

DEVISING AND INTRODUCING A PROCEDURE FOR MEASURING A DYNAMIC STABILIZATION ERROR IN WEAPON STABILIZERS

O. Bezvesilna

Doctor of Technical Sciences, Professor, Honored Worker of Science and Technology of Ukraine
Department of Instrument-Making
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Peremohy blvd., 37, Kyiv, Ukraine, 03056
E-mail: o.bezvesilna@gmail.com

O. Petrenko

Head of Bureau*
E-mail: kvg_group@ukr.net

V. Halytskyi

Postgraduate Student
Department of Computerized Electrical Systems and Technologies
National Aviation University
Kosmonavta Komarova ave., 1, Kyiv, Ukraine, 03058
Head of Department**
E-mail: kza15@ukr.net

M. Ilchenko

Lead Design Engineer*
E-mail: inv125@ukr.net
*Special Design Bureau**

**Public Joint Stock Company «Research-and-Production association «Kyiv avtomatics plant»
Starokiyivska str., 10, Kyiv, Ukraine, 03116

У статті наведено варіанти перевірки середньої похибки стабілізатора озброєння 2Е36 в умовах типової траси методом кінофотографування за допомогою кінокамери з подальшою обробкою кіноплівки і виконання всіх операцій в ручному режимі. Наведено методику вимірювання середньої похибки цифрових стабілізаторів озброєння СВУ-500. Для забезпечення можливості визначення похибок стабілізації кожного з комплектів стабілізатора на підприємстві-виробнику і в умовах головного виробу замовника, без застосування типової траси, була розроблена і впроваджена у виробництво нова методика вимірювання динамічної похибки стабілізації. Дана розробка проводилася з застосуванням методів математичного моделювання, що дозволило визначити точку подачі синусоїдального сигналу в контур управління стабілізатора. Для експериментального підтвердження отриманих результатів моделювання були проведені випробування комплексу стабілізатора на технологічному стенді і на реальній навчальній башті, що додатково дозволило уточнити параметри синусоїдального сигналу. Для проведення таких випробувань була розроблена спеціальна програма алгоритмічного забезпечення, яка була встановлена в додаток до основної програми на час проведення випробувань у блок управління стабілізатора. Проведені подальші випробування підтвердили правильність результатів математичного моделювання, що дозволило ввести перевірки одного з основних параметрів стабілізації динамічної похибки стабілізації до складу прийнятно-здавальних випробувань кожного з комплектів стабілізатора

Ключові слова: стабілізатор, гіротахометр, вібраційний гіроскоп, серединна похибка стабілізації, динамічна похибка стабілізації

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1. Introduction

Underlying practical determining of stabilization error in the stabilizers of light armored vehicles is the procedure for determining the median error of the analog two-planar 2E36 stabilizers, which was developed in the 1980s for the BMP2 product. According to the inspection technique, a stabilization error of the stabilizer should not exceed ± 1 t. d. (one thousandth of a distance=3.6 angle. min.) [2] in each guiding plane: horizontal (HG) or vertical (VG). According to this procedure, the inspection was carried out for the customer's product on a standard path

[3] at periodic tests for 2 stabilizers of serial production once a year.

Following the development of analog SVU-500 and digital SVU-500-3C stabilizers the error of stabilization was checked in line with the procedure and in terms similar to the 2E36 stabilizers. No other tests of stabilization accuracy were carried out.

On the other hand, it is necessary to take into consideration that modern mobile objects move at significant speeds, they are exposed to serious overloads and uncontrolled mechanical disturbances. It is only natural that the requirements for measurement of accuracy, measuring instruments,

control over basic technical parameters of stabilizers are especially relevant to improve the state's defense capability.

2. Literature review and problem statement

Paper [1] reports the measurement of the median error of stabilization of the 2E36 analog stabilizers and those stabilizers that have similar circuitry and technical structure by using video recording. It is shown that the process of measuring the median error of stabilization using a video and photo recording technique implies the involvement of the entire product [2] under conditions of a standard route. This procedure of processing results is rather time-consuming, routine, and takes a lot of time to calculate error in a manual mode.

It is clear to us that the video and photo recording technique was, at the time of its development, specifically mid1980s, progressive and was enabled by a video camera, which was fixed on a weapon unit. A video camera recorded a movement of the sight mark along the horizontal and vertical guiding channels when the product moved along a standard track.

