APPRECIATE INDUSTRIAL MODEL TWO-POWER GYRO OF THE DUSU CLASS IN FIELD SUPERSOUND RAY

Serhii Fesenko[1]

DOI: https://doi.org/10.30525/978-9934-26-602-7-11

Abstract. The study is devoted to an in-depth investigation of the nature of caustic zone formation in the polyaggregate suspension of a float gyroscope, the underlying causes of such zones within the suspension, their temporal and spatial evolution, and their impact on the emergence of additional errors in the float gyroscope at the resonance level of wave coincidence. *The purpose* of the paper is to analyze the nature of the influence of acoustic radiation on the polyaggregate suspension of the gyroscope and the emergence of additional measurement errors at the resonance level of wave coincidence. *Methodology* of the study is based on the method of ray acoustics for the analysis of approximate computational models of the investigated phenomenon under the condition of a large wavelength-to-body-size ratio of the device, and on the shell theory method for the construction of precise computational models. *Results* of the study demonstrates the principles of constructing computational models of the phenomenon and outlines the specific features of developing both approximate and precise computational schemes. The mechanism of natural formation of the caustic zone at the resonance level of wave coincidence is revealed. The content and dynamic evolution of the identified planar caustic models in the gyroscope body's frame plane has been experimentally established. *Practical implications.* The principles for constructing computational models of the elastic interaction between penetrating acoustic radiation and the polyaggregate suspension of a float gyroscope have been formulated. The conditions for the occurrence of four types of resonance are outlined, and the parameter values of the float suspension that lead to a resonant state have been numerically predicted. An analytical justification is provided for a method of reducing technological risks by artificially forming caustic zones as buffer regions to

[1] PhD, Senior Lecturer at the Faculty of Biotechnology and Biotechnics,
National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute", Ukraine

address the problem of minimizing float gyroscope errors under operational conditions. *Value/originality.* The values of the suspension parameters and the direction of ultrasonic irradiation that give rise to the third resonance – manifested as the equality between the trace of the frame ring and the circular wave in the device body at subcritical frequencies – have been calculated. The numerical boundaries of the strong influence of suspension parameters at the resonance level – referred to as combined resonance – have been defined. A software tool has been developed for calculating the acoustic transmissibility of the device housing.

1. Introduction

In control systems of hypersound aircraft which are controlled by launch vehicles (LV), cruise rockets, are widely used the so-called "float gyroscopes" [1, pp. 4-6]. These float gyros are structurally released from the main disadvantages of "*dry*" devices – significant (and, more importantly, variable) moments of the dry friction force on the outgoing axis and unacceptably high sensitivity to shocks and vibration, especially undesirable for integrating gyroscopes [2, pp. 19-20]. The main difference of the float modifications is a movable part of the device immersed in heavy organofluoric (specific gravity $1,9 \bullet 10^3\ Nm^{-3}$) or organochlorine (specific gravity $2,7 \cdot 10^3\ Nm^{-3}$) fluid [3, pp. 113, 116]. The gyromotor was located in a sealed cylindrical float, filled with helium or hydrogen. By means of longitudinal pins the cylindrical float is installed in the outer, also sealed, coaxial circular cylinder, which serves as the body of the device [3, p. 115]. The supports of moving parts in some cases are carried out on the rocks.

Such technical solutions are typical of a number of designs. *Floating* devices, unlike *float,* have no excess weight [4, pp. 1-2].

The clearance between the lateral surface of the float and its body is too small and is about *0,2 mm* in the radial direction. High viscosity of the fluid and a small size of the working clearance allow providing a required damping factor in the integrating gyroscope.

All following conclusions will be made focusing on specific technical realization of commercial manufacture by the aviation industry this float device. For example, we will take into consideration the gyro angle rate sensor DUSU2-30B, standartized, which is designed for use in aircraft of a long-lasted operation [3, pp. 117-120].

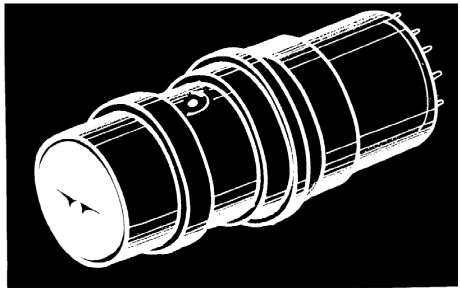


Figure 1. Appearance industrial model gyroscopic sensor angular speed class *DUSU2-30B*

Source: developed by author

As to the principle of operation the device is inertial, that it does not require a contact with the environment. Dynamic properties of the sensor are described by a oscillatory link. Technical performance of the DUSU device is a poly-unit structure. The DUSU purpose is to measure the angle rate of supersonic aircraft. The configuration of the device is shown in Figure 1. The measuring range of angle rate is of ± 30 $deg\ s^{-1}$. The sensor threshold of DUSU2-30B is about $0{,}45\ deg\ s^{-1}$.

2. Brief technical characteristics of standardized gyroscopic sensor for angle rate

a) The sensor normally works fine from power sources: *3-phase AC* voltage of *36 V* frequency of *400 Hz* (for the gyromotor) and direct current voltage $5 \div 30\ V$ (for potentiometer).

It is possible to supply the potentiometer with AC voltage $5 \div 30\ V$ (rms value) at up to *2000 Hz*.

b) The sensor's readiness to work is no more than *50 seconds*. At the *10-second* forced supply *54±3 B* (for the sensors with supply of gyromotors *36 B 1000 Hz*) time of readiness does not exceed *20 seconds*.

c) Alternating current consumption per phase is less than *0,3 A*.

d) The sensor threshold is no more than $0{,}45\ deg\ s^{-1}$.

e) The angle rate range is ± $30\ deg\ s^{-1}$.

e) The dependence of the output signal on the angle rate at the potentiometer supply with voltage *27 V* is in the product certificate.

When the potentiometer is supplied with other, not *27 V*, voltage within *5 ÷ 30 V* the output signal is recalculated by the formula –

$$U_{out1} = \frac{U_{liq1}}{U_{liq}} U_{out} ,$$

where U_{liq} – potentiometer with voltage *27 V;* U_{liq1} – voltage, not *27 V* within *5 ÷ 30 V*; U_{out} – the output signal when the supply of the potentiometer is of voltage *27 V*.

i) The sensor operates in the temperature range from + -*60ºC* to *60ºC*.

c) The sensor vibrationproof in the frequency range from *5 Hz* to *2000 Hz* with overload up to *30 g*.

i) The sensor is resistant to overloads up to *35 g*.

k) Frequency of own undamped oscillation is within *14 - 21 Hz*.

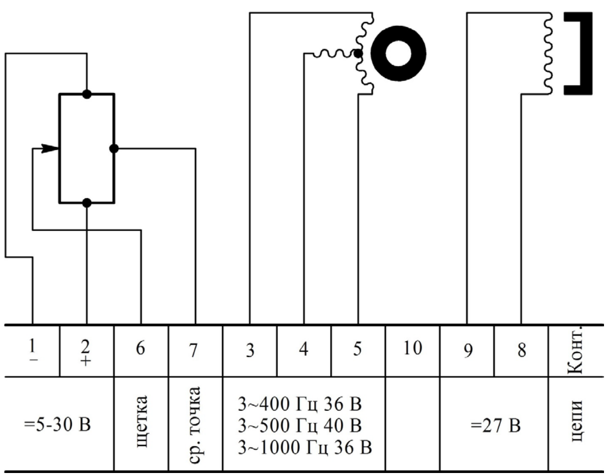
l) The resistance of the potentiometer is *800 ohms ± 20%.*

m) The ratio of amplitudes in half of the period in the temperature range is up to + -*60ºC 60ºC* equal *to 0,05 ÷ 0,5*.

n) The permissible current in a circle of loads of the potentiometer does not exceed *0,03 A*.

o) The weight of the sensor is not more than *4,2 N*.

The electrical circuit of the sensor of the DUSU class



Source: developed by author

When connected to the torque sensor (contacts 9 and 8) DC = *27 V*, polarity "-" on contact 9 and "+" on contact 8 is equivalent to the effect of the sensor in the direction "*clockwise*" on the angle rate.

Output signal of the potentiometer sensor at the supply of direct current is= 27 V (technical conditions data)

Table 1

degree s^{-1}	**0**	**5**	**10**	**15**	**20**	**30**	**90**
Output signal at manufacturing and reception at normal t	$0 \pm 0,2$ only at the range of measurement $\pm 6\ degree\, s^{-1}$ $0 \pm 0,15$ other ranges	$2,25 \pm 0,25$	$4,5 \pm 0,3$	$6,75 \pm 0,4$	$9 \pm 0,4$	$13,5 - 0,7$	$13,5 - 0,7$

Source: developed by author

Table 2

degree s^{-1}	**0**	**5**	**10**	**15**	**20**	**30**	**90**
Output signal at temperature -60^0 and $+60^0$ at the whole period of operation	$0 \pm 0,3$	$2,25 \pm 0,4$	$4,5 \pm 0,6$	$6,75 \pm 0,65$	$9 \pm 0,8$	$13,5 \pm 1,0$	$13,5 \pm 1,0$

Source: developed by author

The manufacturer's warranty.

The manufacturer warrants no-failure operation of the sensor for a period of 150 hours over *12 years*, including:

The term of storage as part of the object for *11 years*, including *6 years* of storage and operation as part of the object in open starting positions in natural conditions.

The term of storage in warehouse including its transportation is 1 year.

The design of the sensor warrants:

a) the instrument no-failure operation at pressure changes of the environment from *900 mm m p* to 10^{-6} *mm m p*;

b) no-failure operation at the environmental temperature linearly variable from +70 to *+200 °C* per *7 min* (only for the sensors with the gyromotor power *36 ~ 400 Hz*). At the same time, continuous operation of the sensor at temperature *+70 ^0C* – less than *15 min*;

c) no-failure operation of the angle rate sensor in reverberation space of acoustic noise with frequency from *100 Hz* to *10000 Hz*;

d) the value of the maximum error is less than *2%* of the voltage supply of the potentiometer.

Table 3

Technical characteristics of DUSU at normal temperature

Date of check	Cause of check	Number of worked hours	Time of readiness	Sensitive threshold	Current, which is consumed by a gyromotor	Dependence of the output signal (in Volts) at supplying the potentiometer with voltage *27 V* on the angle rate, angle rate *degree s^{-1}*												
						Clockwise						0	Anti-clockwise					
						90	30	20	15	10	5		5	10	15	20	30	90
		--	*24 s*	*0,45 degree s^{-1}*	*0, 5 A*	13,49	13,45	9,09	6,84	4,61	2,30	0,10	2,24	4,55	6,91	9,14	13,41	13,45

Source: developed by author

Testing of the angle rate sensor on the functional capacity was conducted on the ultrasonic device **MINI ULTRASONIC CLEANER MODEL** 3560 (Figure 2). The ultrasonic beam is generated by a piezoceramic plate that allows creating radiation, which is not gradient along the front.

