Stand Equipment and Test Methods of Modern Optical Sights

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Abstract

Manufacture of sights with high output characteristics is a prerequisite for achieving the necessary accuracy when shooting. The aim of the work was to analyze the influence of pancratic optical sights' main parameters on their output performance characteristics.

It is shown that in order to achieve the quality level of the world's best samples, high image quality – no drop in contrast by no more than 30 % of the calculated value, careful manufacturing and control of both mechanical and optical parts, as well as components of the assembly units of products, the technological process of assembly and alignment is necessary.

Bench equipment and test methods which made it possible significantly increase the level of serial production are described, also some characteristics of GS3-12×50, GS3-24×56, GS5-25×56 "NTC "LEMT" BelOMO" are presented.

Keywords: pancratic sight, contrast transfer function, resolution, control technique, bench equipment.

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Стендовое оборудование и методики испытаний современных оптических прицелов

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Изготовление прицелов с высокими выходными характеристиками является необходимым условием для достижения необходимых точностей при стрельбе. Целью работы был анализ влияния основных параметров панкратических оптических прицелов на их выходные эксплуатационные характеристики.

Показано, что для достижения уровня качества лучших мировых образцов, высокого качества изображения – непадения контраста на более чем на 30 % от расчётного значения, необходимы тщательное изготовление и контроль как механических и оптических деталей, так и узлов сборочных единиц изделий, технологического процесса сборки и юстировки.

Описаны стендовое оборудование и методики испытаний, позволившие существенно повысить уровень серийной продукции, а также представленны некоторые характеристики прицелов GS3-12×50, GS3-24×56, GS5-25×56 «НТЦ «ЛЭМТ» БелОМО».

Ключевые слова: панкратический прицел, частотно-контрастная характеристика, разрешающая способность, методика контроля, стендовое оборудование.

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Introduction

Progress in development of sniper weapons has provided an increase both in the firing range and in the stability of ballistic parameters [1]. Naturally this puts forward increased requirements for optical sights' whose contribution to high-precision shooting is also important and critical. Existing models of sniper sights presented by domestic manufacturers do not allow firing comparable to the accuracy shown by the weapon [2].

Shooting at long distances requires large optical magnifications which is accompanied by a proportional decrease in the angular field of view. This in turn complicates the task of finding and detecting a target so the use of pankratic sights of variable multiplicity has no alternative [3]. The latter factor makes it relevant and expedient to simultaneously increase not only the optical magnification, but also the difference in the multiplicity of pancratic systems (sights). At the same time the task of ensuring high image quality over the entire optical magnification range becomes more complicated which imposes strict requirements on the optical sight lens which largely determines the quality of the optical image and the pancratic node which must provide large optical magnification differences as well as maintaining and improving high optical image quality over a wider range of optical and mechanical components. In addition it should be borne in mind that the previously mentioned increase in firing range is achieved by increasing the caliber which is accompanied by an increase in mechanical loads on optical parts and assemblies. This fact further complicates the problems of developing and producing high-quality sights [4].

Thus the creation of bench equipment both to ensure a high-performance technological process of assembling and adjusting optical sights, and to control the quality of finished sights is an urgent technical problem without which it is impossible to produce optical products of a high technical level sufficient for the best sniper weapons.

The criteria for sights when working with bench equipment, as well as measurement methods that allow to master the production of optical sights of variable multiplicities (Z4, Z5, Z8) with an increase of up to 40 times which compete in terms of technical level with the best world samples are presented.

High-quality optical sights must have high optical and mechanical characteristics: the maximum resolution value, image contrast in the entire range of the angular field of view of the sight lens both at the values of the maximum resolution and at the values of the resolution greater than the limit, high transmittance of the optical system, immutability of the position of the sighting element – mesh, during and after mechanical action, as well as while working with the elements of the sight (zoom change leash, alignment flywheels, parallactic adjustment leash), smooth operation of mechanisms, no jamming or slippage in their operation.

In connection with the above for an objective assessment several evaluation criteria of these parameters should be set.

