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DEVICE FOR NONCONTACT ANALYSIS OF HETEROGENEITY IN THE SOIL

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Abstract*—The necessity of solving the problem of detecting irregularities in the ground is shown. A brief review of existing hardware search irregularities in the ground is given. The principles of action and non-contact sensor design of seismic reception are considered. A device for search irregularities in the ground built on the consideration of the Principles is proposed. The structure of search engine irregularities in the ground with the placement of sensors on unmanned aerial vehicles is considered.*

Index Terms—Irregularity; sensor; unmanned aerial vehicles.

I. INTRODUCTION

Construction of underground gas pipeline sections, water supply, sewage systems often require analysis of the soil of these areas. More important is the information about the soil structure during the repair of underground equipment or its modification. The presence of sinkholes, naturally watered layers, residues of last period of time similar equipment on these areas, leads to complication of the construction process, requires additional hardware, expenditure of time and expense**.**

The lack of information about the soil state often results in an emergency. The first example of non-uniform ground is shown in Fig. 1. As was reported by means of the mass media (MSM), trunk sewer fell in Zaporozhye in July, 2015 (Fig. 2). The waters of the Dnieper were heavily contaminated.

Fig. 1. An example of non-uniform ground

In addition to the collector, the water main was damaged. Several districts of the city were left without drinking water. This event was caused by the shift of the soil after heavy rains. The control of the soil watering allowed taking the measures to avoid the accident. At the beginning of August, 2015 there was a similar situation in Kyiv. It was limited the water supply of 3 districts of Kyiv. Such situations occur almost on the whole territory of Ukraine, in particular, there are reports from Zhitomir, Uzhgorod, Belaya Cerkov, Ochakov (Nikolaev water supply) and others.

Fig. 2. Accident trunk sewer

Track-laying in the area, where the possibility of presence of ammunition remnants is present, is particularly important. Typically, there is no the information about such areas territory. Today, these problems are even more acute in connection with the events in the east of Ukraine.

Thus, it is obvious that it need to develop a device that would determine the characteristics of the territory, which is planned for laying the track: the heterogeneity of the soil, the depth of any heterogeneity in the soil, the presence of metallic and nonmetallic objects.

II. ANALYSIS OF PROBLEM

At present, reliable and practical polymer or plastic pipes are more and more widely used. Due to the high performance capabilities and simplicity of installation they confidently ousted shot-lived steel pipes in water supply, heating and sewerage lines. In order to prevent accidents which may occur at the lines construction elements shift, it is necessary to provide regular monitoring of the pipelines in accordance with the rules of operation. In the event of

an emergency of such channel, quick search of location of an accident is necessary.

To ensure the safety of people it is of particular importance to search and detect the plastic mines during the track-laying in areas of former armed conflicts (as an example of Iraq).

From the above it is obvious that it need the development of technical means system, which can realize the detection of heterogeneities in the soil with the help of remotely controlled noncontact device.

III. Search of Ways of Decision

Review of existing devices showed the following. For searching of metal objects currently the most widely is used the induction metal detectors IMS-2, built on the principle of electromagnetic induction. The detection objects depth – not more than 1 m. The device is intended for manual usage. As the portal In Future reports, to find plastic mines the developed technique involves analyzing the temperature of the soil in three dimensions using specific software and hardware. The technology is expensive and has very limited performance. The considered devices do not allow solving the problems described above.

It is necessary the development of a device which senses both metallic and non-metallic objects.

In order to find technical means suitable for detection heterogeneities in the soil, there was performed the analysis of operation principle and functioning of devices with capacitive transducers with an "open" field. In particular, the device for non-contact receiving of seismic signals shown in Fig. 3 [1] has been developed. The device sensor is a textolite disk (base). On the bottom surface there are located high-potential (emitting) electrode which have a ring shape and covering an outer part of a base, and low-potential (receiving) electrode, which have a disk shape and arranged at the center of the base. In the gap between the disc and the ring there is placed a screen. The base upper plane is also a screen and is electrically connected to the lower screen. The described system of electrodes is a capacitor with an "open" electromagnetic field. The sensor capacitor is included in the transformer bridge measuring circuit [2]. After the sensor putting into the checkpoint the bridge is balanced by a balancing capacitor. The electromagnetic field generated by the system of electrodes, penetrates into the subsurface layer of the Earth. When there appears an electromagnetic field of volumetric longitudinal wave (wave of compression-expansion) the bridge becomes to be unbalance synchronous to the movement of the waves. This is due to the fact that the volumetric seismic wave changes the density of the medium and, therefore, its dielectric constant. Dielectric constant change, in turn, changes the capacitance of the sensor.

In order to determine the parameters of the developed device it was manufactured the preproduction model and conducted laboratory and field experimental studies.

