕМЫЕ ПРИ ЭКСПИРЕМЕНТАХ НА ВОДЕ

В статье представлен анализ методов и оборудования, используемых при натурных испытаниях ходовых качеств плавающих машин. Приведен анализ существующих методов определения ходовых качеств плавающих машин, их достоинства и недостатки. Представленные в статье материалы позволяют определить цели и задачи исследования по совершенствованию методов определения ходовых качеств плавающих машин на плаву.

Ключевые слова: *плавающая машина, аэродинамические испытания, гидродинамические испытания, опытовый бассейн, натурный эксперимент, модель, скорость движения, измерительные приборы.*

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ПРИЛАДИ ТА МЕТОДИ ВИЗНАЧЕННЯ ХОДОВИХ ЯКОСТЕЙ ПЛАВАЮЧИХ МАШИН, ЩО ЗАСТОСОВУЮТЬСЯ ПРИ ЕКСПЕРИМЕНТАХ НА ВОДІ

У статті представлений аналіз методів та обладнання, що використовується при натурних випробуваннях ходових якостей плаваючих машин. Наведено аналіз існуючих методів визначення ходових якостей плаваючих машин, їх переваги і недоліки. Матеріали, представлені в статті, дозволяють визначити цілі та завдання дослідження щодо вдосконалення методів визначення ходових якостей плаваючих машин на плаву.

Ключові слова: *плаваюча машина, аеродинамічні випробування, гідродинамічні випробування, опитовий басейн, натурний експеримент, модель, швидкість руху, вимірювальні прилади.*