Brief technical characteristics of the ultrasonic device "Model 3560"

- Power supply source of *220 V (110 V*) and *50 Hz (60 Hz)* voltage;
- Dual selection of vibration mode of power *30 W (50 W)*;
- Operating frequency of *42 kHz*;
- Operation duration *1 - 30 minutes* (possible regulation);
- Adjustment of operating modes – button-operated;
- Information is demonstrated on the crystal-free display;

- Radiator is flat and piezoceramic;
- Smart drive MCU;
- Device is used only if the bath is full of water.

Figure 2. Ultrasonic device, Model 3560

Source: developed by author

3.1. Defining the conformance to the requirements of the product certificate

Conformance of the angle rate sensor DUSU2-30B for its functional ability was carried out by radiation of the shell of the device's body. It was conducted by means of a sufficiently wide sound beam (Figure 3). The sensor was sunk, according to the requirements for operating the ultrasonic device **MINI ULTRASONIC CLEANER MODEL 3560** in the bath filled with water and it was rigidly fixed to the rake using bindings. The output device was fixed by measuring instrumentation in two modes – at the absence of power on the gyromotor and at its working condition.

On the one hand, comparative analysis of the output signal will allow determining the degree of influence of the ultrasound beam to the poly-unit gyroscope gimbal, and on the other hand, it allows determining the degree of impact and dynamics of the time of the additional error $\Delta\omega$ of measurement of the angle rate of the aircraft during a hypersonic flight [5, pp. 85-86]. The DUSU sensor is mounted on the rack so that at turning the the device body about its longitudinal axis at a fixed angle φ it could be determined the most dangerous direction of the passing ultrasound beam in flight.

Figure 3. The exterior of the test stand

Source: developed by author

After the gyrodevice is put on at the thermal mode the "*zero*" output signal of the potentiometer was recorded in the analog form (Figure 4) and in the quantitative terms (Table 4). For convenience, the "*zero*" angle sensor is recorded in the degree of error $\Delta\omega$ of the device.

Table 4

Orientation of the device body		**$\varphi=0^0$**			**Gyroscope *“OFF”***		
t, *s*	**Potentio-meter signal,** ***degree s^{-1}***	**t,** *s*	**Potentio-meter signal,** ***degree s^{-1}***	**t,** *s*	**Potentio-meter signal,** ***degree s^{-1}***	**t,** *s*	**Potentio-meter signal,** ***degree s^{-1}***
0,5	-0,0069	15,5	-0,0069	30,5	-0,0069	45,5	-0,0069
1	-0,0069	16	-0,0069	31	-0,0069	46	-0,0069

1,5	-0,0069	16,5	-0,0069	31,5	-0,0069	46,5	-0,0069
2	-0,0069	17	-0,0069	32	-0,0069	47	-0,0069
2,5	-0,0069	17,5	-0,0069	32,5	-0,0069	47,5	-0,0069
3	-0,0069	18	-0,0069	33	-0,0069	48	-0,0069
3,5	-0,0069	18,5	-0,0069	33,5	-0,0069	48,5	-0,0069
4	-0,0069	19	-0,0069	34	-0,0069	49	-0,0069
4,5	-0,0069	19,5	-0,0069	34,5	-0,0069	49,5	-0,0069
5	-0,0069	20	-0,0069	35	-0,0069	50	-0,0069
5,5	-0,0069	20,5	-0,0069	35,5	-0,0069	50,5	-0,0069
6	-0,0069	21	-0,0069	36	-0,0069	51	-0,0069
6,5	-0,0069	21,5	-0,0069	36,5	-0,0069	51,5	-0,0069
7	-0,0069	22	-0,0069	37	-0,0069	52	-0,0069
7,5	-0,0069	22,5	-0,0069	37,5	-0,0069	52,5	-0,0069
8	-0,0069	23	-0,0069	38	-0,0069	53	-0,0069
8,5	-0,0069	23,5	-0,0069	38,5	-0,0069	53,5	-0,0069
9	-0,0069	24	-0,0069	39	-0,0069	54	-0,0069
9,5	-0,0069	24,5	-0,0069	39,5	-0,0069	54,5	-0,0069
10	-0,0069	25	-0,0069	40	-0,0069	55	-0,0069
10,5	-0,0069	25,5	-0,0069	40,5	-0,0069	55,5	-0,0069
11	-0,0069	26	-0,0069	41	-0,0069	56	-0,0069
11,5	-0,0069	26,5	-0,0069	41,5	-0,0069	56,5	-0,0069
12	-0,0069	27	-0,0069	42	-0,0069	57	-0,0069
12,5	-0,0069	27,5	-0,0069	42,5	-0,0069	57,5	-0,0069
13	-0,0069	28	-0,0069	43	-0,0069	58	-0,0069
13,5	-0,0069	28,5	-0,0069	43,5	-0,0069	58,5	-0,0069
14	-0,0069	29	-0,0069	44	-0,0069	59	-0,0069
14,5	-0,0069	29,5	-0,0069	44,5	-0,0069	59,5	-0,0069
15	-0,0069	30	-0,0069	45	-0,0069	60	-0,0069

Source: developed by author

3.2. Effect of ultrasonic waves on the gyroscope gimbal

We will take into consideration eight values of the turning angle of the DUSU body relative about its longitudinal axis, i.e. every $\frac{\neq}{4}$ starting with conditional zero (denoted by $\varphi = 0^0$). When the gyromotor power is off we mark" *shift of zero*" on the diagrams of the output signal of the angle rate sensor by a thin line. A thick line marks the output signal when the gyromotor power is on (Figure 5 – Figure 12). The first five – seven seconds and last five- seven seconds of implementations can be excluded because it is time for a nominal mode of the gyro radiator and a stoptime, respectively [6, p. 61]. The device and the and the radiator operate in a non-stationary mode.

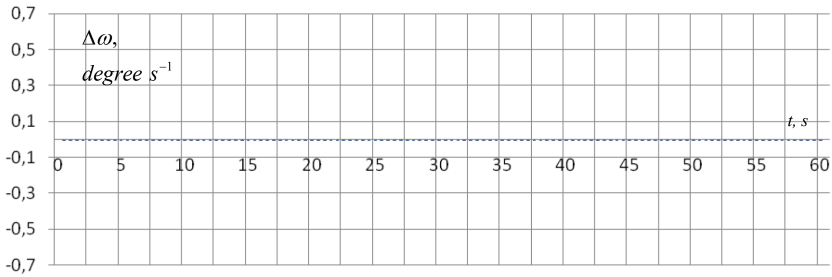


Figure 4. "*Zero*" implementation of the output signal

Source: developed by author

The gyrodevice is "OFF". As it can be seen, the output signal of the angle rate sensor in the ultrasound beam undergoes stochastic changes at the value (Figure 6, Figure 8, Figure 9, Figure 10, Figure 12) and the sign (Figure 5, Figure 6, Figure 9, Figure 12). The value of "*zero shift*" can grow to $0,5\ \deg ree\ s^{-1}$ (in terms of angle rate). At the $\varphi = 0^0$ "*zero shift*" is practically missed, more exactly, it is below the sensitive threshold of the sensor.

Minor changes in sign in the output signal occur in $\varphi = 0^0$ (Figure 5). Instead, when $\varphi = 270^0$, they do not only range in sign, but have a substantial range in the amplitude (Figure 11). If the angle $\varphi = 225^0$, the range of values is greater than $0{,}1\ \deg ree\ s^{-1}$, but always an unchanged sign (Figure 10).

Obviously, the existing "*zero shift*" in the ultrasonic DUSU sensor rays when the gyromotor is off is determined the integral reaction of the gyroscope gimbal components. First of all, it concerns the current-collectors of the potentiometer, which look like a console.

Not the least part play the nonlinear oscillations of the "*float*" surface as well as emerging caustic areas which are results of resonance phenomena of wave coincidence [7, pp. 37-41].

The tables of numerical values of the DUSU output signal for different angular positions of the device allow (for example, the duration of the ultrasound beam in 60 seconds) evaluating its development in time and the value of "*zero shift*" of the device in the field of ultrasonic radiation (Table 5 – Table 12).

The gyrodevice is "ON". Of course, under these conditions serious changes of the output signal of the device will take place due to a gyroscopic reaction. If $\varphi = 0^0$, the device error $\Delta\omega$ is being increased almost in ten times and changes its sign (Figure 5). The maximum value of it reaches $\Delta\omega_{\max} = 1 \deg ree\ s^{-1}$. The average value equals $\Delta\omega_{mid} = 0,7 \deg ree\ s^{-1}$ (Figure 13).

If $\varphi = 45^0$, the average error $\Delta\omega_{mid}$ and its maximum value $\Delta\omega_{\max}$ is slightly decreased in magnitude, but changes its sign for the opposite (Figure 6):

$\Delta\omega_{mid} \approx +0,55 \deg ree\ s^{-1}$, $\Delta\omega_{\max} \approx +0,72 \deg ree\ s^{-1}$ (Figure 14).

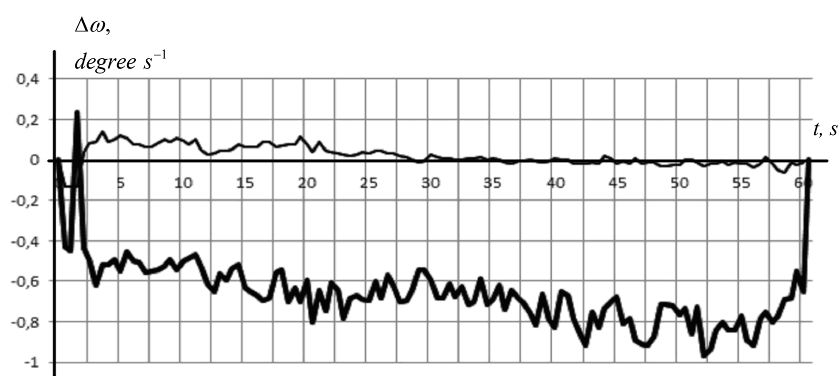


Figure 5. The DUSU output signal at φ=0⁰; a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

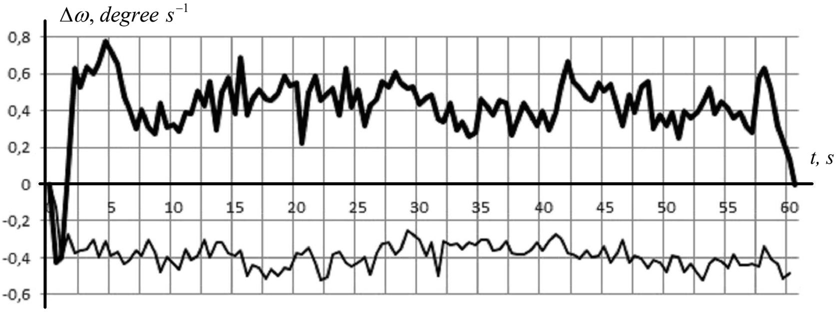


Figure 6. The DUSU output signal at φ=45⁰: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

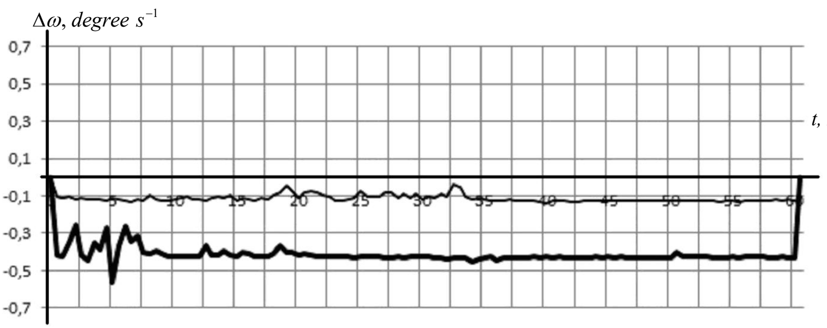


Figure 7. The DUSU output signal at φ=90⁰: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

A turn of the DUSU body at the angle $\varphi = 90^0$ allowes stabilizing the error of the device in time at the level $\Delta\omega_{mid} \approx -0,45 \deg ree\ s^{-1}$ (Table 15), (Figure 7).