The disadvantage of this procedure was the fact that the tests involved only two sets of stabilizers once a year during regular tests. The reason for this may be the objective difficulties associated with the complexity of the test. To reduce the complexity, a variant of measuring the median error was to use a device for measuring the median stabilization error (Instrument PS) from a set of the 2E26M stabilizer [3]. The instrument PS is an electronic measuring device that is designed to determine the value of median error and the percentage of time of the non-stabilized state of the 2E26M stabilizer in planes VG and HG.

The use of this device greatly facilitated the measurement of median error.

The difficulties of measuring the error of stabilization were eliminated in the 2E52 stabilizer [4], which was designed with new technical characteristics. The specifications for the 2E52 stabilizer included the requirements for checking the median and dynamic error [5] (as part of the main product) of stabilization, which must not exceed 2 t. d. (as of 1988) when processing the sinusoidal signal $A=2,5^\circ \sin t$.

It should be noted that the 2E36 and 2E52 stabilizers have different circuit-technical principles of construction. The 2E36 stabilizer is built on the principle of "force" stabilization, which implies:

- first, optical sighting devices are "rigidly" [6] connected to a weapon unit;

- second, the aiming of the weapon unit and turret is performed directly by the operator or commander's stabilizer controls. Under such a design principle, the aiming of a turret or a weapon unit, with large masses and moments of inertia, from an operator's (or commander's) control unit results in significant errors.

In the 2E52 stabilizer [6], the weapon unit and a sighting device are executed on the principle of "independent" stabilization, namely, the weapon unit has no rigid connection with the device to sight a target.

The shortcomings of the procedure for checking the dynamic error in the 2E36 and 2E52 stabilizers are that the tests are carried out on technological turrets, which is very costly.

A review of technical literature [7] confirms the conclusions that the structure and necessary parameters of the

stabilizer are eventually determined by the predefined accuracy of operation. At the same time, the evaluation criteria may vary, but the accuracy requirements are focused on a maximum stabilization error [8]. In most cases, of importance is the stabilization angle value: maximum, medium, or mean square.

Thus, various generally available publications [1–10] provide only a superficial view of the facts related to the control of the dynamic error of stabilization only in the stabilizers that are built on the principle of an "independent" stabilization.

The unsolved issues include, first, the impossibility to check the dynamic error of stabilization on the stabilizers that are built on the principle of "rigid" stabilization, and, second, the lack of technical requirements and a procedure for measuring a dynamic error.

3. The aim and objectives of the study

The aim of this study is to devise and implement a procedure for measuring the dynamic stabilization error in stabilizers – one of the basic technical parameters. The measurement would be carried out at the stage of stabilizers fabrication at an enterprise that manufacture them and in the main product of the customer without application of tests under field conditions.

To accomplish the aim, the following tasks have been set:

- to determine the point of sending the sinusoidal signal to the stabilizer control circuits;

- to determine values of the basic parameters of the sinusoidal signal $A=2,5^\circ \sin \omega t$ as regards the mechanical characteristics of the CTM02 bench and the UK675 assembly (technological training turret of BMP2 on a rack);

- to define the procedure for sending the $A=2,5^\circ \sin \omega t$ signal in the technological bench CTM02 and the UK675 assembly;

- to determine the sufficiency of computing capabilities of the control unit and control panel without introducing a personal computer to the testing workplace.

4. The main part of the procedure for determining a dynamic stabilization error

To apply technical requirements for determining the dynamic error of stabilization in the digital stabilizers SVU-500, it was necessary to devise technical requirements and a procedure for estimating the specified stabilization error.

To accomplish this task, we conducted analytical and experimental research in order to determine the following:

- 1) location to send the sinusoidal signal $A=2,5^\circ \sin \omega t$ to the stabilizer;

- 2) parameters of the sinusoidal signal $A=2,5^\circ \sin \omega t$ concerning the mechanical characteristics of the CTM02 bench (Fig. 1, *a*) and the technological turret UK675 (Fig. 1, *b*);

- 3) procedures for sending the signal $A=2,5^\circ \sin \omega t$ in the technological bench CTM02 and the UK675 assembly;

- 4) procedures for calculating the dynamic error of stabilization;

- 5) sufficient computing capacities of the control unit or control panel without introducing a PC to the testing workplace.

