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ИЗВЕСТИЯ

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ГЕОЛОГИЯ ЖӘНЕ ТЕХНИКАЛЫҚ ҒЫЛЫМДАР СЕРИЯСЫ

♦

СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

♦

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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DEVICE FOR AUTOMATED LEVELING

Abstract. The article describes the issue of automation of surface leveling performed during the reconstruction of artificial aerodrome covers. The existing methods of surface leveling using satellite technologies, electronic (digital) and laser rotational levels are described. The main drawbacks of existing methods are analyzed, the essence of which is reduced mainly to the large amount of manual measurements. A new mobile device for automated surface leveling is proposed, the distinctive parts of which are mobile platform, leveling optoelectronic device (LOED) and ultrasonic location block. The LOED includes lenses and a double Charge-Coupled Device (CCD) Matrix. To perform the leveling of the surface in the leveling marking the ends of the leveling lines, which are parallel to the longitudinal axis of the leveling plot is done. The leveling lines fix two points (benchmarks) where elevation points are first-order as compared with elevation points of leveling the surface. Two reference sighting targets on the benchmarks are installed. In the memory of the device such data as: instrumental elevations, elevations LOED and elevations sighting targets, as well as the scanning step are entered. The device LOED is installed to the alignment between sighting targets the position in the alignment of the images of targets on the display are controlled. The device is installed sequentially to the points of scanning the surface along the alignment line and define the readings on the LOED matrixes at the points of leveling the surface during stops or movement of the device on the alignment line.

As a result of measurements in automatic mode, the instrumental elevations along the alignment line with an adjustable scan step are obtained. Such a device due to increased mobility is effective for leveling large and length areas, such as take-off and landing strip, take-off starts, airplane platforms, etc.

Keywords: leveling of the horizontal platform, level, aerodrome covers.

Statement of the problem. For reconstruction of artificial surfacing at airports: take-off and landing strips, take-off starts, runways, airplane platforms, it is necessary to know the individual instrumental elevations of surfacing. In geodesy the technology for determining the instrumental elevations located on this surface was called the leveling of the area.

The analysis of recent research and publications. Recently, in practice of geodetic measurements, satellite technology is increasingly being used [1-7]. They have following advantages in comparison with traditional methods of geodesy: independence from weather conditions, absence of referenced to a geodetic stations (autonomy), obtaining point coordinates in real time.

However, the accuracy of the definition of vertical coordinates (coordinates instrumental elevations), has lower accuracy of the horizontal coordinates definition. The values of coordinates instrumental elevations, used by satellite-based positioning equipment (e.g. GPS), have systematic errors. They arise because during the processing of satellite level data a global geoid's model is used. It does not take into account its local features in the area of observation.

Leveling of the surface can be done using rotational laser levels [8-10]. To do this, the rotational laser level is usually installed in the center of the platform and brought to work. Around the level the area laser radiation is formed. The operator step by step moves the rod to the point of defining instrumental elevations on the surface and readings on rod. Also he uses a detector that can be moved along the rod. The accuracy of the best rotational laser levels is about one millimeter per 10 m from the level. The maximum distance to the rod is 400-700 m.

Surface leveling is performed using electronic (digital) levels [11-13]. For this purpose the level is brought to work condition. The level's telescope is directed on the rod the rod is installed at separate points of the surface. The rod's readings are determined automatically.

Standard calculations for instrumental elevations are performed using the built-in processor. The accuracy of the vertical distance definition is several hundredths of a millimeter - using a invar rod with bar code and about one millimeter - using a standard rod with bar code. The maximum distance from the level to the rod is 100 m.

The laser rotational levels and digital levels, the horizontal coordinates of the leveling points are not determined. Therefore, on the surface it is necessary to designate and fix on the places of rods's installation.

The analysis of the above-mentioned methods of leveling surfaces indicates that the movement of rods or satellite receivers is carried out manually. It is necessary to designate out marking of places of their installation on surface. In the case of a rotational level, records readings are also handled manually.

The purpose of the article. The main purpose of this article is to introduce the new device for automated leveling.

The exposition of research results. The new device [14, 15] for automated leveling (figure 1) contains: mobile device 1; chassis 2; vertical rack 3; operator seat 4; control panel 5; control panel rack 6; leveling optoelectronic device (LOED) 7; the mechanism of rotation block 7-8; ultrasonic location block 9; sighting targets 10; sighting target's racks 11; sighting beam 12; surface of the platform 13.