A turn of the DUSU body at the angle $\varphi = 135^0$ allows reducing the average error to the value. $\Delta\omega \approx -0,05 \deg ree\ s^{-1}$. However, the range of values will be (Table 16). In addition a superposition of short-period and long-period components take place (Figure 8).

If the angle $\varphi = 180^0$, the DUSU output signal has a minimal variation in amplitude, and the average error does not exceed $\Delta\omega_{mid} \approx -0,45 \deg ree\ s^{-1}$ (Figure 9), (Table 17).

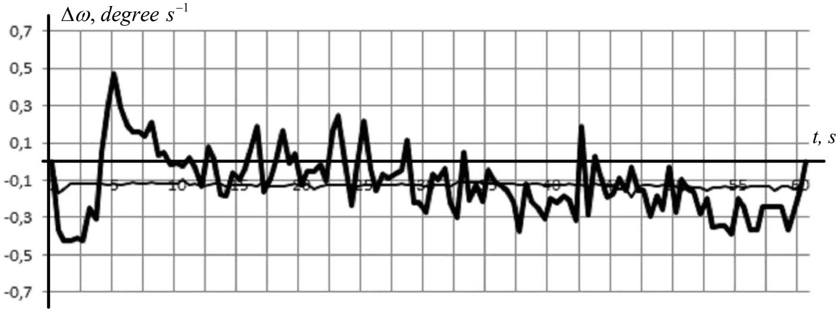


Figure 8. The DUSU output signal at φ=135^0: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

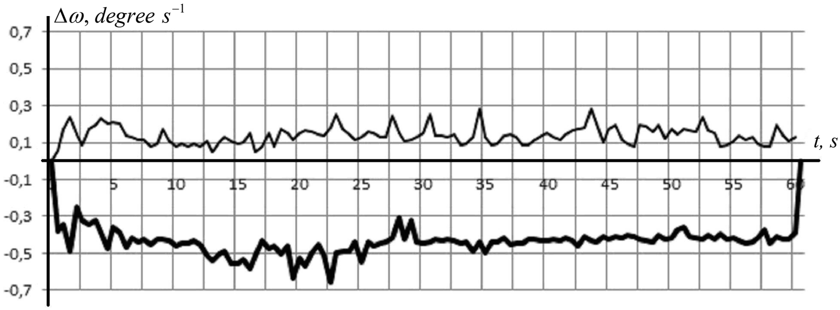


Figure 9. The DUSU output signal at φ=180^0: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

A turn of the DUSU body at the angle $\varphi = 225^0$ practically does not change the situation (Figure 10). The same concerns the numerical values (Table 18).

At the turning angles $\varphi = 270^0$ and $\varphi = 315^0$ the diagram of the error is not changed (Figure 11, Figure 12). The average value also won't be changed.

$$\Delta\omega_{mid} \approx -0,45\ \deg ree\ s^{-1}$$

and remains stable over time (Table 19). At the same time a slight range appears (Table 4.20).Thus, the angular orientation of the DUSU body at values $\varphi = 180^0, 225^0$, 270^0 and 315^0 practically have no effect on the diagram of the device's error over time (Figure 9-12).

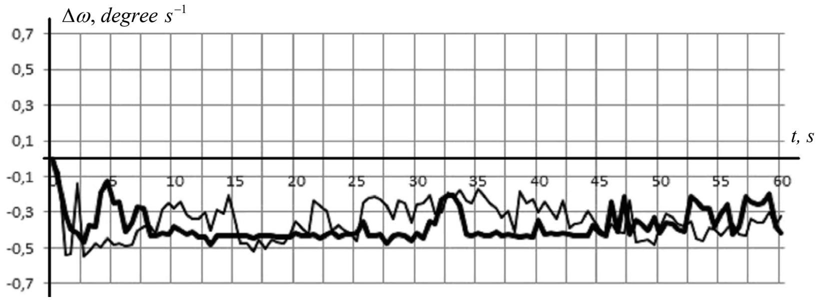


Figure 10. The DUSU output signal at φ=225⁰: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

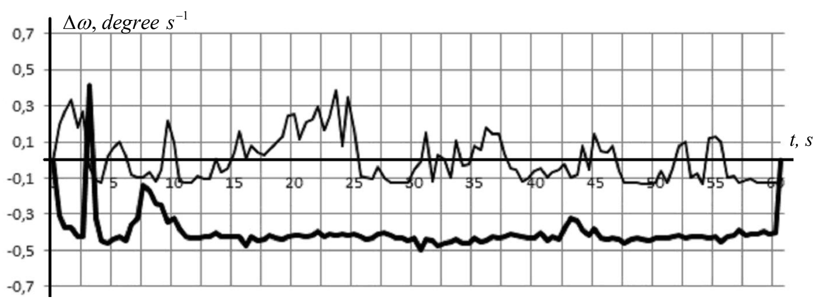


Figure 11. The DUSU output signal at φ=270⁰: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

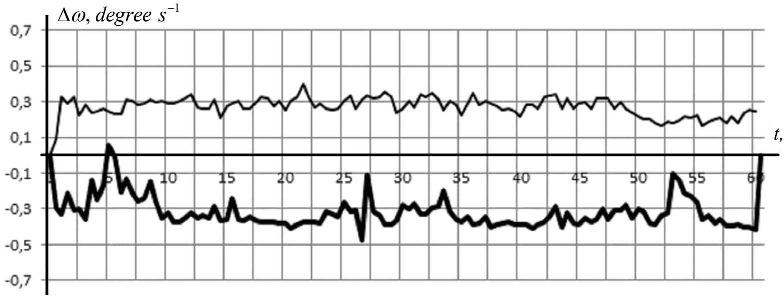


Figure 12. The DUSU output signal at φ=315^0: a thin line – the gyrodevice is "*OFF*"; a thick line – the gyrodevice is "*ON*"

Source: developed by author

Table 5

"*Zero shift*" of DUSU in an ultrasonic beam: φ=0^0

Orientation of the device body		φ=0^0	Volume	V=400 ml	Gyroscope is	" OFF"	
t, s	Output value, *degree s^{-1}*	*t, s*	Output value, *degree s^{-1}*	*t, s*	Output value, *degree s^{-1}*	*t, s*	Output value, *degree s^{-1}*
0,5	-0,1311	15,5	0,0667	30,5	0,0115	45,5	-0,0069
1	-0,1311	16	0,0621	31	0,0069	46	-0,0184
1,5	-0,1311	16,5	0,0874	31,5	0,0069	46,5	0,0069
2	0,0391	17	0,0897	32	0	47	-0,0184
2,5	0,0828	17,5	0,0644	32,5	0,0023	47,5	-0,0115
3	0,0874	18	0,069	33	0,0069	48	-0,0138
3,5	0,1426	18,5	0,0759	33,5	0,0046	48,5	-0,0299
4	0,0874	19	0,0759	34	0,0161	49	-0,0299
4,5	0,1012	19,5	0,115	34,5	0,0023	49,5	-0,023
5	0,1219	20	0,0759	35	0,0069	50	-0,023
5,5	0,1104	20,5	0,0391	35,5	-0,0023	50,5	0
6	0,0736	21	0,0897	36	-0,0092	51	0
6,5	0,0759	21,5	0,0437	36,5	-0,0161	51,5	-0,0115
7	0,0621	22	0,0368	37	-0,0069	52	-0,0299
7,5	0,0644	22,5	0,0345	37,5	-0,0046	52,5	-0,0161
8	0,0805	23	0,0253	38	0	53	-0,0161
8,5	0,0989	23,5	0,0207	38,5	-0,0046	53,5	-0,0046
9	0,092	24	0,0253	39	-0,0138	54	-0,023
9,5	0,1058	24,5	0,0414	39,5	-0,0046	54,5	-0,0138
10	0,0966	25	0,0322	40	0,0069	55	-0,0161
10,5	0,0736	25,5	0,0437	40,5	0	55,5	-0,0184
11	0,1035	26	0,046	41	-0,0023	56	-0,0345
11,5	0,0483	26,5	0,0345	41,5	-0,0207	56,5	-0,0184

12	0,023	27	0,0322	42	-0,0161	57	0,0138
12,5	0,0322	27,5	0,0207	42,5	-0,0207	57,5	-0,0207
13	0,046	28	0,0115	43	-0,0092	58	-0,0483
13,5	0,0437	28,5	-0,0023	43,5	-0,0161	58,5	-0,0598
14	0,0483	29	-0,0092	44	0,0184	59	-0,0115
14,5	0,0736	29,5	-0,0069	44,5	0,0069	59,5	-0,023
15	0,0621	30	0,0253	45	-0,0161	60	-0,0092

Source: developed by author

Table 6

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=45^0$

Orientation of the device body		**$\varphi=45^0$**	**Volume**	**V=400 ml**	**Gyroscope is**	***"OFF"***	
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,1311	15,5	-0,3588	30,5	-0,3864	45,5	-0,4301
1	-0,3956	16	-0,4991	31	-0,3151	46	-0,3726
1,5	-0,2714	16,5	-0,4393	31,5	-0,4968	46,5	-0,3059
2	-0,3749	17	-0,4531	32	-0,3082	47	-0,4278
2,5	-0,3588	17,5	-0,5152	32,5	-0,3289	47,5	-0,3887
3	-0,3542	18	-0,46	33	-0,3266	48	-0,4048
3,5	-0,299	18,5	-0,4991	33,5	-0,3542	48,5	-0,4531
4	-0,3979	19	-0,4554	34	-0,3174	49	-0,414
4,5	-0,3105	19,5	-0,4646	34,5	-0,3335	49,5	-0,4232
5	-0,3864	20	-0,3772	35	-0,3036	50	-0,4784
5,5	-0,368	20,5	-0,3818	35,5	-0,299	50,5	-0,3864
6	-0,437	21	-0,3496	36	-0,3634	51	-0,4002
6,5	-0,4117	21,5	-0,4255	36,5	-0,3519	51,5	-0,4807
7	-0,3611	22	-0,5198	37	-0,3128	52	-0,4347
7,5	-0,3933	22,5	-0,5083	37,5	-0,3726	52,5	-0,4853
8	-0,3013	23	-0,3841	38	-0,3795	53	-0,5244
8,5	-0,368	23,5	-0,368	38,5	-0,3818	53,5	-0,437
9	-0,4761	24	-0,4278	39	-0,3611	54	-0,4048
9,5	-0,4002	24,5	-0,4462	39,5	-0,3197	54,5	-0,4209
10	-0,4347	25	-0,4232	40	-0,3588	55	-0,4577
10,5	-0,4646	25,5	-0,3956	40,5	-0,3128	55,5	-0,3841
11	-0,3542	26	-0,4922	41	-0,276	56	-0,4393
11,5	-0,4094	26,5	-0,3749	41,5	-0,2921	56,5	-0,4393
12	-0,391	27	-0,322	42	-0,3772	57	-0,437
12,5	-0,299	27,5	-0,3151	42,5	-0,3795	57,5	-0,4485
13	-0,4002	28	-0,3818	43	-0,4071	58	-0,3404
13,5	-0,3174	28,5	-0,3542	43,5	-0,3634	58,5	-0,4071
14	-0,3151	29	-0,2484	44	-0,3956	59	-0,4324
14,5	-0,3726	29,5	-0,276	44,5	-0,391	59,5	-0,5106
15	-0,3887	30	-0,3059	45	-0,3381	60	-0,483