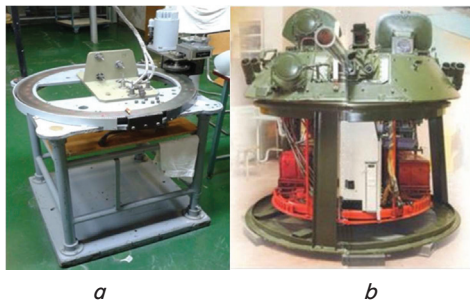


Fig. 1. Equipment for testing: *a* – bench CTM02; *b* – technological turret UK675

4. 1. Determining the point to send a sinusoidal signal to the stabilizer control circuits

The main task of this study was to meet the following requirements: first, the point to send a signal is chosen so that the action of the signal covers all the components from the stabilizer control circuit. Second, the signal at the control point, which contains information about the dynamic error of stabilization, should not affect the effect of the assigned sinusoidal signal $A=2,5^{\circ}\sin\omega t$. Third, the dynamic stabilization error should have a minimum value at the control point.

We have established three points for sending the sinusoidal signal $A=2,5^{\circ}\sin\omega t$ to the control circuits in the stabilizer and investigated, by using mathematical modelling [11, 12], the magnitude of the dynamic error of stabilization at each specified point:

Point 1: sending a sinusoidal signal to the control unit at the point of “beating” (after the integrator) and determining the sum of the current value of the integrator’s output amplitude, and the assigned sinusoidal signal, taking into consideration the phase lag.

Point 2: sending a sinusoidal signal to the control unit at the point of “beating” (after the integrator) and determining the difference between maximum values of the amplitude of the signal after the integrator and the assigned signal.

Point 3: sending a sinusoidal signal to the control unit at the point after digitization of the angular velocity sensor output with the subsequent integration of the total AVS output signal and the assigned signal to derive an error in the values of the weapon’s angle of deviation.

Mathematical modeling was carried out on the SVU-500 digital stabilizers with the use of electromechanical gyro tachometers (SVU-500-4C) and the modern Coriolis vibrating gyroscopes [13–16] SVU-500-7C. Based on the results, it was determined that the closest value of the dynamic error to that stated in the specifications for 2E52 (≤ 2 t. d.) would be derived in the case of its determining when sending a sinusoidal signal to the point after the sensor’s angular velocity output.

The following results were obtained in the study:

1) The values of a dynamic error at the point of “beating” taking into consideration the phase lag (point 1) always exceeded 2 t. d.;

2) The smallest value of a dynamic error (0.015 t. d.) was obtained when determining it based on the difference between the amplitudes of signals at the point of “beating” (point 2) at the frequency of calculating the control unit of 400 Hz for GT46 when a vibrational link of 20 Hz $\zeta=0.3$ was used as a model. This link introduces delay to control. In this case, the error accepted the minimum value and,

consequently, the mathematical model involving GT46 is a mechanically weakened link, which reduces existing mechanical disturbances, that is, it acts as a shock absorber.

For the mathematical model of KVG the value of a dynamic error (point 2) at the computational frequency of 1,000 Hz is equal to 1 t. d.;

3) The value of a dynamic error when sending a signal to the control unit at the point after digitization the output of the sensor angular velocity GT46 and computational frequency of 400 Hz in the control unit is equal to 1.15 t. d. (point 3).

For the mathematical model of KVG the value of the dynamic error of stabilization was 1.5 t. d. at the frequency of calculation of 1,000 Hz, and 1.15 t. d. at the frequency of calculation of 400 Hz.

Thus, based on the results, it was determined that the smallest value of the dynamic error (0.015 t. d.) to that stated in the specifications for 2E52 (≤ 2 t. d.) was achieved when sending a sinusoidal signal to the point after the output of the sensor of angular velocity (point 2).

4. 2. Determining the values of basic parameters for the sinusoidal signal $A=2,5^{\circ}\sin\omega t$ regarding the mechanical characteristics of the CTM02 bench and the UK675 assembly

Based on the results of modeling, we performed an experimental study to work out the determining of the dynamic error of the SVU500-4C stabilizers as part of the technological bench CTM02 and the technological turret UK675.

The dynamic error of weapon stabilizers φ_{\max} was determined as a maximum value of the function obtained by integrating the values of steady, under the action of disturbance, and total angular velocity (the error of working out the disturbing angular velocity) of the bench CTM02 platform motion or a weapons unit of the product UK675 (ω_{Σ}).

4. 3. Assigning the disturbing angular velocity ω_d

1. To assign the disturbing angular velocity ω_d , we investigated two variants of execution: a variant of the development of new algorithmic software (ASW) SVU-500-4C and a variant to refine the actual one (ASW). We have adopted a variant to refine current ASW by introducing an additional technological program to it.