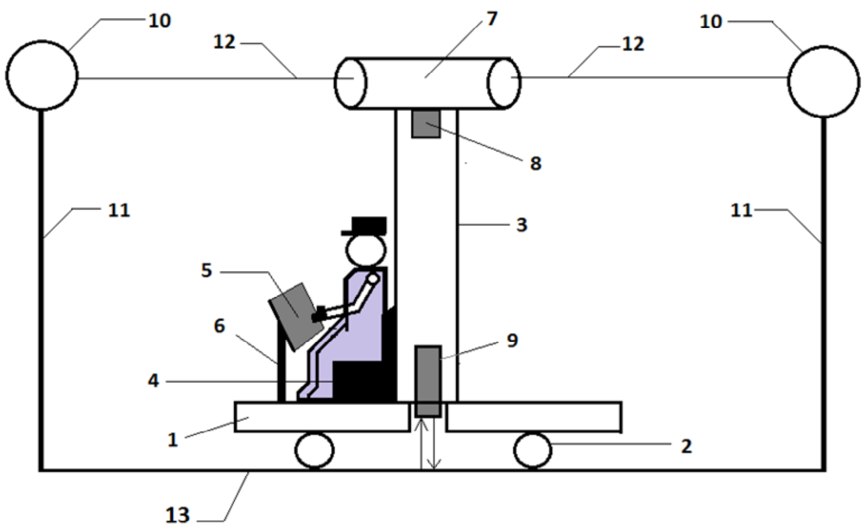


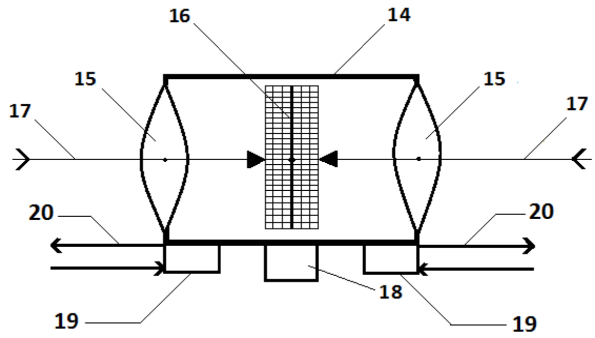
Figure 1 – Automated leveling device scheme:
1- mobile device; 2 - chassis; 3 - vertical rack; 4 - operator seat; 5 - control panel; 6 - control panel rack;
7 - leveling optoelectronic device (LOED); 8 - the mechanism of rotation block 7; 9 - ultrasonic location block;
10 - sighting targets; 11 - sighting target's racks; 12 - sighting beam; 13 - surface of the platform

All components of the device are mounted on a single platform 1 and fixed on the chassis 2. LOED 7 is located on a vertical rack 3. The vertical rack 3 has a mechanism 8 for rotating block 7 on 180° about the vertical axis.

Figure 2 shows the construction scheme LOED [14, 15]: 14 – box LOED; 15 - LOED lenses; 16 is a double CCD Matrix.

From the targets 10 the light beams 17 take on lenses 15. Elements 15 and 16 form two digital cameras. In addition: 18 – the detail of the mechanism 8 the axis rotation of the device 7, controlled from the control panel 5; 19 – light range-finder block; 20 - light-location rays.

Figure 2 –
Scheme of a level optoelectronic device structure:
14 - box LOED; 15 - LOED lenses;
16 is a double CCD Matrix;
17 - light beams;
18 - the detail of the mechanism 8
the axis rotation of the device 7;
19 - light range-finder block;
20 - light-location rays



Sighting targets 10 (see figure 1) can be installed on permanent or temporary (mobile) vertical pillars. In the lower part of the sighting targets, reflectors are installed for light range-finder measurements using blocks 19.

Figure 3 shows the scheme of the device with the main components involved in the measurements [14, 15]: 5 - control panel; 21 - electronic unit for processing information; 7 - LOED; 9 - ultrasonic location block; 10 - high sighting targets; 19 – light range-finder block; 22 - reflectors; 13 - the surface.

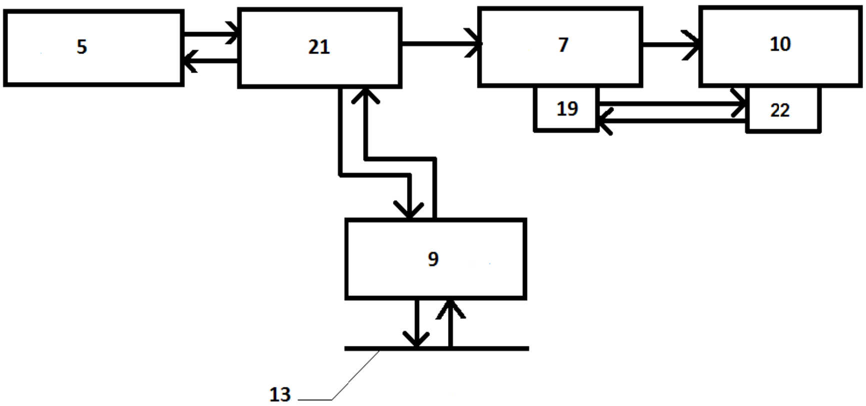


Figure 3 – Automated leveling device main units scheme:
5 - control panel; 7 - LOED; 9 - ultrasonic location block; 10 - high sighting targets; 13 - the surface;
19 - light range-finder block; 21 - electronic unit for processing information; 22 - reflectors

The automatic leveling device operates as follows [14, 15].

1. Preparation for leveling.

1.1. On the surface leveling, marking the ends of the leveling lines, which are parallel to the longitudinal axis of the leveling plot is done. They fix two points (benchmarks) where elevation points are first-order as compared with elevation points of leveling the surface.