Source: developed by author

Table 7

"*Zero shift*" of DUSU in an ultrasonic beam: φ=90^0

Orientation of the device body		φ=90^0	Volume	V=400 ml	Gyroscope is	*“OFF“*	
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,1035	15,5	-0,1104	30,5	-0,1058	45,5	-0,1265
1	-0,1104	16	-0,1196	31	-0,1081	46	-0,1288
1,5	-0,1058	16,5	-0,1242	31,5	-0,0897	46,5	-0,1288
2	-0,1173	17	-0,1081	32	-0,1035	47	-0,1265
2,5	-0,1081	17,5	-0,115	32,5	-0,0345	47,5	-0,1288
3	-0,115	18	-0,0943	33	-0,0506	48	-0,1288
3,5	-0,1173	18,5	-0,0805	33,5	-0,1058	48,5	-0,1265
4	-0,1173	19	-0,046	34	-0,115	49	-0,1265
4,5	-0,1219	19,5	-0,0759	34,5	-0,1127	49,5	-0,1265
5	-0,1127	20	-0,1081	35	-0,115	50	-0,1288
5,5	-0,115	20,5	-0,0805	35,5	-0,1219	50,5	-0,1242
6	-0,1219	21	-0,0759	36	-0,1242	51	-0,1265
6,5	-0,1334	21,5	-0,0805	36,5	-0,1242	51,5	-0,1265
7	-0,1173	22	-0,0943	37	-0,1196	52	-0,1288
7,5	-0,1219	22,5	-0,1012	37,5	-0,1288	52,5	-0,1265
8	-0,0966	23	-0,1219	38	-0,1265	53	-0,1288
8,5	-0,115	23,5	-0,1242	38,5	-0,1242	53,5	-0,1288
9	-0,1219	24	-0,115	39	-0,1288	54	-0,1311
9,5	-0,1219	24,5	-0,1104	39,5	-0,1311	54,5	-0,1288
10	-0,1173	25	-0,0759	40	-0,1426	55	-0,1288
10,5	-0,1127	25,5	-0,1035	40,5	-0,1288	55,5	-0,1311
11	-0,1012	26	-0,1035	41	-0,1288	56	-0,1288
11,5	-0,1196	26,5	-0,1035	41,5	-0,1288	56,5	-0,1288
12	-0,1196	27	-0,0828	42	-0,1311	57	-0,1288
12,5	-0,1219	27,5	-0,0828	42,5	-0,1311	57,5	-0,1288
13	-0,1104	28	-0,1081	43	-0,1288	58	-0,1288
13,5	-0,1035	28,5	-0,092	43,5	-0,1288	58,5	-0,1173
14	-0,1081	29	-0,1127	44	-0,1288	59	-0,1265
14,5	-0,0989	29,5	-0,092	44,5	-0,1288	59,5	-0,1173
15	-0,1219	30	-0,1196	45	-0,1288	60	-0,1242

Source: developed by author

Table 8

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=135^0$

Orientation of the device body		**$\varphi=135^0$**	**Volume V=400 ml**		**Gyroscope is *"OFF"***		
t, s	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***
0,5	-0,1679	15,5	-0,1219	30,5	-0,1265	45,5	-0,1495
1	-0,1449	16	-0,1288	31	-0,1219	46	-0,1449
1,5	-0,115	16,5	-0,1357	31,5	-0,1288	46,5	-0,1909
2	-0,1173	17	-0,1012	32	-0,1357	47	-0,1357
2,5	-0,1173	17,5	-0,1334	32,5	-0,1127	47,5	-0,1288
3	-0,1196	18	-0,1357	33	-0,1127	48	-0,1265
3,5	-0,1173	18,5	-0,1357	33,5	-0,1104	48,5	-0,1334
4	-0,1173	19	-0,1219	34	-0,1127	49	-0,1288
4,5	-0,1265	19,5	-0,1173	34,5	-0,1104	49,5	-0,1334
5	-0,1196	20	-0,1311	35	-0,1196	50	-0,1311
5,5	-0,1219	20,5	-0,1196	35,5	-0,1196	50,5	-0,1541
6	-0,1196	21	-0,1449	36	-0,1173	51	-0,1334
6,5	-0,1127	21,5	-0,1334	36,5	-0,1196	51,5	-0,1403
7	-0,115	22	-0,1265	37	-0,1196	52	-0,1426
7,5	-0,1173	22,5	-0,1242	37,5	-0,1219	52,5	-0,1564
8	-0,1127	23	-0,1265	38	-0,1242	53	-0,1426
8,5	-0,115	23,5	-0,1265	38,5	-0,1173	53,5	-0,138
9	-0,115	24	-0,1265	39	-0,1196	54	-0,1311
9,5	-0,1196	24,5	-0,1311	39,5	-0,1242	54,5	-0,1403
10	-0,1196	25	-0,1265	40	-0,1288	55	-0,1334
10,5	-0,0989	25,5	-0,1265	40,5	-0,1265	55,5	-0,1403
11	-0,1242	26	-0,1288	41	-0,1242	56	-0,1334
11,5	-0,1196	26,5	-0,1265	41,5	-0,1196	56,5	-0,1311
12	-0,1357	27	-0,1219	42	-0,1265	57	-0,1311
12,5	-0,1219	27,5	-0,1219	42,5	-0,1219	57,5	-0,1311
13	-0,1196	28	-0,1173	43	-0,1311	58	-0,1541
13,5	-0,1173	28,5	-0,1219	43,5	-0,1196	58,5	-0,1334
14	-0,1311	29	-0,1288	44	-0,1288	59	-0,1334
14,5	-0,1265	29,5	-0,1288	44,5	-0,1219	59,5	-0,1449
15	-0,1242	30	-0,1311	45	-0,1288	60	-0,1357

Source: developed by author

Table 9

"*Zero shift*" of DUSU in an ultrasonic beam: φ=180^0

Orientation of the device body		φ=180^0	Volume	V=400 ml	Gyroscope is	*“OFF“*	
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	0,0575	15,5	0,1012	30,5	0,2553	45,5	0,1978
1	0,1748	16	0,1541	31	0,1357	46	0,115
1,5	0,2369	16,5	0,0529	31,5	0,138	46,5	0,0897
2	0,1472	17	0,0759	32	0,1311	47	0,0782
2,5	0,0874	17,5	0,1541	32,5	0,1472	47,5	0,1955
3	0,1702	18	0,0805	33	0,0851	48	0,1886
3,5	0,1932	18,5	0,1725	33,5	0,0897	48,5	0,161
4	0,2346	19	0,1495	34	0,1311	49	0,1955
4,5	0,2001	19,5	0,115	34,5	0,2852	49,5	0,1196
5	0,2116	20	0,1518	35	0,1288	50	0,1725
5,5	0,2024	20,5	0,1679	35,5	0,0874	50,5	0,1426
6	0,1357	21	0,161	36	0,092	51	0,1771
6,5	0,1311	21,5	0,1449	36,5	0,1357	51,5	0,1656
7	0,1173	22	0,1357	37	0,1449	52	0,1564
7,5	0,1173	22,5	0,1794	37,5	0,1334	52,5	0,2392
8	0,0805	23	0,2507	38	0,0828	53	0,1656
8,5	0,0966	23,5	0,1748	38,5	0,0828	53,5	0,1495
9	0,1725	24	0,1472	39	0,115	54	0,0782
9,5	0,1104	24,5	0,1127	39,5	0,1357	54,5	0,0851
10	0,0759	25	0,1265	40	0,1541	55	0,1081
10,5	0,092	25,5	0,1587	40,5	0,1334	55,5	0,1403
11	0,0782	26	0,1541	41	0,115	56	0,1127
11,5	0,0943	26,5	0,1334	41,5	0,1426	56,5	0,1334
12	0,0782	27	0,1334	42	0,1633	57	0,092
12,5	0,1058	27,5	0,2461	42,5	0,1748	57,5	0,0805
13	0,0506	28	0,1541	43	0,1794	58	0,0759
13,5	0,1035	28,5	0,1058	43,5	0,2806	58,5	0,1932
14	0,1311	29	0,1173	44	0,2047	59	0,1403
14,5	0,1058	29,5	0,1265	44,5	0,1035	59,5	0,1104
15	0,0943	30	0,1518	45	0,1702	60	0,1334

Source: developed by author

Table 10

"*Zero shift*" of DUSU in an ultrasonic beam: φ=225^0

Orientation of the device body		φ=225^0	Volume	V=400 ml	Gyroscope is	*"OFF"*	
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,0851	15,5	-0,4738	30,5	-0,2507	45,5	-0,4232
1	-0,5405	16	-0,4761	31	-0,207	46	-0,3657
1,5	-0,5313	16,5	-0,5198	31,5	-0,3059	46,5	-0,4117
2	-0,1403	17	-0,4554	32	-0,3036	47	-0,4163
2,5	-0,5497	17,5	-0,506	32,5	-0,1909	47,5	-0,2346
3	-0,5198	18	-0,4554	33	-0,2185	48	-0,4646
3,5	-0,4784	18,5	-0,4646	33,5	-0,1771	48,5	-0,4623
4	-0,4968	19	-0,4761	34	-0,2369	49	-0,4531
4,5	-0,4439	19,5	-0,4255	34,5	-0,2507	49,5	-0,483
5	-0,483	20	-0,3542	35	-0,1679	50	-0,3887
5,5	-0,4761	20,5	-0,391	35,5	-0,2162	50,5	-0,3105
6	-0,4899	21	-0,4255	36	-0,2507	51	-0,3289
6,5	-0,4807	21,5	-0,2369	36,5	-0,2806	51,5	-0,3634
7	-0,4002	22	-0,2645	37	-0,3312	52	-0,3772
7,5	-0,3772	22,5	-0,2944	37,5	-0,2944	52,5	-0,3519
8	-0,3841	23	-0,4048	38	-0,4071	53	-0,4485
8,5	-0,4186	23,5	-0,3703	38,5	-0,1863	53,5	-0,46
9	-0,2852	24	-0,4025	39	-0,2461	54	-0,3864
9,5	-0,253	24,5	-0,414	39,5	-0,2277	54,5	-0,3979
10	-0,2806	25	-0,46	40	-0,3013	55	-0,4347
10,5	-0,2438	25,5	-0,253	40,5	-0,2438	55,5	-0,391
11	-0,3151	26	-0,2231	41	-0,2967	56	-0,368
11,5	-0,3358	26,5	-0,2093	41,5	-0,3404	56,5	-0,4209
12	-0,3381	27	-0,2254	42	-0,2369	57	-0,4324
12,5	-0,3036	27,5	-0,2668	42,5	-0,3887	57,5	-0,3381
13	-0,4002	28	-0,3358	43	-0,3634	58	-0,3611
13,5	-0,2875	28,5	-0,2346	43,5	-0,3565	58,5	-0,3588
14	-0,3105	29	-0,253	44	-0,2967	59	-0,299
14,5	-0,2024	29,5	-0,3565	44,5	-0,3335	59,5	-0,3657
15	-0,3542	30	-0,2553	45	-0,3979	60	-0,3243