In the course of our experiment, we developed and installed to the control unit BU1022-04 and the control panel PU03-05 the technological program of algorithmic software ASW51 in addition to the main program. This program made it possible to perform research in a manual mode at the time of determining the dynamic error of vertical DVN or horizontal DGN channels. At the same time, the function $U=U_{MVG(HD)}\cos\omega t$ was formed in the path of the passage of the GT signal “HG” at the output of the analog-to-digital converter. Under this function, the oscillations of UK675 or the CTM02 platform took place. Oscillation parameters: frequency 0.8 Hz, amplitude 2.5° over 3.75 s (3 periods).

The influence of separate components of function $U_{\omega d}=U_{MVG(HG)}\cos\omega t$ was investigated during tests.

To determine the parameters of angular velocity (ω), we considered three variants: $\omega = 5,02 \cdot \frac{1}{s}$; $\omega = 12,55 \cdot \frac{1}{s}$; $\omega = 25,1 \cdot \frac{1}{s}$, which were investigated for each velocity sep-

arately. Base on the results of our work, the value of the angular velocity $\omega = 5.02 \times \frac{1}{s}$ was chosen.

The time of action (t) of the angular velocity of disturbance was determined based on the oscillation frequency 0.8 Hz. In this case, the number of periods of fluctuations should be equal to three and, during their action, the self-withdrawal of the armament unit and turrets must be minimal, that is, such that does not affect the dynamic error of stabilization.

The value U_M was chosen experimentally based on the movement of the laser beam within the target and equaled: for UK 675 – $U_{MVG}=1.39$ V, $U_{MHG}=1.46$ V; for CTM 02 – $U_{MVG}=1.5$ V, $U_{MHG}=1.7$ V.

Fig. 2 shows the scheme of a workplace for checking the dynamic error of the stabilizer SVU-500-4C.

During tests, the fluctuations of the UK675 turret or the CTM02 platform were driven by the action of function $U_M \cos 5,02t$ with a frequency of 0.8 Hz, the amplitude 2.5° over 3.75 s (3 periods).

2. We experimentally studied two variants of the registration of signals of total velocity ω_Σ :

- a variant of accumulation of an array of values at the outputs of the demodulators of the corresponding channels after ADC (input to link 4) of the control unit with further transfer of information to a personal computer after stopping the rotation of the bench or turret;

- a second variant (defined as the most simplistic and rational) – the registration and transfer of the accumulated array of values at the outputs of the demodulators of the corresponding channels after ADC (input to link 4) to a personal computer connected to PU03-05, and building the charts of functions U_{ω_Σ} and $\int_{t=0}^{t=3,75s} U_{\omega_\Sigma} dt$ on a computer with out stopping the rotation of the bench or turret.

The links of signal passage from the sensors of angular velocity GT-VG and GT-HG, junction box PK18, control unit BU1022-04, control panel PU03-05 to a personal computer PC are shown in Fig. 2.