1.2. Two reference sighting targets (RST) are installed on the benchmarks.

1.3. On the control panel 5, the data memory is recorded:

- the value of the elevation benchmarks H_{R_1}, H_{R_2};

- the value of the size (height) l of the device 7 relatively to the lower plane of the transducer transmitting ultrasound sensor;

- the value of the elevation points sighting targets (from the center of the sighting target to the benchmark) l_{M_1}, l_{M_2};

- step of surface scanning.

1.4. The operator places the device to the alignment between sighting targets 10. Control of the alignment position and orientation of the inspection axes device LOED 7 are performed on the control panel 5. For this the sighting targets mutual position of the marking on the display screen during the installation and during leveling are evaluated.

2. Surface leveling along the lines alignment of the PST.

The device is installed sequentially to the points of scanning the surface along the alignment line of centers PST 1 and 2. Define the readings a_1 and a_2 on the LOED matrixs at the points of leveling the surface during stops or movement of the device on the alignment line. The vertical distance Δl_i is measured at each point leveling from the surface to the sensitive site of the ultrasonic sensor 17. Then the arrangement of the device on the alignment line by the image of reference datum sighting targets 1 and 2 on the screen of the control panel 5 is controlled. The distances from the LOED 7 to reference sighting target 1 – S_1, to the reference sighting target 2 – S_2 are measured.

At each point the leveling the values are measured:

distances S_1 and S_2;

distance Δl;

readings a_1 and a_2.

These data come from units 7, 9 to the control panel 5, which has such units as computing, memory and storing and recording information unit.

The height of the surface at the scan points can be calculating as:

$$H_i = \frac{1}{2}\left[H_{bM_1} + H_{bM_2} - \frac{(S_1 - S_2)(H_{bM_1} - H_{bM_2})}{S_1 + S_2}\right] - \frac{1}{2f}(S_1 a_1 + S_2 a_2) - l - \Delta l,$$

where $\left.\begin{matrix} H_{bM_1} = H_{R_1} + l_{M_1}; \\ H_{bM_2} = H_{R_2} + l_{M_2}, \end{matrix}\right\}$ is the instrumental elevations of the centers of RST; H_{R_1} and H_{R_2} is the instrumental elevations of reference benchmark R_1 and R_2; l_{M_1} and l_{M_2} is the sighting targets of vertical racks sizes (from benchmarks R_1 and R_2 to targets centers bM_1 and bM_2); f is the focal lengths of digital cameras of a leveling optoelectronic device; S_1 and S_2 is the horizontal distances measured from the optoelectronic device to the sighting targets centers; a_1 and a_2 is the readings in pixel fractions on the targets of the double matrix of the optoelectronic device; l is the length of the rack of the optoelectronic rack from the receiving and transmitting plane of the ultrasonic sensor to the center point of the optoelectronic unit; Δl is the distance from the surface to the receiving and transmitting plane of the ultrasonic sensor.

Conclusions. The new automatic leveling device allows to get the instrumental elevations of the automatic mode in a given alignment line with an adjustable scan step. Such a device due to increased mobility is effective for leveling large and length areas, such as take-off and landing strip, take-off starts, runways, airplane platforms, etc.

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УСТРОЙСТВО ДЛЯ АВТОМАТИЧЕСКОГО НИВЕЛИРОВАНИЯ

Аннотация. В статье рассматривается вопрос автоматизации нивелирования поверхности, выполняемого при проведении реконструкции искусственных покрытий аэродромов. Описаны существующие методы нивелирования поверхности, использующие спутниковые технологии, электронные и лазерные ротационные нивелиры. Проанализированы основные недостатки существующих методов, суть которых сводится в основном к большому объему ручных измерений. Предложено новое мобильное устройство для автоматизированного нивелирования поверхности, отличительными частями которого являются подвижная платформа, нивелирный оптико-электронный прибор (НОЭП) и блок ультразвуковой локации. В состав НОЭП входят объективы и двойная ПЗС-матрица (прибор с зарядовой связью). Для выполнения нивелирования поверхности на участке нивелирования выполняют разметку параллельных продольной оси участка концов линий нивелирования. На таких линиях фиксируют два репера с отметками на класс нивелирования выше, чем нивелирование поверхности участка. На реперы устанавливают две опорные визирные марки. В память устройства вводят данные: отметки реперов, НОЭП и визирных марок, а также шаг сканирования. Устройство НОЭП выставляют в створ между визирными марками, выполняя контроль его положения в створе по изображениям марок на дисплее. Устройство устанавливают последовательно на точках сканирования поверхности вдоль створной линии и снимают отсчеты по матрицам НОЭП в точках нивелирования поверхности во время остановок или движения устройства по створной линии. В результате измерений в автоматическом режиме получают значения высот точек по заданной створной линии с регулируемым шагом сканирования. Такое устройство, благодаря повышенной мобильности, эффективно для нивелирования значительных по площади и протяженности поверхностей, например, взлетно-посадочных полос, грунтовых стартов, рулежных дорожек, перронов аэропортов и др.

Ключевые слова: нивелирование горизонтальной поверхности, нивелир, аэродромные покрытия.

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