Source: developed by author

Table 11

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=270^0$

Orientation of the device body		**$\varphi=270^0$**	**Volume**	**V=400 ml**	**Gyroscope is**	***“OFF“***	
t, s	**Output value,** ***degree s^{-1}***	***t, s***	**Output value,** ***degree s^{-1}***	***t, s***	**Output value,** *degree s^{-1}*	***t, s***	**Output value,** ***degree s^{-1}***
0,5	0,1955	15,5	0,1564	30,5	-0,0115	45,5	0,0483
1	0,2668	16	0,0046	31	0,1541	46	0,0414
1,5	0,3358	16,5	0,0782	31,5	-0,1173	46,5	0,0782
2	0,184	17	0,0437	32	0,0299	47	-0,0598
2,5	0,2714	17,5	0,0253	32,5	0,0046	47,5	-0,1288
3	-0,0391	18	0,0598	33	-0,0943	48	-0,1288
3,5	-0,1104	18,5	0,0897	33,5	0,1104	48,5	-0,1288
4	-0,1242	19	0,1265	34	-0,0322	49	-0,1311
4,5	0,0184	19,5	0,2484	34,5	-0,0253	49,5	-0,1311
5	0,0667	20	0,2507	35	0,0782	50	-0,1265
5,5	0,1035	20,5	0,1127	35,5	0,0598	50,5	-0,0598
6	0,023	21	0,2116	36	0,184	51	-0,1242
6,5	-0,0828	21,5	0,2231	36,5	0,1426	51,5	-0,0437
7	-0,0966	22	0,2967	37	0,1472	52	0,0759
7,5	-0,0966	22,5	0,1633	37,5	0,0368	52,5	0,0989
8	-0,0644	23	0,2392	38	-0,0483	53	-0,0943
8,5	-0,1173	23,5	0,3818	38,5	-0,0552	53,5	-0,0759
9	-0,0552	24	0,0782	39	-0,1173	54	-0,1311
9,5	0,2162	24,5	0,3519	39,5	-0,0989	54,5	0,1219
10	0,0943	25	0,1679	40	-0,0598	55	0,1288
10,5	-0,1196	25,5	-0,092	40,5	-0,0483	55,5	0,0989
11	-0,1219	26	-0,0966	41	-0,0943	56	-0,0966
11,5	-0,1288	26,5	-0,1058	41,5	-0,0667	56,5	-0,0874
12	-0,0874	27	-0,0391	42	-0,0552	57	-0,1288
12,5	-0,1035	27,5	-0,0943	42,5	-0,0207	57,5	-0,1081
13	-0,1035	28	-0,1242	43	-0,0966	58	-0,1035
13,5	0,0069	28,5	-0,1265	43,5	-0,0851	58,5	-0,1265
14	-0,0667	29	-0,1242	44	0,0782	59	-0,1242
14,5	-0,046	29,5	-0,1265	44,5	-0,0529	59,5	-0,1242
15	0,0414	30	-0,0529	45	0,1449	60	-0,1242

Source: developed by author

Table 12

"Zero shift" of DUSU in an ultrasonic beam: φ=315⁰

Orientation of the device body		**φ=315⁰**	**Volume**	**V=400 ml**	**Gyroscope is**	***"OFF"***	
t, s	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***
0,5	0,0966	15,5	0,2921	30,5	0,3036	45,5	0,2967
1	0,3266	16	0,3036	31	0,2714	46	0,2622
1,5	0,2898	16,5	0,2576	31,5	0,3381	46,5	0,322
2	0,3243	17	0,2645	32	0,3289	47	0,3197
2,5	0,2231	17,5	0,2967	32,5	0,3519	47,5	0,3174
3	0,2829	18	0,3266	33	0,3105	48	0,2599
3,5	0,2415	18,5	0,322	33,5	0,253	48,5	0,299
4	0,2461	19	0,2737	34	0,3013	49	0,2645
4,5	0,2576	19,5	0,3036	34,5	0,2806	49,5	0,2392
5	0,2461	20	0,2507	35	0,2254	50	0,2162
5,5	0,2346	20,5	0,3013	35,5	0,2898	50,5	0,2001
6	0,23	21	0,3266	36	0,345	51	0,2047
6,5	0,3105	21,5	0,3979	36,5	0,2852	51,5	0,1794
7	0,3036	22	0,3243	37	0,3082	52	0,1679
7,5	0,2852	22,5	0,2668	37,5	0,2875	52,5	0,1909
8	0,2875	23	0,2875	38	0,2737	53	0,184
8,5	0,3151	23,5	0,2622	38,5	0,2507	53,5	0,1955
9	0,2967	24	0,2507	39	0,2576	54	0,2162
9,5	0,3082	24,5	0,2599	39,5	0,2461	54,5	0,207
10	0,2875	25	0,3082	40	0,2162	55	0,2231
10,5	0,2921	25,5	0,3335	40,5	0,2852	55,5	0,1679
11	0,3036	26	0,2622	41	0,2806	56	0,1863
11,5	0,3174	26,5	0,3105	41,5	0,2599	56,5	0,2001
12	0,3427	27	0,3312	42	0,3289	57	0,2116
12,5	0,2691	27,5	0,3197	42,5	0,3312	57,5	0,184
13	0,2599	28	0,3289	43	0,3427	58	0,2162
13,5	0,2599	28,5	0,3542	43,5	0,2576	58,5	0,1794
14	0,3128	29	0,3289	44	0,322	59	0,2369
14,5	0,207	29,5	0,2392	44,5	0,2576	59,5	0,2553
15	0,2783	30	0,2645	45	0,2921	60	0,2461

Source: developed by author

Table 13

"*Zero shift*" of DUSU in an ultrasonic beam: φ=0^0

Orientation of the device body		**φ=0^0**	**Volume V=400 ml**		**Gyroscope is *"ON"***		
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,4278	15,5	-0,6486	30,5	-0,6831	45,5	-0,8073
1	-0,44735	16	-0,67045	31	-0,6831	46	-0,78085
1,5	0,2369	16,5	-0,69575	31,5	-0,61525	46,5	-0,89355
2	-0,437	17	-0,68195	32	-0,6785	47	-0,9108
2,5	-0,49105	17,5	-0,5543	32,5	-0,6279	47,5	-0,9154
3	-0,6164	18	-0,54165	33	-0,7107	48	-0,874
3,5	-0,52095	18,5	-0,70265	33,5	-0,70265	48,5	-0,7153
4	-0,5152	19	-0,63365	34	-0,58765	49	-0,71415
4,5	-0,4945	19,5	-0,7038	34,5	-0,71645	49,5	-0,7199
5	-0,552	20	-0,59455	35	-0,6877	50	-0,76245
5,5	-0,4531	20,5	-0,80155	35,5	-0,61755	50,5	-0,73025
6	-0,50025	21	-0,6463	36	-0,736	51	-0,85905
6,5	-0,5037	21,5	-0,7475	36,5	-0,6463	51,5	-0,72565
7	-0,5566	22	-0,60605	37	-0,68195	52	-0,96945
7,5	-0,54855	22,5	-0,6417	37,5	-0,7084	52,5	-0,93725
8	-0,5428	23	-0,782	38	-0,75555	53	-0,8372
8,5	-0,52325	23,5	-0,6808	38,5	-0,8119	53,5	-0,80155
9	-0,49565	24	-0,67275	39	-0,66355	54	-0,84295
9,5	-0,54395	24,5	-0,68885	39,5	-0,7866	54,5	-0,83835
10	-0,4968	25	-0,6923	40	-0,82915	55	-0,76935
10,5	-0,4853	25,5	-0,60145	40,5	-0,6532	55,5	-0,8901
11	-0,46805	26	-0,67965	41	-0,667	56	-0,9177
11,5	-0,5221	26,5	-0,5704	41,5	-0,782	56,5	-0,782
12	-0,61295	27	-0,62215	42	-0,85675	57	-0,74865
12,5	-0,6486	27,5	-0,6992	42,5	-0,9154	57,5	-0,8004
13	-0,56465	28	-0,69805	43	-0,75095	58	-0,7705
13,5	-0,59685	28,5	-0,6463	43,5	-0,828	58,5	-0,69
14	-0,53705	29	-0,54395	44	-0,7314	59	-0,6808
14,5	-0,5175	29,5	-0,5405	44,5	-0,7038	59,5	-0,55085
15	-0,6302	30	-0,5934	45	-0,6739	60	-0,65205

Source: developed by author

Table 14

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=45^0$

Orientation of the device body		$\varphi=45^0$	Volume	V=400 ml	Gyroscope is	*"ON"*	
t, s	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***	***t, s***	**Output value, *degree s⁻¹***
0,5	-0,4301	15,5	0,6877	30,5	0,4669	45,5	0,54625
1	-0,3956	16	0,37605	31	0,48645	46	0,42205
1,5	0,07935	16,5	0,46115	31,5	0,35305	46,5	0,3174
2	0,62905	17	0,5152	32	0,3427	47	0,483
2,5	0,52555	17,5	0,46	32,5	0,4439	47,5	0,39215
3	0,6394	18	0,45425	33	0,29325	48	0,529
3,5	0,6049	18,5	0,49335	33,5	0,3404	48,5	0,5543
4	0,6601	19	0,5842	34	0,2599	49	0,30245
4,5	0,7751	19,5	0,53245	34,5	0,2783	49,5	0,3726
5	0,7245	20	0,55315	35	0,46575	50	0,31395
5,5	0,64975	20,5	0,22425	35,5	0,4163	50,5	0,3887
6	0,47725	21	0,50025	36	0,3772	51	0,253
6,5	0,40365	21,5	0,5888	36,5	0,45655	51,5	0,39675
7	0,3036	22	0,45655	37	0,43815	52	0,36225
7,5	0,4071	22,5	0,48875	37,5	0,2691	52,5	0,391
8	0,30705	23	0,52325	38	0,3634	53	0,43815
8,5	0,27255	23,5	0,3772	38,5	0,4439	53,5	0,52095
9	0,4416	24	0,63135	39	0,3795	54	0,3864
9,5	0,3082	24,5	0,4186	39,5	0,3174	54,5	0,44735
10	0,32545	25	0,5175	40	0,3956	55	0,41285
10,5	0,2898	25,5	0,32085	40,5	0,299	55,5	0,3634
11	0,39215	26	0,42665	41	0,39215	56	0,38985
11,5	0,38065	26,5	0,4623	41,5	0,53475	56,5	0,30935
12	0,506	27	0,55775	42	0,66585	57	0,2829
12,5	0,4232	27,5	0,52555	42,5	0,5543	57,5	0,5819
13	0,56005	28	0,6072	43	0,5221	58	0,63135
13,5	0,2944	28,5	0,55315	43,5	0,4738	58,5	0,51635
14	0,5014	29	0,51865	44	0,4554	59	0,3151
14,5	0,5796	29,5	0,529	44,5	0,5497	59,5	0,23805
15	0,38295	30	0,4324	45	0,50945	60	0,1357