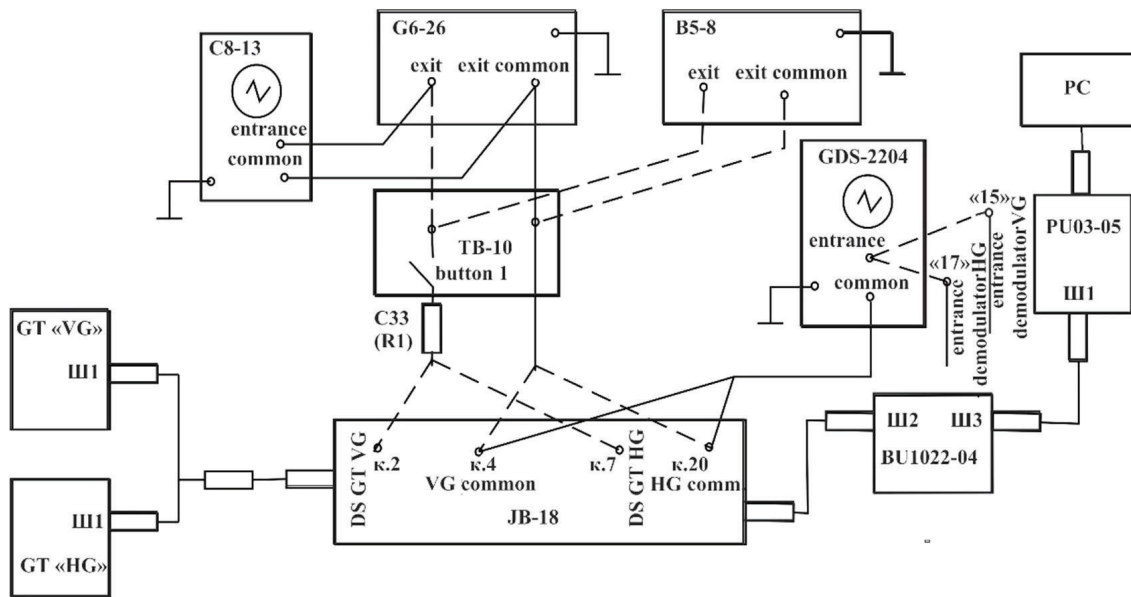


Fig. 2. Scheme of a workplace to check the dynamic error of the stabilizer SVU-500-4C: C8-13 – oscilloscope; G6-26 – generator of signals; B5-8 – power unit; TB-10 – technological box; GDS-2204 – oscilloscope; GT-VG, GT-HG – angular velocity sensors (AVS); JB-18 – junction box; BU1022-04 – stabilizer control unit; PU03-05 – stabilizer control panel; PC – personal computer

3. During the experiment, the calculation of dynamic errors φ_{\max} was performed according to the procedure in chapter 4.3

$$\int_{t=0}^{t=3,75s} U_{\omega \Sigma VG(HG)} dt = \int_{t=0}^{t=3,75s} K_{\omega} n \omega_{\Sigma VG(HG)} dt = K_{\omega} \varphi(t), \quad (1)$$

where φ is the angle of deviation of the investigated axis from the assigned direction; K_{ω} is the steepness of the characteristics of the AVS signal path.

The calculation of a dynamic error was performed taking into consideration the maximum value, which equals $K_{\omega VG(HG)} \cdot \varphi(t)_{\max VG(HG)}$, from the chart of function $\int_{t=0}^{t=3,75s} U_{\omega \Sigma VG(HG)} dt$ from formula:

$$\varphi_{\max VG(HG)} = \frac{\varphi(t)_{VG(HG)}}{K_{\omega VG(HG)}} \times \frac{60}{3.6} [\text{t.d.}] \quad (2)$$

The formula was also supplemented with a coefficient $\frac{60}{3,6}$ that made it possible to derive the value of a stabilization error in the t. d. dimensionality.

4. Our study has established that in order to determine the steepness of the gyro tachometer in the structure of the stabilizer (Fig. 1) it is necessary to generate a DC voltage surge of $U_{MVG(HG)}$. The voltage surge was applied to the JB-18 box: to pin 2 relative to pin 4 for the HG channel, and to pin 7 relative to pin 20 for the VG channel. The surge was supplied from the power unit B5-8 and we registered the turning time $t_{pVG(HG)}$ and the rotation angle $\alpha_{VG(HG)}$:

- α_{VG} (from the lower to the upper stops);
- α_{HG} (counting at the azimuthal device UC675).

During the experiment, we revised the software ASW 351 in terms of issuing a programmed voltage surge at the level of $U_{MVG(HG)}$ at time 3.75 s and registering the angle of rotation of the bench CTM02 platform or the UK675 turret. In this case, the ASW computed the steepness from formula (3).

$$K_{\omega BH(TH)} = \frac{U_{MVG(HG)}}{\omega_{VG(HG)}}, \tag{3}$$

where

$$\omega_{VG(HG)} = \frac{\alpha_{VG(HG)}}{t_{pVG(HG)}}.$$

The results of experimental testing of the dynamic error of a stabilizer are given in Table 1.

Our study established that determining the steepness of the initial characteristic of the angular velocity sensors

is necessary for a more accurate calculation of the dynamic stabilization error and should be carried out at each stabilizer kit because the steepness of each specific angular velocity sensor may vary within the assigned limits.

The results of research into a dynamic stabilization error are given in Table 1 and shown in Fig. 3–6.

Thus, the results of our study given by charts in Fig. 3–6 clearly demonstrate a time-dependent change of the basic signals of the stabilizer $U_{link.3}$, U_{cos} , $\text{sum}(U_{link.3}+U_{cos})$, $\int \text{sum}$, based on calculating which we computed the dynamic error of stabilization. For greater visibility, the chart $\int \text{sum}$ is enlarged.

