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THE EARLIER EXPERIENCES OF PHOTOGRAPHIC MEASUREMENTS IN RUSSIA

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ABSTRACT

Contactless measurement methods are widely used in industry and research. As we know, they passed more than one century of development, but the main principles remained constant. Photographic measurement methods are taking the very special place between others because of easy results treatment and precision control, low complexity and high integration level of the used equipment. This paper presents a path of evolution of early photographic measurements to the new perspectives of photogrammetric control in Russia. Alexey N. Krylov, the famous Russian scientist, was the pioneer who forced usage of photographic measurements for applied needs of Russian Navy. Additionally, he developed the new ship pitching measurement method that had become a precursor of the most modern sophisticated methods.

Keywords: contactless measurement, photographic method, A.N. Krylov, ship pitching, evolution of measurements

1 INTRODUCTION

The photographic contactless measurement methods in their evolution are all practically derived from very earlier experiences of well-known scientists E. Muybridge and E. Marey [13, 14, 23]. These researches were usually based on synchronic photography with time points. The object broke the time point wire bound to activate recording device (figure 1). From the beginning, they used the photographic contactless measurement methods to record a motion of animals. Further development of equipment and recordings treatment techniques led to appearance of more sophisticated methods such as strobelight photography [17] and photogrammetric treatment [2, 16]. However, before beginnings of 20th century the photographic contactless measurements were not presented in Russia. There were several researches known [20], but they described photography only as a technique of visualization for high-speed processes. Practically the first Russian scientist who began to use such methods as basis of precise experiment was Alexey Nikolaevich Krylov.

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1.1 ALEXEY N. KRYLOV: BRIEF BIOGRAPHY

Alexey Nikolaevich Krylov was born on the 15th of August, 1863, in Siberia. He worked in Compass Forge of Hydrographic Department from 1885 to 1887. Later Krylov continued his education in the Naval Academy where he also began to teach as a tutor of mathematics. As mathematician, he built a basis, inter alia, for photographic measurement and analysis of trajectories. However, as the experimentalist, Krylov developed several new methods of measurement and photographic ship pitching recording was the one of them.

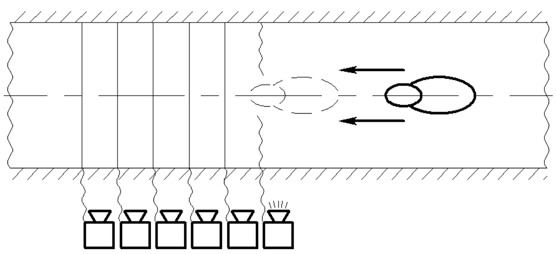

Figure 1. Synchronic photography with time points (Muybridge's schema) [13]

From February, 1902 to January, 1904 he was active in carrying investigations of survivability and insubmersibility of ironclad ships [11]. A research of artillery direction systems behaviour in case of pitching was a part of these investigations. In the era of supersized artillery, the correction of projectile trajectories was necessary. Especially, combination of factors (e.a. large shooting distance, necessity of synchronous measurement for large and small values, high perturbation velocity, and low temporal density of measurements) required to develop special principles of measurement. Krylov developed the new photographic method near 1904 – 1906.

2 PECULIARITIES AND REALIZATION OF PHOTOGRAPHIC PITCHING MEASUREMENT

As beginning, assigned development of idea and base theory to French engineer Huet [9] with reference to ”Mémorial du Génie Maritime”, 1874. Krylov forced to collect data about contactless measurement techniques from all around the world. Krylov also had visited Italy; there at he could learn theory of photography and photogrammetric methods [11]. Studies of photogrammetry helped him to produce several original measurement techniques in Russia, thus Krylov was an inventor in all cases. For example, he developed a photogrammetric technique of artillery shooting control and trace registration [8].
The method proposed by Krylov [19], turns practically the photo camera to analog oscilloscope with direct values conversion. As it is shown on figure 2, camera is installed on the ship with optical axis oriented perpendicular to lengthwise keel plane (rolling mode) or to lengthwise axis (plunging mode). The sighting point of a camera should be positioned to the skyline.