Source: developed by author

Table 15

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=90^0$

Orientation of the device body		$\varphi=90^0$	Volume	V=400 ml	Gyroscope is	*"ON"*	
t, s	**Output value *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,41515	15,5	-0,4048	30,5	-0,4278	45,5	-0,42895
1	-0,4278	16	-0,4071	31	-0,42895	46	-0,4278
1,5	-0,35305	16,5	-0,42205	31,5	-0,4324	46,5	-0,42895
2	-0,25415	17	-0,4232	32	-0,43815	47	-0,42895
2,5	-0,41745	17,5	-0,4255	32,5	-0,43125	47,5	-0,4301
3	-0,44505	18	-0,4094	33	-0,4324	48	-0,4301
3,5	-0,35305	18,5	-0,368	33,5	-0,4301	48,5	-0,43125
4	-0,38525	19	-0,40595	34	-0,45195	49	-0,4301
4,5	-0,27485	19,5	-0,40595	34,5	-0,43585	49,5	-0,4301
5	-0,56235	20	-0,41975	35	-0,4301	50	-0,43125
5,5	-0,36915	20,5	-0,4117	35,5	-0,4278	50,5	-0,40595
6	-0,2668	21	-0,414	36	-0,44275	51	-0,4278
6,5	-0,34155	21,5	-0,4278	36,5	-0,4301	51,5	-0,42435
7	-0,31395	22	-0,42665	37	-0,4301	52	-0,4278
7,5	-0,39905	22,5	-0,4232	37,5	-0,42895	52,5	-0,4278
8	-0,4094	23	-0,42205	38	-0,42895	53	-0,4278
8,5	-0,3979	23,5	-0,42205	38,5	-0,42895	53,5	-0,43125
9	-0,4094	24	-0,4278	39	-0,42665	54	-0,4301
9,5	-0,4255	24,5	-0,4301	39,5	-0,42895	54,5	-0,4324
10	-0,4255	25	-0,4255	40	-0,4278	55	-0,4278
10,5	-0,42665	25,5	-0,4232	40,5	-0,42895	55,5	-0,42895
11	-0,42205	26	-0,42665	41	-0,4278	56	-0,4278
11,5	-0,42435	26,5	-0,4278	41,5	-0,42895	56,5	-0,4278
12	-0,4232	27	-0,4301	42	-0,43125	57	-0,42665
12,5	-0,368	27,5	-0,42895	42,5	-0,4301	57,5	-0,42665
13	-0,41515	28	-0,4255	43	-0,42895	58	-0,4324
13,5	-0,41515	28,5	-0,42895	43,5	-0,43125	58,5	-0,42895
14	-0,3956	29	-0,4255	44	-0,4278	59	-0,4278
14,5	-0,4163	29,5	-0,4255	44,5	-0,42895	59,5	-0,42895
15	-0,42205	30	-0,4278	45	-0,4278	60	-0,43125

Source: developed by author

Table 16

"Zero shift" of DUSU in an ultrasonic beam: φ=135^0

Orientation of the device body		φ=135^0	Volume	V=400 ml	Gyroscope is	*"ON"*	
t, s	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***
0,5	-0,36685	15,5	-0,0345	30,5	-0,0644	45,5	-0,0897
1	-0,42435	16	0,0851	31	-0,09315	46	-0,15755
1,5	-0,4209	16,5	0,1909	31,5	-0,0345	46,5	-0,0276
2	-0,40825	17	-0,15985	32	-0,2185	47	-0,1541
2,5	-0,4232	17,5	-0,0897	32,5	-0,29785	47,5	-0,15525
3	-0,2507	18	0,0046	33	0,04715	48	-0,29325
3,5	-0,3059	18,5	0,1656	33,5	-0,207	48,5	-0,18515
4	0,05175	19	-0,00805	34	-0,12535	49	-0,2599
4,5	0,31165	19,5	0,0437	34,5	-0,21045	49,5	-0,0276
5	0,4738	20	-0,1219	35	-0,0483	50	-0,26795
5,5	0,2898	20,5	-0,0552	35,5	-0,1081	50,5	-0,09545
6	0,1978	21	-0,0506	36	-0,1242	51	-0,1495
6,5	0,161	21,5	-0,0161	36,5	-0,1541	51,5	-0,16445
7	0,1587	22	-0,1035	37	-0,2231	52	-0,27945
7,5	0,1403	22,5	0,1633	37,5	-0,3726	52,5	-0,20125
8	0,21045	23	0,24725	38	-0,1173	53	-0,3496
8,5	0,03565	23,5	0	38,5	-0,2162	53,5	-0,3427
9	0,04945	24	-0,23575	39	-0,2507	54	-0,3473
9,5	-0,01725	24,5	-0,0138	39,5	-0,3059	54,5	-0,38755
10	-0,0069	25	0,21735	40	-0,20125	55	-0,19895
10,5	-0,02185	25,5	-0,0414	40,5	-0,21735	55,5	-0,24265
11	0,0184	26	-0,1564	41	-0,184	56	-0,3634
11,5	-0,0322	26,5	-0,0667	41,5	-0,2047	56,5	-0,36455
12	-0,1334	27	-0,0897	42	-0,3151	57	-0,24495
12,5	0,0782	27,5	-0,07015	42,5	0,18745	57,5	-0,24265
13	0,01035	28	-0,0437	43	-0,28405	58	-0,24495
13,5	-0,1794	28,5	0,1173	43,5	0,02875	58,5	-0,24495
14	-0,18285	29	-0,2231	44	-0,07475	59	-0,36915
14,5	-0,06325	29,5	-0,22195	44,5	-0,1886	59,5	-0,27485
15	-0,09315	30	-0,2737	45	-0,1748	60	-0,1495

Source: developed by author

Table 17

"*Zero shift*" of DUSU in an ultrasonic beam: φ=180^0

Orientation of the device body		**φ=180^0**	**Volume**	**V=400 ml**	**Gyroscope is**	***"ON"***	
t, s	**Output value** ***degree s^{-1}***	***t, s***	**Output value** ***degree s^{-1}***	***t, s***	**Output value** ***degree s^{-1}***	***t, s***	**Output value** ***degree s^{-1}***
0,5	**-0,38295**	**15,5**	**-0,5336**	**30,5**	**-0,4416**	**45,5**	**-0,40825**
1	-0,34155	16	-0,58535	31	-0,4232	46	-0,414
1,5	-0,4876	16,5	-0,50945	31,5	-0,42895	46,5	-0,4002
2	-0,24955	17	-0,4324	32	-0,42435	47	-0,4094
2,5	-0,3197	17,5	-0,47725	32,5	-0,4347	47,5	-0,42435
3	-0,34615	18	-0,4623	33	-0,4462	48	-0,4347
3,5	-0,32545	18,5	-0,50715	33,5	-0,44045	48,5	-0,43585
4	-0,3887	19	-0,45885	34	-0,48875	49	-0,40595
4,5	-0,4738	19,5	-0,63595	34,5	-0,44045	49,5	-0,42665
5	-0,35765	20	-0,5267	35	-0,4991	50	-0,41515
5,5	-0,391	20,5	-0,56925	35,5	-0,43585	50,5	-0,3726
6	-0,4669	21	-0,50025	36	-0,44045	51	-0,3565
6,5	-0,414	21,5	-0,4508	36,5	-0,41975	51,5	-0,4071
7	-0,43585	22	-0,5129	37	-0,45195	52	-0,4163
7,5	-0,42665	22,5	-0,65435	37,5	-0,44505	52,5	-0,4255
8	-0,4531	23	-0,49795	38	-0,4439	53	-0,40135
8,5	-0,4278	23,5	-0,4899	38,5	-0,4278	53,5	-0,42665
9	-0,4278	24	-0,48645	39	-0,42435	54	-0,39675
9,5	-0,4301	24,5	-0,44045	39,5	-0,4301	54,5	-0,42435
10	-0,45885	25	-0,54625	40	-0,42895	55	-0,41975
10,5	-0,4462	25,5	-0,44045	40,5	-0,4278	55,5	-0,42895
11	-0,4439	26	-0,46345	41	-0,4301	56	-0,44275
11,5	-0,4324	26,5	-0,44275	41,5	-0,41745	56,5	-0,44045
12	-0,4554	27	-0,4416	42	-0,43355	57	-0,4163
12,5	-0,51405	27,5	-0,414	42,5	-0,4623	57,5	-0,37605
13	-0,5405	28	-0,3059	43	-0,41055	58	-0,44965
13,5	-0,5037	28,5	-0,4209	43,5	-0,43125	58,5	-0,4071
14	-0,49335	29	-0,32545	44	-0,4393	59	-0,42665
14,5	-0,55545	29,5	-0,43585	44,5	-0,40825	59,5	-0,4232
15	-0,5543	30	-0,4462	45	-0,42665	60	-0,38755