Table 1

Summary table of results from experimental tests of stabilization dynamic error

Article	Surge level U_M , V	Test time t_p , s	Rotation angle α , degree	$\Omega = \frac{\alpha}{t_p}$, °/s	$K_{\omega} = \frac{U_M}{\omega}$, V·s/degree	Integral maximum value ϕ_{max} , V·s	Dynamic error $\frac{\phi_{max} \cdot 60}{K_{\omega} \cdot 3.6}$, t. d.	Fig. No.
VG Channel								
SVU-500-4C on CTM02	1.5	3.75	41.6	11.09	0.134	0.0157	1.95	4, a 4, b
SVU-500-4C (UK675)	1.39	8.06	80	9.92	0.14	0.0076	0.93	6, a 6, b
HG Channel								
SVU-500-4C on CTM 02	1.7	3.75	43.9	11.7	0.145	0.021	2.4	3, a 3, b
SVU-500-4C on UK675	1.46	6.59	60	9.1	0.160	0.0185	1.93	5, a 5, b

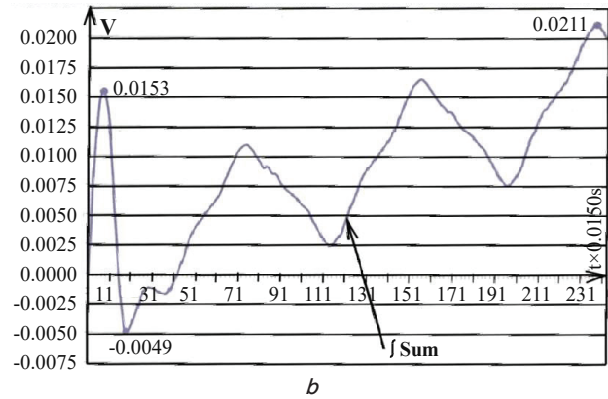
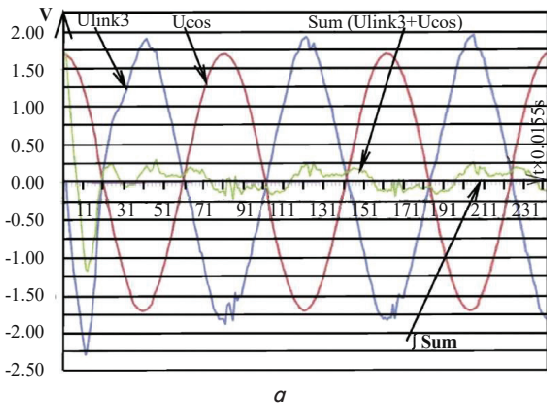


Fig. 3. SVU-500-4C on the CTM02 HG channel: a – charts of processing the main components to determine a dynamic error; b – enlarged chart of $\int \text{sum}$ curve

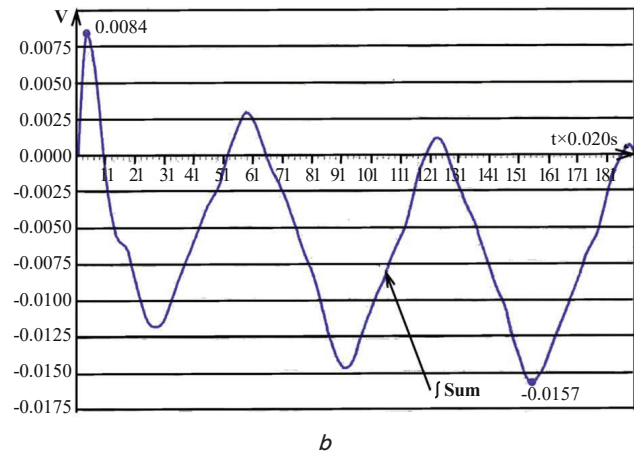
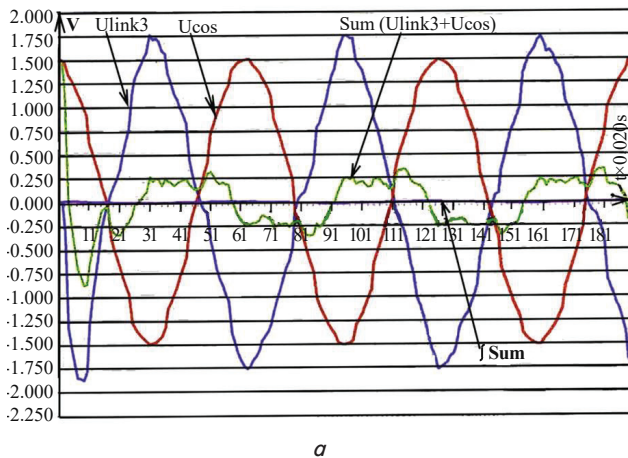


Fig. 4. SVU-500-4C on the CTM02 VG channel: a – charts of processing the main components to determine a dynamic error; b – enlarged chart of signal $\int \text{sum}$