1. The maximum resolution of the sight – should differ from the calculated ideal value by more than 30 %.

2. Contrast of the transmitted image on the axis with a resolution behind the eyepiece of 1 shtr/mrad should be at least 0.4, at 1.5 shtr/mrad – at least 0.25, at 2 shtr/mrad – 0.15.

3. Contrast value of the transmitted image at the angle of the field of view of 6° should not differ from the contrast of the transmitted image by more than 50 %.

4. Transmission of the optical system must be at least 90 %.

5. Change in the position of the reticle after exposure to shock and vibration loads, as well as when working with movable elements of the sight should not exceed 0.05–0.1 mrad.

6. Thermal stabilization of the optical system at operating temperatures ±50 °C.

7. Rotation torque of the magnification change drive, parallax should not exceed 70 H·m.

Equipment and measurement methods

Control of basic optical and mechanical parameters guarantees high-quality production of a sight. To carry out such control special equipment is required that allows measuring parameters with high accuracy. The following equipment is used during operation:

1. Universal stand for optical parameters' measurind

The stand (Figure 1) allows measuring characteristics: resolution, optical magnification, diopritic detuning, contrast transfer function (CTF), transmission of the optical system, vignetting, distortion, size and removal of the exit pupil, angle of field of view, stability of the position of the sighting element (when using a special seat). Use of high-resolution video cameras and special software minimizes operator errors that will subsequently affect the final measurement result and also significantly reduces time of changes and the complexity of the process itself which is especially important in mass production.

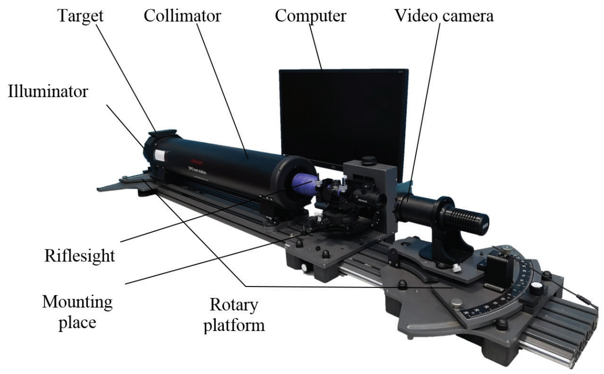


Figure 1 – Universal optical parameter control stand

One of the most important optical parameters that determine the image quality is the CTF. This parameter is more general characterizing the quality of the optical image because it shows a change in the resolution of the image transmitted by the sight depending on the decrease in contrast of the object under consideration at different angles of passage of optical rays [5].

Of course it should be taken into account that quality of the optical image directly depends on the accuracy of the manufacture of optical parts (the decentricity of the manufacture of optical elements, N – permissible sphericity and ΔN – the tolerance field of the surface shape – an interference ring or strip), as well as the accuracy of the installation of optical elements (the decentricity and inclination of the optical axis of the part relative to the axis of the optical system) [5]. Moreover depending on the features of the optical system, the values of these parameters can have a different effect on the image quality. At the same time in order to obtain a high-quality optical system and, accordingly, a device with high output characteristics, such methods should be selected that would contribute to the manufacturability of the device [6, 7].

Figure 2 shows the obtained graphs of the CTF for an optical sight of variable multiplicity with different sphericity and the tolerance field of the surface shape.

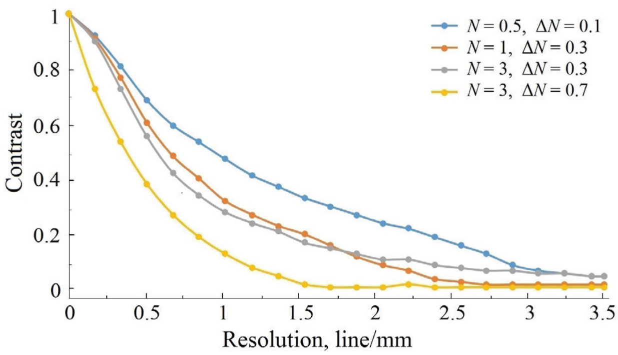


Figure 2 – Graphs of frequency-contrast characteristics with different surface manufacturing quality using the example of the GS5-25×56M1 sight

As can be seen from the graphs, the greatest contribution to improving the image quality is made by the parameter of the tolerance field of the surface shape – ΔN. In this regard, in the manufacture of optical elements, it is important that this parameter has a minimum deviation from the nominal value. Therefore the control of the tolerance field of the surface shape of optical elements is a particularly important part of the control of the parameters of parts and components of the sight.