Source: developed by author

Table 18

***"Zero shift"* of DUSU in an ultrasonic beam: φ=225⁰**

Orientation of the device body		**φ=225^0**	**Volume**	**V=400 ml**	**Gyroscope is**	***"ON"***	
t, s	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***
0,5	-0,14145	15,5	-0,43355	30,5	-0,44275	45,5	-0,43355
1	-0,3174	16	-0,43355	31	-0,35075	46	-0,2392
1,5	-0,39445	16,5	-0,4485	31,5	-0,3634	46,5	-0,4117
2	-0,4163	17	-0,43125	32	-0,2254	47	-0,2093
2,5	-0,4669	17,5	-0,43355	32,5	-0,2047	47,5	-0,4255
3	-0,3703	18	-0,4301	33	-0,20815	48	-0,34155
3,5	-0,3818	18,5	-0,437	33,5	-0,26565	48,5	-0,36455
4	-0,18975	19	-0,437	34	-0,4255	49	-0,40135
4,5	-0,12765	19,5	-0,44045	34,5	-0,4301	49,5	-0,3312
5	-0,2484	20	-0,4163	35	-0,4186	50	-0,41745
5,5	-0,24495	20,5	-0,4301	35,5	-0,4324	50,5	-0,3588
6	-0,4094	21	-0,43125	36	-0,4301	51	-0,36685
6,5	-0,3565	21,5	-0,4278	36,5	-0,40825	51,5	-0,39215
7	-0,27025	22	-0,44275	37	-0,43125	52	-0,4071
7,5	-0,2806	22,5	-0,4278	37,5	-0,4255	52,5	-0,2093
8	-0,4324	23	-0,41285	38	-0,43125	53	-0,23805
8,5	-0,4324	23,5	-0,44045	38,5	-0,4416	53,5	-0,2783
9	-0,41975	24	-0,42435	39	-0,43355	54	-0,2806
9,5	-0,4232	24,5	-0,4255	39,5	-0,437	54,5	-0,38295
10	-0,3841	25	-0,41975	40	-0,34155	55	-0,30705
10,5	-0,40595	25,5	-0,3542	40,5	-0,42665	55,5	-0,2599
11	-0,42435	26	-0,4324	41	-0,4186	56	-0,42205
11,5	-0,41285	26,5	-0,43355	41,5	-0,42435	56,5	-0,38295
12	-0,43585	27	-0,42665	42	-0,4163	57	-0,2139
12,5	-0,43585	27,5	-0,47265	42,5	-0,42435	57,5	-0,24495
13	-0,4853	28	-0,4324	43	-0,4301	58	-0,2599
13,5	-0,43125	28,5	-0,4278	43,5	-0,4301	58,5	-0,2484
14	-0,43125	29	-0,4324	44	-0,4301	59	-0,1955
14,5	-0,43355	29,5	-0,4577	44,5	-0,37605	59,5	-0,3841
15	-0,43125	30	-0,4186	45	-0,4186	60	-0,41745

Source: developed by author

Table 19

"*Zero shift*" of DUSU in an ultrasonic beam: φ=270⁰

Orientation of the device body		φ=270^0	Volume	V=400 ml	Gyroscope is	“*ON*”	
t, s	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***	***t, s***	**Output value, *degree s^{-1}***
0,5	-0,30475	15,5	-0,42665	30,5	-0,4945	45,5	-0,43125
1	-0,3703	16	-0,4784	31	-0,43585	46	-0,437
1,5	-0,3703	16,5	-0,42665	31,5	-0,44965	46,5	-0,4301
2	-0,4209	17	-0,4439	32	-0,4761	47	-0,437
2,5	-0,4278	17,5	-0,437	32,5	-0,45885	47,5	-0,46
3	0,4117	18	-0,41975	33	-0,45425	48	-0,4393
3,5	-0,3243	18,5	-0,43125	33,5	-0,437	48,5	-0,4347
4	-0,44505	19	-0,43585	34	-0,45885	49	-0,43585
4,5	-0,4577	19,5	-0,42665	34,5	-0,46	49,5	-0,4485
5	-0,4393	20	-0,4163	35	-0,4347	50	-0,4301
5,5	-0,42665	20,5	-0,41975	35,5	-0,45655	50,5	-0,43125
6	-0,4439	21	-0,4278	36	-0,44735	51	-0,42895
6,5	-0,35995	21,5	-0,41745	36,5	-0,4278	51,5	-0,42205
7	-0,32315	22	-0,3979	37	-0,4301	52	-0,41975
7,5	-0,13915	22,5	-0,4232	37,5	-0,42435	52,5	-0,4301
8	-0,16905	23	-0,41285	38	-0,4117	53	-0,4209
8,5	-0,24265	23,5	-0,41745	38,5	-0,41745	53,5	-0,4209
9	-0,253	24	-0,41055	39	-0,4278	54	-0,42435
9,5	-0,34385	24,5	-0,414	39,5	-0,4301	54,5	-0,42895
10	-0,32315	25	-0,41285	40	-0,4324	55	-0,42435
10,5	-0,3818	25,5	-0,4278	40,5	-0,40365	55,5	-0,4531
11	-0,4255	26	-0,4393	41	-0,44735	56	-0,42205
11,5	-0,4301	26,5	-0,43355	41,5	-0,42435	56,5	-0,4163
12	-0,4347	27	-0,4071	42	-0,44045	57	-0,3887
12,5	-0,42665	27,5	-0,40365	42,5	-0,37835	57,5	-0,4163
13	-0,42205	28	-0,4186	43	-0,322	58	-0,41055
13,5	-0,40135	28,5	-0,4324	43,5	-0,3404	58,5	-0,4094
14	-0,4255	29	-0,4324	44	-0,3864	59	-0,3979
14,5	-0,4209	29,5	-0,44505	44,5	-0,414	59,5	-0,4094
15	-0,4209	30	-0,4347	45	-0,38065	60	-0,40595

Source: developed by author

Table 20

"*Zero shift*" of DUSU in an ultrasonic beam: $\varphi=315^0$

Orientation of the device body		**$\varphi=315^0$**	**Volume V=400 ml**		**Gyroscope is**	***"ON"***	
t, s	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***	***t, s***	**Output value *degree s^{-1}***
0,5	-0,2967	15,5	-0,2438	30,5	-0,3013	45,5	-0,34845
1	-0,3312	16	-0,3588	31	-0,27025	46	-0,37145
1,5	-0,21275	16,5	-0,36455	31,5	-0,32775	46,5	-0,35535
2	-0,3059	17	-0,3427	32	-0,3289	47	-0,3013
2,5	-0,3036	17,5	-0,3634	32,5	-0,2944	47,5	-0,36225
3	-0,3588	18	-0,37375	33	-0,2875	48	-0,30705
3,5	-0,14145	18,5	-0,37605	33,5	-0,2001	48,5	-0,30475
4	-0,25185	19	-0,3726	34	-0,3174	49	-0,27945
4,5	-0,16675	19,5	-0,37835	34,5	-0,36225	49,5	-0,3496
5	0,0598	20	-0,38065	35	-0,37375	50	-0,3013
5,5	-0,01035	20,5	-0,4117	35,5	-0,34155	50,5	-0,31625
6	-0,20355	21	-0,38755	36	-0,38985	51	-0,37835
6,5	-0,1357	21,5	-0,37605	36,5	-0,3772	51,5	-0,38525
7	-0,2116	22	-0,3726	37	-0,3473	52	-0,33925
7,5	-0,2553	22,5	-0,37145	37,5	-0,4048	52,5	-0,3197
8	-0,2415	23	-0,3818	38	-0,38755	53	-0,10695
8,5	-0,14835	23,5	-0,31855	38,5	-0,37835	53,5	-0,138
9	-0,25875	24	-0,33005	39	-0,3703	54	-0,2162
9,5	-0,3542	24,5	-0,34385	39,5	-0,38985	54,5	-0,23115
10	-0,32315	25	-0,2645	40	-0,391	55	-0,2668
10,5	-0,3749	25,5	-0,3174	40,5	-0,3887	55,5	-0,3565
11	-0,3726	26	-0,3059	41	-0,40825	56	-0,3404
11,5	-0,3519	26,5	-0,47495	41,5	-0,391	56,5	-0,37835
12	-0,3243	27	-0,11385	42	-0,3726	57	-0,3565
12,5	-0,3542	27,5	-0,31165	42,5	-0,34385	57,5	-0,3933
13	-0,3404	28	-0,3404	43	-0,2829	58	-0,3956
13,5	-0,3496	28,5	-0,391	43,5	-0,4048	58,5	-0,3887
14	-0,28635	29	-0,3887	44	-0,32315	59	-0,4002
14,5	-0,368	29,5	-0,3634	44,5	-0,3841	59,5	-0,40135
15	-0,3565	30	-0,28175	45	-0,38985	60	-0,414

Source: developed by author

Errors of DUSU *at tossing*

Giving kinematic excitation to the sensor of angle rate in the form of a triaxial swinging with frequency of *0,5 Hz ~*, we obtain the realization of the output signal (Figure 13). The diagram shows the absence of a systematic component in the stochastic structure of the output signal as a whole. The numerical values are given in Table 21.

Table 21

The DUSU output signal at tossing

Orientation of the device body		**φ=0⁰**					
t, s	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***
0,5	-0,0782	15,5	0,2047	30,5	-0,0782	45,5	-0,2277
1	0,0207	16	-0,9177	31	-0,46	46	-0,2047
1,5	0,161	16,5	0,2438	31,5	-0,1081	46,5	0,2438
2	0,161	17	0,0667	32	-1,1661	47	0,0667
2,5	0,161	17,5	-0,1518	32,5	-0,0391	47,5	0,1518
3	0,161	18	-0,9269	33	-0,2553	48	-0,2162
3,5	-0,2806	18,5	1,1339	33,5	0,6854	48,5	-0,184
4	-0,2806	19	-0,2162	34	0,1955	49	-0,1196
4,5	-0,4439	19,5	-0,5313	34,5	-0,3864	49,5	0,2875
5	0,437	20	-0,5129	35	-0,0184	50	-0,3174
5,5	0,0529	20,5	0,184	35,5	0,69	50,5	0,1541
6	-0,2369	21	-0,1196	36	-1,8561	51	0,2139
6,5	-0,1587	21,5	-0,2875	36,5	0,0299	51,5	-0,1679
7	0,1265	22	-0,4899	37	0,0046	52	1,1132
7,5	-0,3611	22,5	0,2323	37,5	-0,0184	52,5	-0,3335
8	0,6831	23	-0,3174	38	-0,0115	53	0,2484
8,5	-0,0644	23,5	-0,1771	38,5	0,0667	53,5	-0,46
9	-0,4876	24	-0,1541	39	-0,0759	54	-0,1081
9,5	0,4462	24,5	-0,2139	39,5	-0,0736	54,5	1,1661
10	1,0787	25	2,0746	40	-0,0782	55	0,6854
10,5	-0,1702	25,5	0,0759	40,5	-0,0207	55,5	0,1955
11	-0,1449	26	0,1035	41	-0,2806	56	0,2001
11,5	-0,2645	26,5	0,1679	41,5	0,2829	56,5	0,0299
12	0,3726	27	0,0529	42	-0,1587	57	-0,2829
12,5	-0,4577	27,5	1,1132	42,5	0,3611	57,5	-0,0368
13	0,4715	28	0,3657	43	-0,6762	58	0,0575
13,5	-0,0161	28,5	-0,3335	43,5	-0,1702	58,5	0,2208
14	-0,2829	29	0,0851	44	-0,2645	59	0,1426
14,5	-0,2277	29,5	-0,46	44,5	-0,4508	59,5	-0,3151
15	-0,3289	30	0,2484	45	-0,0161	60	0,0046

Source: developed by author

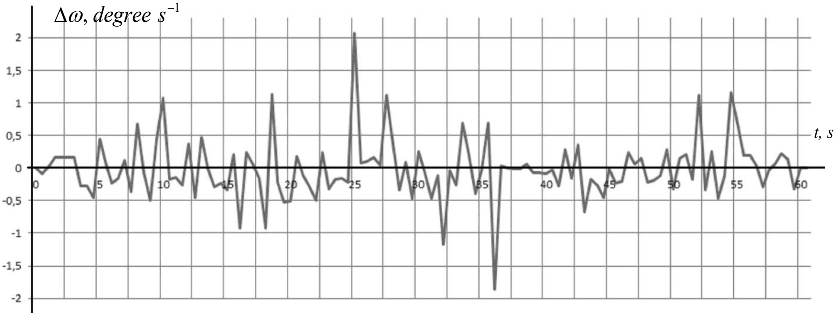


Figure 13. The DUSU output signal on the tossing of the basis

Source: developed by author

A distinctive feature of the signal is the lack of a systematic component in the output signal of the angle rate sensor.