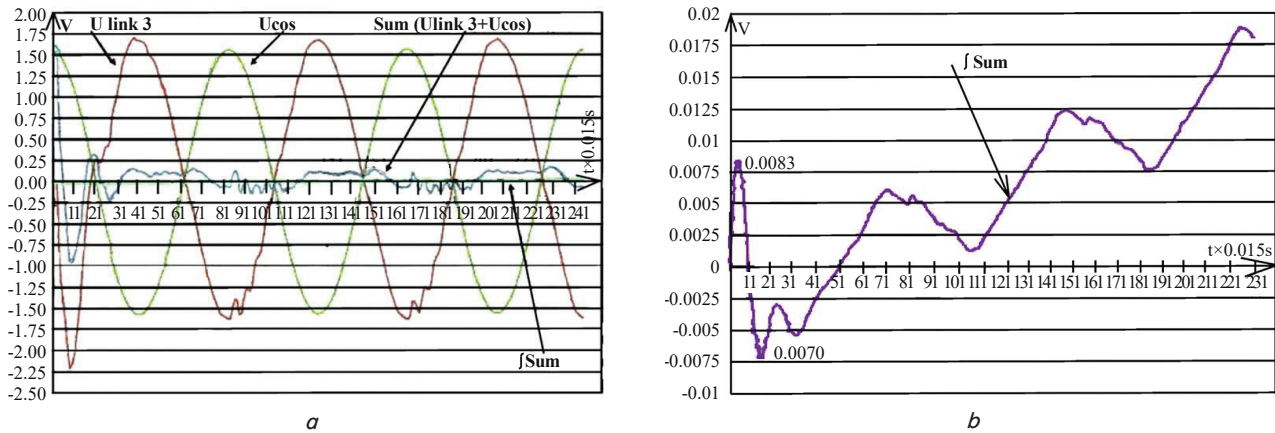


Fig. 5. SVU-500-4C on the UK675 HG channel: *a* – charts of processing the main components to determine a dynamic error; *b* – enlarged chart of signal *jSum*

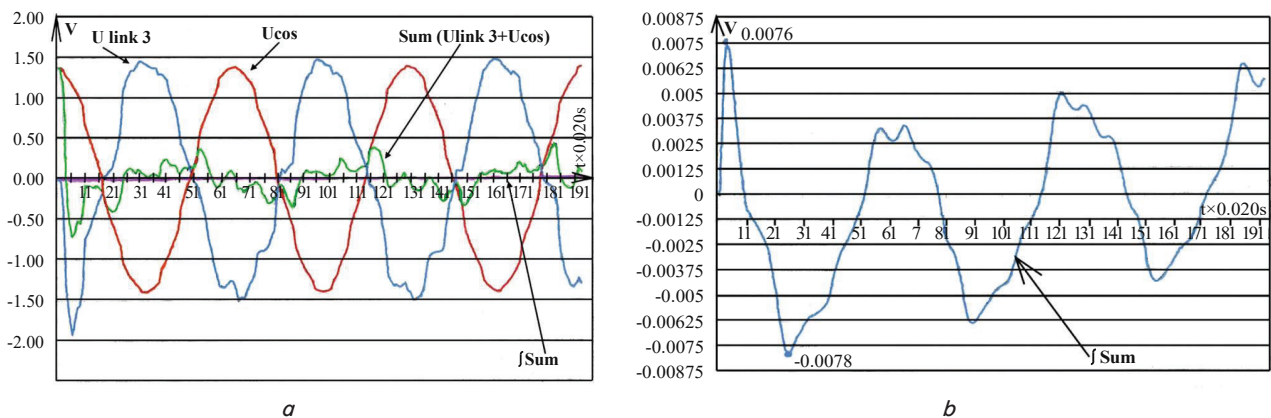


Fig. 6. SVU-500-4C on the UK675 VG channel: *a* – charts of processing the main components to determine a dynamic error; *b* – enlarged chart of signal *jSum*

5. Discussion of research findings on defining a procedure for measuring a dynamic stabilization error

We have devised a procedure for measuring a dynamic error of stabilization for the SVU-500 weapon stabilizers, built on the principle of “rigid” stabilization in contrast to the 2E52 stabilizers with “independent” stabilization. To solve this task, the chosen basis for our study was the requirements for the 2E52 stabilizer in terms of the type of the sinusoidal signal $A=2,5\sin\omega t$ and technical requirements for determining the value of a dynamic error of stabilization (≤ 2 t. d.).

To devise the procedure, we conducted analytical, research, and experimental studies, involving mathematical modeling and the development of additional software.

When devising a procedure for determining the dynamic error of stabilization, the following tasks were solved:

- determining a point to send a sinusoidal signal to the stabilizer control circuits;
- determining the values of basic parameters for a sinusoidal signal as regards the mechanical characteristics of the CTM02 bench and the UK675 assembly;
- assigning the disturbing angular velocity ω_d and registration of signals of total velocity ω_Σ ;
- determining the steepness K_ω of angular velocity sensors on the equipment for testing;
- defining a dynamic error calculation.