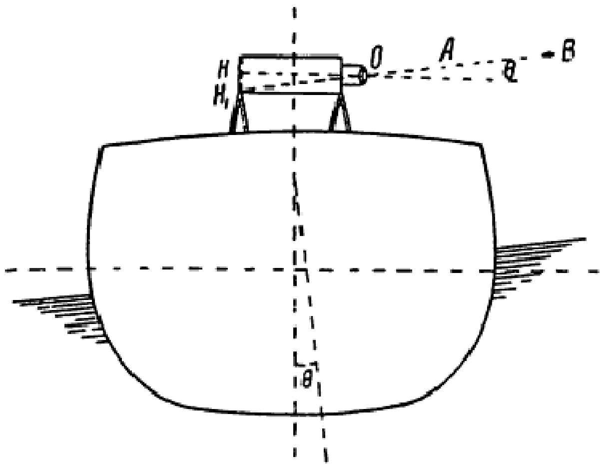

Figure 2. Installation of a camera

Resulting photograph registers the viewable (by brightness) boundary between sky and water. When pitch angle value is θ, then the boundaries on photograph become displaced by:

$$HH_1 = OH \cdot \tan(\theta) = f \cdot \tan(\theta) \qquad (1)$$

where OH is a distance from refraction point to focal plane; f — focal length of the lens. Timebase for recording is obtained using following decision. There is the slot diaphragm near focal plane.
The paper tape coated with photosensitive material is being driven by the slit with known speed using clockwork. Resulting oscillogram looks like it is shown on figure 3.
Measurement kit includes a gearing set for the clockwork for different tape drive speed setting. Constrained by camera stand toughness, the described installation provides excellent angular resolution and precision on level of lens aberration amount.

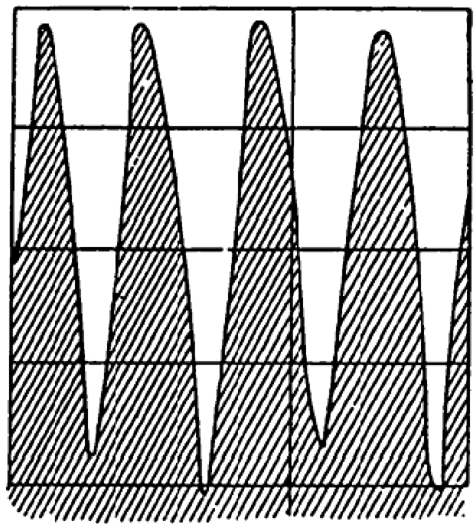

Figure 3. Oscillogram sample

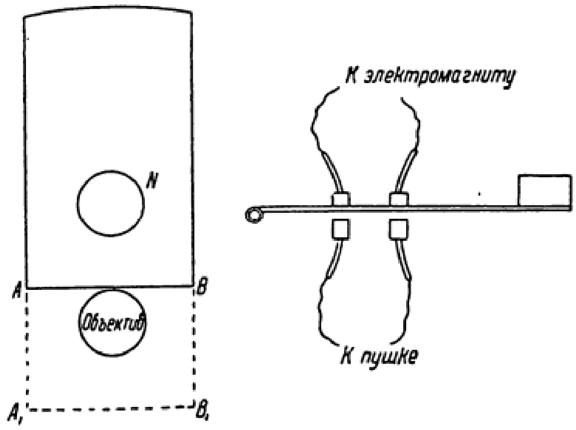

Figure 4. Shot marker (original facsimile)

Krylov developed the special camera for ship pitching recording. This camera, its drawings and full technical description aren’t preserved until present. It contained electromagnetic shot marker (figure 4), which connected to cannon shutter releasing button. Marker consists of shutter N, which is released when cannon fires by electric signal.

Shutter is driven by pre-pressurized spring and provide timings near 1/100 seconds. Releasing of the shutter was implemented by electromagnet which still working when cannon shutter releasing button is not pressed. The oscillogram with shot mark given on figure 5. The lens kit made it possible to vary the measurement scale within wide range. Parameters of the lenses were preserved until now [9] and they are presented in table 1.

The first proved document that contained a reference to practical application of the photographic ship pitching recording technique is ”Uraletz” gunboat workbook [5]. This document contains also the original oscillogram (145-mm negative photographic paper tape more than 5 meters length). Sample of an oscillogram is shown on figure 6.