2. Climate test chamber

Conducting climatic tests in the chamber (Figure 3*a*) implies that in addition to the already standard control of the mechanical parts of the device, such as the maximum resolution, the parallax of the sighting grid, the operation of the backlight, the removal of the aiming line, the quality and purity of coatings, it is necessary to check the sight for the thermal stability of the optical system. Stability of the parameters of the optical system in the operating temperature range is carried out at the stage of optical calculation of the sight by selecting glass grades that allow to exclude or compensate for image defocusing.

Optical sights with a thermocompensated optical system will provide a high-quality optical image and allow you to work with the sight in a larger range of temperature differences.

3. Stands for mechanical tests

Stands for mechanical tests include two types of stands – a stand of vibration loads (Figure 3*b*) and a stand of horizontal shock loads (Figure 3*c*).

On these stands preservation of mechanical and optical parameters is checked, such as the removal of the aiming line, the functioning of electronic components, the rotation of the device elements after exposure to mechanical loads simulating a shot impact and vibration during operation or transportation of the sight.

Vibration load stand allows you to simulate the conditions that arise when the sight is exposed to various kinds of vibrations that will appear during operation, and check the stability of parts, assemblies and their connections for resistance to this kind of loads. The presence of a special device for fixing the device allows moving vibrate along the axes for the most accurate simulation of the processes that occur during operation.

Shock loading stand allows creating conditions that arise when firing weapons of various capacities, and check the sight for strength to shock loads. To accurately recreate the conditions that occur when a shot is fired the stand must strike in a horizontal direction, simultaneously along the optical axis of the device.

4. Leakproofness control chamber

Control chamber which provides an adjus-table level of additional pressure, allows simulating the immersion of the sight in water to a depth of up to 30 m, which allows you to guarantee the tightness of the tested devices under hydrostatic pressure conditions. After this test the sight is subjected to dust protection and sprinkling tests.

This test confirms the full functioning and operability of the sight after exposure to high external pressure which corresponds to the IPX8.

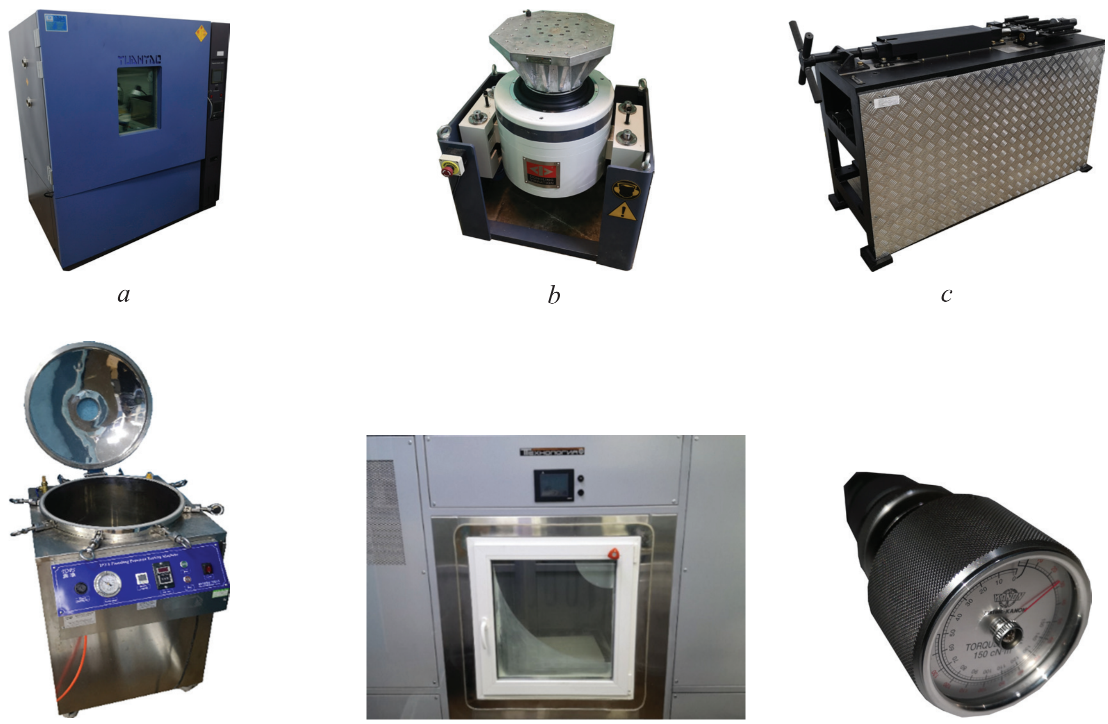
5. Moisture protection class. Dust chamber