Our results of the development and implementation of the procedure for measuring the dynamic error of the SVU-500 weapon stabilizers testify (Table 1, Fig. 3–6) to that the ex-

amined and proposed procedure makes it possible to measure the dynamic error of stabilizers within the limits of (≤ 2 t. d.).

According to the positive results of our study obtained in the development and measurement of the dynamic error of stabilizers, the procedure was introduced to the technological process of manufacturing stabilizers. In turn, this allows us to argue that the purpose of the work has been achieved.

Thus, in the course of our study it was found that in determining the point to send a sinusoidal signal to the circuit of the stabilizer control, the use of mathematical modeling was effective. The point to send a signal was chosen according to the minimum value of the dynamic error (0.015, t. d.) (point 2).

A distinctive feature was the development of the sub-program ASW51 in addition to the main software for mathematical support. A given program was operated at the time of research in the manual mode, which greatly simplified the experimental study and made it possible to determine and correct the separate coefficients of function $U_M \cos 5,02t$.

The proposed procedure for measuring the dynamic error of stabilization in stabilizers is distinguished by that it can be used for other armament stabilizers with different mechanical parameters of combat modules. At the same time, its adaptation would involve the adjustment of individual coefficients, given in function $U_M \cos 5,02t$ and formulae (1) to (3).

Given this, our procedure should be considered promising.

Note that this procedure was tested at the technological bench CTM02 and at the UK675 assembly, which, in terms of its mechanical characteristics, has small differences from other combat modules.

A limitation of the devised procedure of dynamic error measurement is the fact that this procedure was devised for the variant of a “rigid” principle of stabilization and there is no margin to reduce the error to value $\varphi_{\max} \leq (0.5) \text{ t. d.}$ To improve the accuracy of stabilization and reduce the values of the dynamic error of stabilization to values $\varphi_{\max} \leq (0.5) \text{ t. d.}$, it is necessary to use, in the circuits of the stabilizer control, a variant of the “independent” stabilization. There are no other restrictions for the implementation of a given procedure.

This study could be further advanced by applying it in the customer’s hardware exposed to actual mechanical loads.

6. Conclusions

1. The suggested method for locating the point to send a sinusoidal signal to the stabilizer control circuits with the help of mathematical modeling has made it possible to solve the set task. The results obtained fully agree with the requirements for the measurement of a dynamic error ($\leq 2 \text{ t. d.}$) in the 2E52 stabilizer. It has been shown that we identified, among three examined points to send a sinusoidal signal to the stabilizer circuits of control, a point with the lowest value of the stabilization error (0.015 t. d.). This is the point where a dynamic error was determined based in the difference between the amplitudes of signals after the integrator and the signal, which is assigned at the point of “beating” (point 2).

2. Application of the experimental testing technique is effective for determining values of the basic parameters for a sinusoidal signal as regards the mechanical characteristics of the CTM02 bench and the training assembly UK675. A distinctive

feature of this procedure is that the testing is carried out on the equipment, which, in terms of its mechanical characteristics, imitates mechanical loads on the actual turret. At the same time, the frequency of sending a signal remained unchanged and was adopted to equal 0.8 Hz , which meets the requirements for the 2E52 stabilizer. Characteristically, the values of other coefficients of function $U_M \cos 5.02t$ were determined based on the mechanical parameters of the turret (U_M), while others – based on the lack of influence of the turret self-withdrawal (t, ω).

3. We have proposed a procedure to send signals to the stabilizer control circuits and the sequence of its execution: assigning the disturbing angular velocity ω_d , registration of signals of total velocity ω_Σ , determining the value of steepness K_ω , calculation of the dynamic errors; it was developed and programmed into the control unit and the stabilizer control panel.

A distinctive feature of a given procedure to send a signal within the technological bench CTM02 and the assembly UK675 is that it was programmed in the form of ASW51 application to the main program of the stabilizer mathematical support. The ASW51 software included all the planned stages of operation. It is characteristic that the program worked, at the time of research, under a manual mode, which greatly simplified the experimental study and made it possible to adjust individual coefficients.

4. Applying in our study the additional algorithmic software ASW51 required 0.2 KB of the amount of memory of the control unit calculator. Note that the main software requires 4 KB of memory out of the total calculator volume of 8 KB.

It is especially important to note that there is no need to use an additional personal computer in the workplace that tests the stabilizer operation.

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