Table I - Scaling parameters for different lenses.

Focal length, mm	***Ort length, mm***	***Pitching angle***	***Scale, mm/rad***
250 (Zeiss)	10	2°29’	230.72
350 (Zeiss)	10	1.63°	351.51
600 (DeRogée)	10	0.95°	603.11
900 (DeRogée)	10	0.64°	895.25

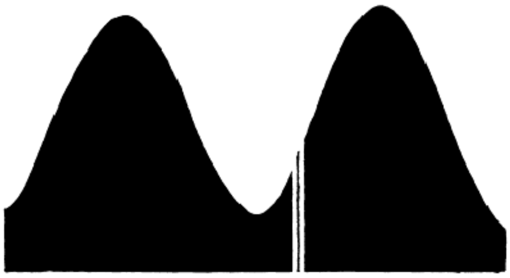

Figure 5. Oscillogram with shot mark

When scales were determined, the oscillogram was used to calculate deviations and influence of shots on pitching. There is unclassified document in Krylov’s personal archive, which contains table of deviations. The results obtained in 1907 were included into the scientific report [6] and unpublished work ”The Influence of Pitching to Shooting Accuracy”[7]. The experimental protocol contains impact points coordinates as it was marked on photograph, real coordinates of that points on field and standard deviations which are snapped to timings. Then using mathematical analysis [6] the pitching (rolling or pludging separately, if needed) component of ship motion could be extracted from protocol.

In described case of measurement Krylov was a pioneer in Russian Navy, and possibly, in Europe also. As a proof to this the Krylov’s memoir books [9, 11] could be used. At that level of the measurement devices development the photographic contactless technique of pitching recording was on the same level of precision with most progressive gyroscopic methods, as Krylov had written about later [10] and where he mentioned photographic technique as primary for calibration of equipment.

Figure 6. Pitching oscillogram

3 VERIFICATION

Main practical application of photographic ship pitching recording technique has been found in February, 1913 when carried out large research with Fram tanks. Tank system was being prepared to install on battle cruisers ”Izmail” and ”Kinburn” which are under construction that time, and it also being prepared to commit into project of ship family ”Gangut”. The test was performed [10] on steamship ”Meteor”. It was equipped with Fram tanks, and immediately before experiment it have been retrofitted with photogoniometers, gyroscopic pitching recorders designed by Fram and Petrovac, photographic oscilloscope designed by Krylov. Photographic chemicals and materials, laboratory equipment components for film treatment and fixation were also loaded aboard. In one of empty storerooms, the darkroom laboratory with semi-automatic film treatment was developed under guidance of professor N. A. Smirnov [11]. Photographic oscilloscopes and gyroscopic recorders were placed at point where pitching is most noticeable — on uppermost deck near wireless house. Krylov described the registration process [10]:

"A tank testing performs as following. The ship lay on course at odds wave. It was laying on that course for 10 minutes with dry tanks and then for 10 minutes with full tanks. Besides, the rolling pitch value was being recorded by all devices and moreover, pludging pitch was being recorded by Petrovac device and one of photographic devices.

After that the ship changed course by 45° e. a., to the right and again it was laying on that course for 10 minutes with dry tanks and then for 10 minutes with full tanks, and after change the course again on 45° to the right, and so on until the ship had laid on course at odds wave finally.

…

On evening of the same day all data was treated as follows:

1. *Records of roll pitching obtained with each device were copied*
2. *Records of pludge pitching obtained with Petrovac device and photographic device, also were copied*
3. *All roll pitching amplitudes obtained with gyroscopic devices were measured, and the most characteristic ones compared with photographic oscillograms to control precision of gyroscopic devices*
4. *Results of amplitude measurement for each course were collected into separate worksheet, and then average and maximal amplitudes* (figure 7) *are determined…"*