Dust protection test chamber of the devices is used to simulate natural weather conditions that occur during a dust storm in which the dust concentration in the chamber is 2 g/m^3, but not less than 0.1 % of the useful volume, with an ambient temperature of 50 °C, or to simulate rain conditions.

These tests make it possible to guarantee the operation of the sight after exposure to dust and the compliance of the sight with the IP6X dust protection class.

6. Torsiometer

One of the most important parameters of the sight, like any other equipment affecting the subjective assessment of the quality of the device is the softness and smoothness of the rotation of the sight elements, the absence of slippage during rotation. This parameter can be checked on a special torsiometer (Figure 3*f*) with attachments adapted for each model of the sight.



a *b* *c*

d *e* *f*

Figure 3 – Bench equipment used for the study of optical sights: *a* – climate test chamber; *b* – vibration test stand; *c* – horizontal shock load stand; *d* – immersion test chamber; *e* – dust chamber; *f* – torsiometer

The leash of the magnification change, parallactic detuning should not rotate spontaneously while working with the sight, however, for comfortable operation of the operator, the rotation moment of these elements for their diameter should not exceed 70 H·m.

The main parameters of the sights created and serially mastered at the STC "LEMT", which are successfully exported including highly developed countries are shown in Table vignetting and CHKX graphs for maximum and minimum magnifications are shown in Figures 4, 5 and 6, respectively.

Table

The main parameters of sights

Type of control and testing	Test parameters				
	GS3-12×50	GS5-25×56M1	GS3-24×56	GS1-8×24	GS1-8×24FFP
Magnification	3–12	5–25	3–24	1–8	1–8
Control of critical lens surfaces	$N = 3$ $\Delta N = 0.3$	$N = 2$ $\Delta N = 0.3$	$N = 3$ $\Delta N = 0.3$	$N = 5$ $\Delta N = 0.5$	$N = 5$ $\Delta N = 0.5$
Shock loads	450 g 1–2 ms	600 g 1–2 ms	450 g 1–2 ms	450 g 1–2 ms	450 g 1–2 ms
Vibration loads	4 g 20–80 Hz 4 g 25 Hz				
Withdrawal of the aiming line	0.1 mrad	0.05 mrad	0.1 mrad	0.1 mrad	0.1 mrad
Transmition	Not less 85–90 %				
Field of view	6.3° 1.95°	3.1° 0.85°	6.6° 0.85°	20° 2.7°	20° 2.7°
Exit pupil diameter	10 mm 3 mm	10 mm 2.1 mm	9 mm 2.3 mm	9.5 mm 3 mm	9.5 mm 3 mm
Thermal loads	-40 °C – +50 °C				
Dust and moisture protection	IP68	IP68	IP67	IP67	IP68
Rotation force of the elements	70 N·m				
Alignment flywheel pitch	0.1 mrad				

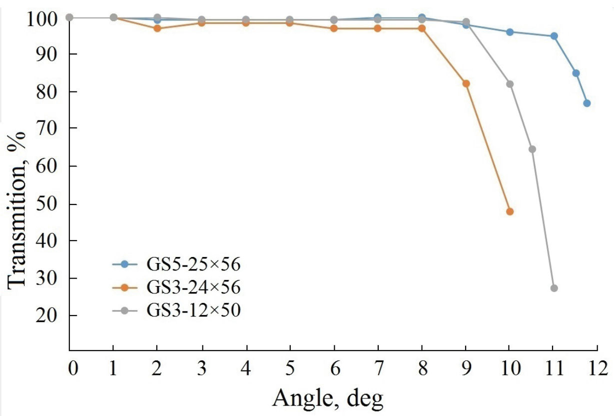


Figure 4 – Vignetting graph of GS3-24×56, GS5-25×56, GS3-12×50 sights at maximum magnification