The DUSU errors at a simultaneous action of tossing and ultrasonic radiation

It is of practical interest a comparative analysis of DUSU error for a kinematic effect (tossing) and a joint, simultaneous action of tossing and ultrasonic radiation (Figure 14), Table 22.

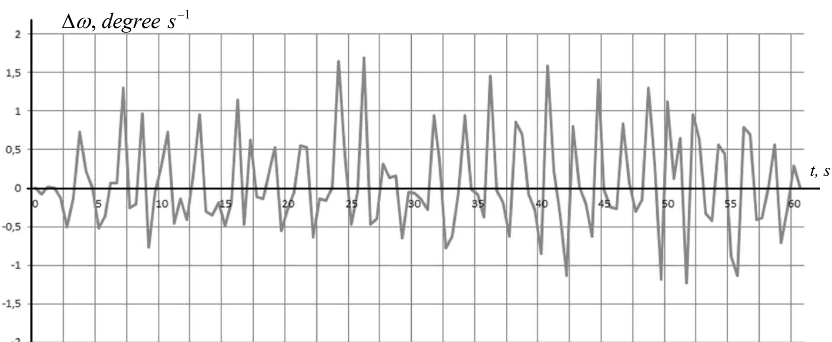


Figure 14. The DUSU output signal at a joint action of tossing and ultrasonic radiation

Source: developed by author

Obviously, the spectrum of the output signal becomes saturated, the range of values is also being increased in *2-3 times* of the signal at one tossing.

A slight systematic component ($0{,}15$ *degree* s^{-1}) is below the sensitive threshold of the device ($0{,}45$ *degree* s^{-1}) and that is why in this context it cannot be the subject of discussion.

Table 22

The DUSU output signal for a joint action on the tossing device and ultrasonic radiation

Orientation of the device body		**φ=0⁰**					
t, s	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***	***t, s***	**Output signal, *degree s⁻¹***
0,5	-0,0828	15,5	-0,1817	30,5	-0,1541	45,5	-0,2392
1	0,0184	16	1,1477	31	-0,2806	46	-0,2622
1,5	0,0069	16,5	-0,4692	31,5	0,9453	46,5	0,8349
2	-0,1242	17	0,6302	32	0,3611	47	0,069
2,5	-0,506	17,5	-0,115	32,5	-0,7797	47,5	-0,3059
3	-0,1196	18	-0,1426	33	-0,6279	48	-0,1472
3,5	0,736	18,5	0,23	33,5	-0,0437	48,5	1,3018
4	0,2254	19	0,5244	34	0,9499	49	0,3082
4,5	0	19,5	-0,5543	34,5	-0,0184	49,5	-1,1845
5	-0,5152	20	-0,2668	35	-0,0828	50	1,1201
5,5	-0,3657	20,5	-0,0552	35,5	-0,3703	50,5	0,1219
6	0,0598	21	0,5474	36	1,4582	51	0,6532
6,5	0,0713	21,5	0,529	36,5	-0,0253	51,5	-1,2259
7	1,3018	22	-0,6325	37	-0,1886	52	0,9522
7,5	-0,2599	22,5	-0,1311	37,5	-0,6233	52,5	0,6394
8	-0,2139	23	-0,1656	38	0,8602	53	-0,3266
8,5	0,9637	23,5	0,0115	38,5	0,6992	53,5	-0,4163
9	-0,7682	24	1,6491	39	-0,0805	54	0,5704
9,5	-0,0529	24,5	0,4232	39,5	-0,2829	54,5	0,4508
10	0,2921	25	-0,4669	40	-0,8487	55	-0,8878
10,5	0,7314	25,5	-0,0437	40,5	1,5893	55,5	-1,1408
11	-0,4554	26	1,6905	41	0,2231	56	0,7866
11,5	-0,1334	26,5	-0,4692	41,5	-0,3588	56,5	0,6969
12	-0,4117	27	-0,3933	42	-1,1362	57	-0,4048

12,5	0,1679	27,5	0,3174	42,5	0,8073	57,5	-0,3887
13	0,9545	28	0,1311	43	0,0207	58	0,00138
13,5	-0,3082	28,5	0,1564	43,5	-0,1909	58,5	0,5635
14	-0,3519	29	-0,6509	44	-0,621	59	-0,7107
14,5	-0,1817	29,5	-0,0552	44,5	1,4053	59,5	-0,2622
15	-0,4968	30	-0,0598	45	-0,0207	60	0,2967

Source: developed by author

This saturation of output nonlinear oscillations, which constitute the error $\Delta\omega$, is explained by the superposition of its components $\Delta\omega_k$ and $\Delta\omega^a$ (that is, kinematic and acoustic components). Moreover, the acoustic component is explained by the influence of Euler inertial forces acting on the impedance surface of the float.

4. Conclusions

A laboratory setup was prepared for conducting experimental investigations of the influence of an ultrasonic beam on a float gyroscope. The ultrasonic system MINI ULTRASONIC CLEANER MODEL 3560 and the ultrasonic emitter unit of the UZP-6-1 type were configured to assess the degree of influence of the beam's angle of incidence on the surface of the cylindrical housing of the float gyroscope. Resonance zones were identified – both near the coincidence angle and at the angles of coincidence of circular waves.

Practical implementation of a buffer zone for the float gyroscope was carried out, along with experimental studies of the gyroscope suspension's response to the ultrasonic beam – specifically, determining the output signal zero-shift and recalculating it into the additional measurement error of the device in an acoustic environment.

A software tool was developed for determining the acoustic transmissibility of the housing under the influence of an ultrasonic beam, aimed at identifying and characterizing the development of resonance-level phenomena. An extreme increase in acoustic transmissibility of the device housing was revealed under varying ratios of symmetric to antisymmetric impedance of the housing material.

Theoretically predicted and experimentally confirmed is the risk of the occurrence, under certain conditions, of a resonance phenomenon in the polyaggregate suspension of the gyroscope – geometric resonance (wave coincidence). This arises in the form of coincidence angles between the trace of the incident and flexural wave in the housing at frequencies above the critical threshold ($\theta_c = 21°07^{/}$;), and between the trace of the incident and circular wave at frequencies below the critical threshold ($\theta_c = 3°41^{/}$). Additional resonance scenarios include the equality between the trace of the frame ring projected onto a plane parallel to the incident plane wave front and the trace of a circular wave, as well as a combined resonance in the gyroscope suspension resulting from the simultaneous variation of parameters in both the approximate and refined models (quasi "acoustically transparent" device housing).

References:

1. Karachun V.V. Dyfraktsiia zvukovykh khvyl na metalevomu kiltsi / V.V. Karachun, V.M. Melnyk, S.V. Fesenko // «Tekhnolohichnyi audyt ta rezervy vyrobnytstva». – 2016. – № 6/2 (32). – P. 4-9.

2. Karachun V. Reduction of technological risks of flight operation by artificial formation of the buffer zone to penetrating acoustic radiation / V. Karachun, V. Melnick, S. Fesenko // «Technology audit and production reserves». – 2017. – № 4/1 (36). – P. 19-24.

3. Karachun V.V. Dyfraktsyia zvukovыkh voln na perekrestnom upruhom sharnyre podvesa hyroskopa / V.V. Karachun, S.V. Fesenko // «Avyatsyonno-kosmycheskaia tekhnyka y tekhnolohyia». – 2017. – № 7 (142). – P. 112-122.

4. Patent na vynakhid № 110911 Ukraina, MPK: G01C 19/20. Poplavkovyi hiroskop / V.V. Karachun, V.M. Melnyk, S.V. Fesenko. zaiavl. 14.05.2015; opubl. 25.02.2016, Biul № 4/2016. – 4 pp.

5. Melnyk V.M. Shtuchne formuvannia zon aktyvnoi turbulentnosti zvukovymy khvyliamy / V.M. Melnyk, V.V. Karachun, S.V. Fesenko // «Mizhnarodnyi naukovyi zhurnal». – 2016. – № 11 (21). – T.1. – P. 85-89.

6. Fesenko S.V. Doslidzhennia osoblyvostei povedinky tsylindrychnoi obolonky v ultrazvukovomu poli / S.V. Fesenko, V.Iu. Shybetskyi // Intehrovani intelektualni roboto-tekhnichni kompleksy (IIRTK-2016): Deviata Mizhnar. nauk.-prakt. konf., 17-18 travnia 2016 r., Kyiv, Ukraina. – K. NAU. – 2016. – P. 61.

7. Dydkovskyi, V.S. Proektyrovanye ohrazhdaiushchykh konstruktsyi s optymalnymy zvuko- y vybroyzoliatsyonnymy svoistvamy [Tekst]: monohr./ V.S. Dydkovskyi, V.V. Karachun, V.Y. Zaborov. – K.: Budyvelnyk, 1991. – 120 p.

Список літератури:

1. Карачун В.В. Дифракція звукових хвиль на металевому кільці / В.В. Карачун, В.М. Мельник, С.В. Фесенко // «Технологічний аудит та резерви виробництва». – 2016. – № 6/2 (32). – С. 4-9.

2. Karachun V. Reduction of technological risks of flight operation by artificial formation of the buffer zone to penetrating acoustic radiation / V. Karachun, V. Mel'nick, S. Fesenko // «Technology audit and production reserves». – 2017. – № 4/1 (36). – P. 19-24.

3. Карачун В.В. Дифракция звуковых волн на перекрестном упругом шарнире подвеса гироскопа / В.В. Карачун, С.В. Фесенко // «Авиационно-космическая техника и технология». – 2017. – № 7 (142). – С. 112-122.

4. Патент на винахід № 110911 Україна, МПК: G01C 19/20. Поплавковий гіроскоп / В.В. Карачун, В.М. Мельник, С.В. Фесенко. заявл. 14.05.2015; опубл. 25.02.2016, Бюл № 4 / 2016. – 4 с.

5. Мельник В.М. Штучне формування зон активної турбулентності звуковими хвилями / В.М. Мельник, В.В. Карачун, С.В. Фесенко // «Міжнародний науковий журнал». – 2016. – №11 (21). – Т.1. – С. 85-89.

6. Фесенко С.В. Дослідження особливостей поведінки циліндричної оболонки в ультразвуковому полі / С.В. Фесенко, В.Ю. Шибецький // Інтегровані інтелектуальні робото-технічні комплекси (ІІРТК-2016): Дев'ята Міжнар. наук.-практ. конф., 17-18 травня 2016 р., Київ, Україна. – К. НАУ. – 2016. – С. 61.

7. Дидковский, В.С. Проектирование ограждающих конструкций с оптимальными звуко- и виброизоляционными свойствами [Текст]: моногр./ В.С. Дидковский, В.В. Карачун, В.И. Заборов. – К.: Будівельник, 1991. – 120 с.