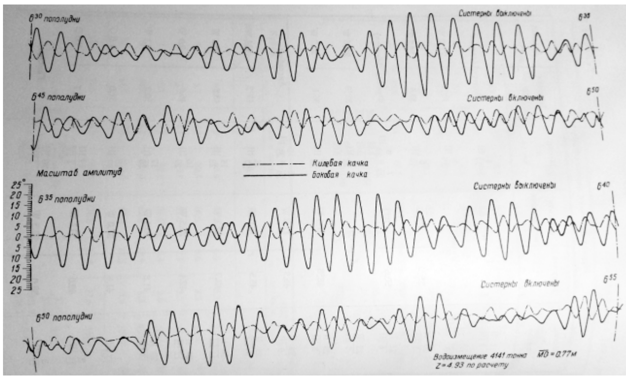

Figure 7. Oscillogram worksheet (original facsimile)

The resulting diagram (figure 8) contains polar distribution of pitching amplitudes with full and dry tanks. As it was shown that diagram was obtained and verified using photographic contactless pitching measurement. It could be used to calculate cycle of filling for Fram tanks.

Simplicity of photographic pitching recording technique in theory and realization brings it to leadership in terms of accuracy and reliability, further given that gyroscopic technology level was slightly low that time, in spite of highest standards of measurement devices design and production.

4 DEVELOPMENT OF CONTACTLESS METHODS

Other mentions of photographic non-invasive measurements in Krylov's memoirs located after 1917. As pointed in "Notes about Works of acad. A. N. Krylov" which are presented in USSR Academy of Science between 1918–1940, he returned in theme near 1920. It were mostly unfinished works dedicated to distant recording of artillery shell trajectory and explosion using photogoniometers. Subsequently before invention of digital photography the photographic contactless measurement techniques occupied in Russian science a narrow niche in sphere of sophisticated experiments on stationary equipment. From that times photographic equipment were integrated into measurement facility, e.a. bubble chamber or emulsion tracker. These applications are difficult to consider as contactless measurements.

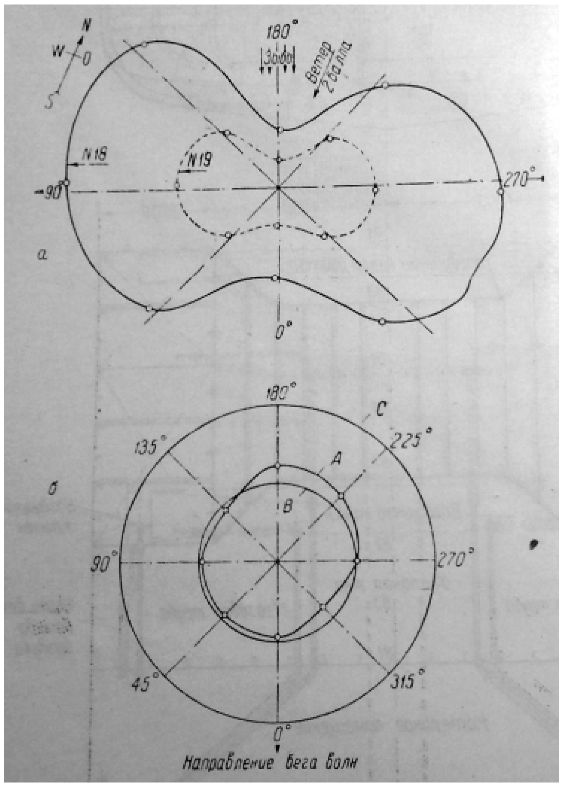

Figure 8. Angular pitching distribution diagram

Gambaryan, Sukhanov and Zacyorsky [15] used photographic measurement methods for animal motion registration. These experiments [24] were the extension of researches of Hildebrand [21, 22] about horse gaits. Just after 1970s perspectives of contactless measurements in Russia are obscured.

Development of digital photo equipment made it possible to use photogrammetry and direct measurements to determine geometry [16, 25]. These works explored error sources while usage of new cameras.

Very wide usage of contactless photographic measurements takes place in robotics [26]. Mathematical methods developed by Krylov built a basin for these researches, especially, in section of technical vision. Some new perspectives of photographic contactless measurements were discovered in accordance with development of digital

video sources [18]. Digital video allows recording of very large amount of data to recover errors. The similar process the strobelight photography also uses [17, 18].
In present, the photographic and photogrammetric contactless measurement methods are widely used in digital image processing and specific tasks, e.g. bullet-time application or 3D-photographic conversion [2].