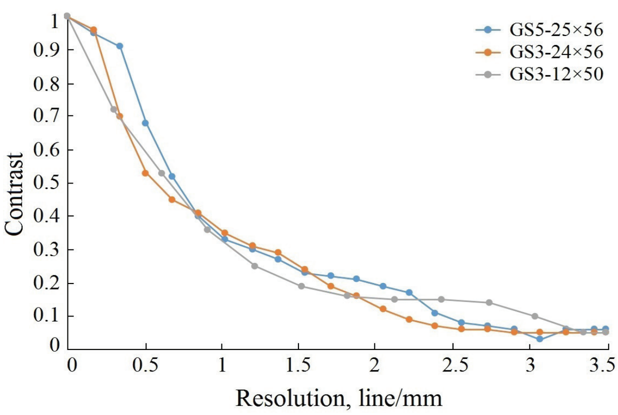


Figure 5 – Plot of the GS3-12×50, GS3-24×56, GS5-25×56 scopes at maximum magnification

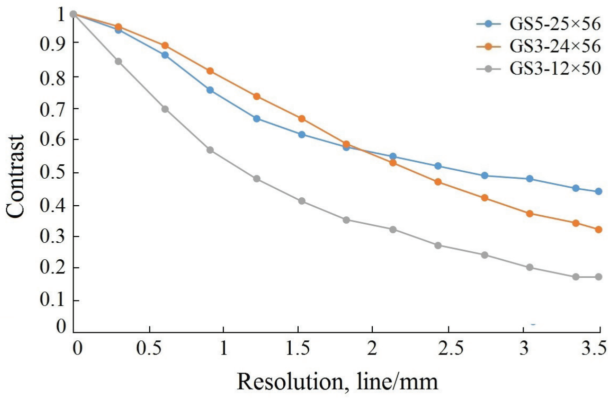


Figure 6 – Plot of the GS3-12×50, GS3-24×56, GS5-25×56 scopes at minimum magnification

Technological aspects of creating modern-level sights are due to the optimization of the manufacture of optical and mechanical parts, the assembly and alignment process, as well as quality control. At the same time the manufacturability and design of the sight is carried out taking into account the available equipment for processing and monitoring parts assemblies and the entire sight as a whole [8]. A special role is given to the choice of the method of fastening parts, optimizing the mechanical processes of applying both optical and mechanical coatings as well as ensuring the purity of the field of view and the absence of scree on all optical elements of the device. However the issue of high image quality of optical sights is solved not only by correcting the decentering and inclination of the optical elements relative to the common optical axis, but also by using high-quality glass, high precision processing of optical elements, matching the position of the optical elements of the pancratic system with the calculated magnification changes and the quality of the antireflection coatings of the optical surfaces of the sight [9].

Conclusion

High optical quality (an optical system can be considered of higher quality if the contrast at the same magnification of the optical system at the same resolution value is higher than the one being compared however for simple distinction the od should not be less than 0.2) can be manufactured only if the manufacturing processes are followed by careful element-by-element and operational control their parameters. Mechanical quality of the device (the absence of jamming during the rotation of the sight elements, as well as sufficient force for rotation – 70 H·m) important also. It is necessary to guarantee the preservation of these parameters at large temperature differences of the external environment – from minus 40 °C to plus 60 °C, high mechanical loads – impacts with acceleration 350–500 g which corresponds to acceleration 3432.3–4905.3 m/s^2.

Compliance with these requirements allows us to withstand all the tests imposed by the modern level of development of small arms and in some cases exceed the requirements for some fundamental parameters for small arms – accuracy of firing (0.2 angular minutes), immutability of the position of the aiming element – grid, stability in a wide range of temperatures which allows us to compete with the world's leading models produced by famous manufacturers.

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