CONCLUSIONS

New hardware systems and software products (figure 9) turn photographic equipment to universal optical measurement facility. This is correct through all process of contactless measurement evolution.

Krylov's works and early experiments built a basin for applicable techniques, which use a digital processing. From pioneers' works they returned as instruments of a high-tech data creation, art and computer science.
The methods that are based partially on Krylov's researches are widely used today in many areas: geophysics [27], robotics [26], geotechnic, large-area technical vision [28, 29], and biomedics [30].
According to development of new sophisticated methods of digital signal treatment, photographic contactless measurement methods have large perspectives of usage in wide range of areas such as robotics, architectural maintenance procedures, remote control of dangerous objects.

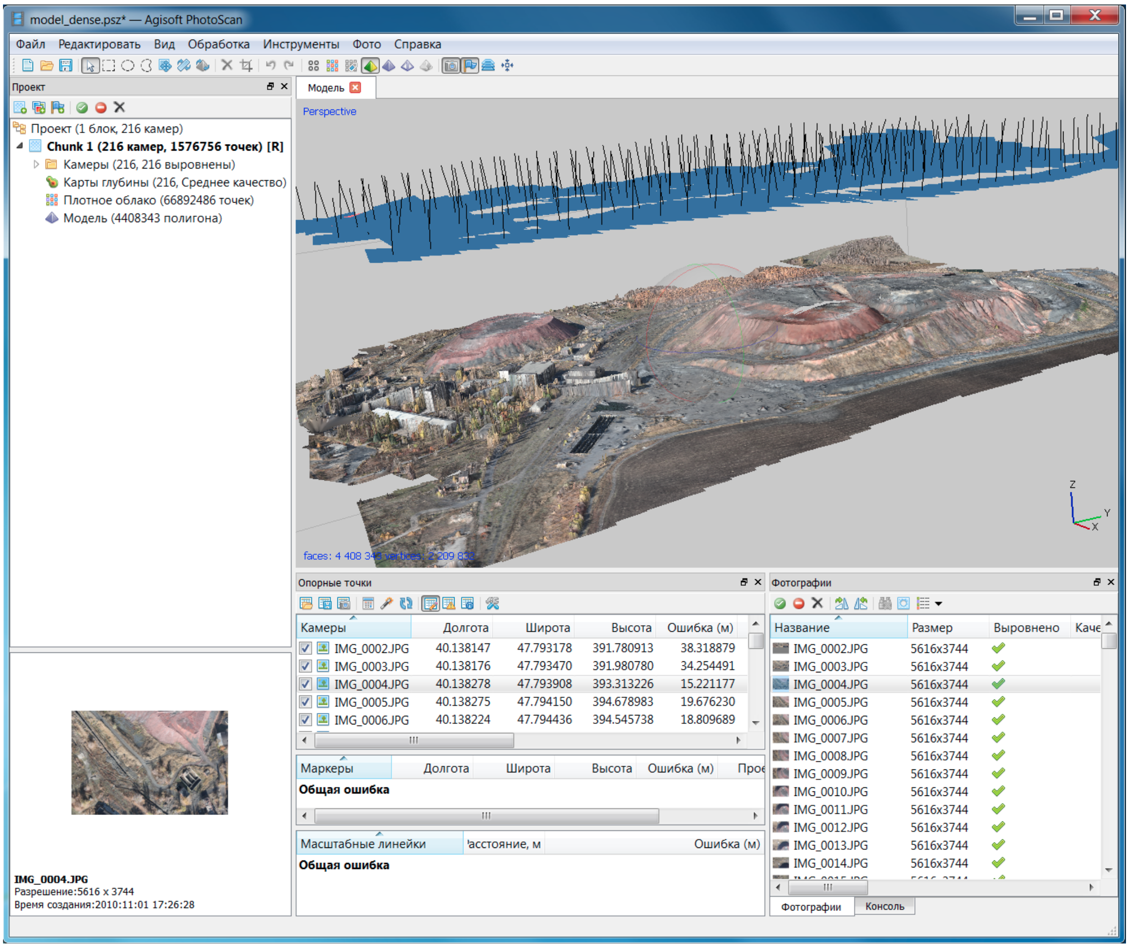

Figure 9. Software product, which uses photogrammetric contactless measurement method [2]

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