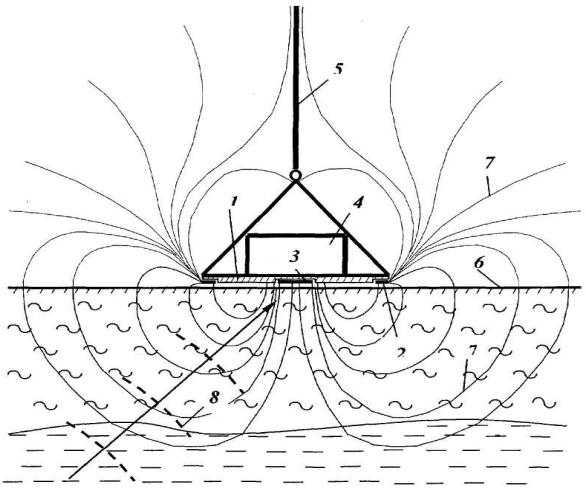

Fig. 3. Electro-capacitive receiver of seismic signals: *1* is the electro-capacitive converter; *2* is the high-potential electrode; *3* is the low-potential electrode; *4* is the measuring unit; *5* is the geophone suspension; *6* is the terrestrial ("daytime") surface; *7* is the force lines of the transmitter electromagnetic field; *8* is the density elastic waves

The experimental studies results have shown that the developed device allows realizing the noncontact receiving of seismic signal which, as noted above, carries information about the presence of an electromagnetic field in the space of the sensor area (zone), having a dielectric constant different from the environment dielectric constant. Thus, it is evident that when the body with a dielectric constant different from the environment, moves in the region of the sensor electromagnetic field, the sensor output signals parameters will carry information about its movement.

Analysis of the functioning of the above considered geophone shows that the described phenomenon can be used as the basis of the action principle of the device, which will be used to find heterogeneities in the soil. For the development of sensor design and structure of search system it was reviewed the results of studies of similar devices intended for usage in special purposes aviation. In particular, the automatic control system for helicopter landing on a limited area [3], the system of stabilizing the helicopter position symmetry relatively the gas pipelines during the control of gas leaks by the thermal imager (Fig. 4). The developed structure of the electro-capacitive converter electrodes placement in the helicopter generates an electromagnetic field which is sufficiently similar in configuration for solving of assigned task.

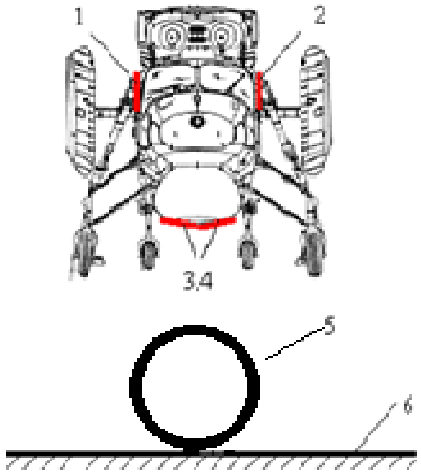

Fig. 4. Scheme of placing of capacitive sensor electrodes elements e symmetrically are on the Ka-25: *1*, *2* are high-potential electrodes, low-potential electrodes; *3*, *4*, *5* is the gas pipeline; 6 is the ground's surface

As seen from the characteristics (Fig. 5) at a certain distance from the pipeline $C_{13} = C_{24}$. During approaching to the pipeline capacity balance is disturbed, as the configuration of the electromagnetic field is distorted on the left side of the helicopter. The configuration changes and from the right side of the helicopter of the electromagnetic field, approaching to the pipeline. As the measuring circuit reacts to the differences of capacities, then the achievement of a symmetric arrangement of the helicopter over the pipeline has the expression $C_{13} - C_{24} = 0$.

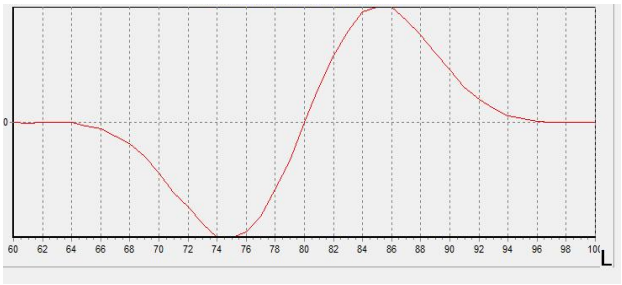

Fig. 5. Static characteristic of symmetry meter

The similar sensor will react on non-metallic objects. For this purpose, as it was discussed above, it is enough that the dielectric permeability of the object should be different from its environment.

Development of measuring technology, the introduction of unmanned aerial vehicles in various applications and computerization of automation technical means of management allows to create a search engine irregularities in the ground.

Review and analysis of measuring devices suitable for the usage in the discussed devices [3], [4] shows that transformer measuring bridges are the most suitablest. The main features of the bridge measuring circuits are high stability, good steadiness from the influence of external electromagnetic disturbances and internal stray electrical and magnetic contacts, wide frequency range and exceptional flexibility that provides different measuring modes and opportunities in dealing with the diverse functional problems.

To perform a safe and operative search of irregularities in the ground in a given area of the territory the elektrocapacitive sensor (see Fig. 4) is planed to be placed on unmanned aerial vehicle (UAV) which is controlled remotely.

The scanning system in a given area can be constructed using satellite systems or ground beacons of a close navigation. In our opinion, a system of radio beacons for special purposes is more acceptable. The scanning system consists of 2 beacons, UAV with heading meter, radio compass and a capacitive sensor on the external load located on it, and also with ground support equipment for the formation of a predetermined flight trajectory and remote traffic control of the UAV. Ground equipment is PEOM, a programmer and a communication block with the UAV. Scheme of the UAV is shown in Fig. 6. For a more accurate determination of coordinates of UAV it is necessary to use applying of 3 beacons.

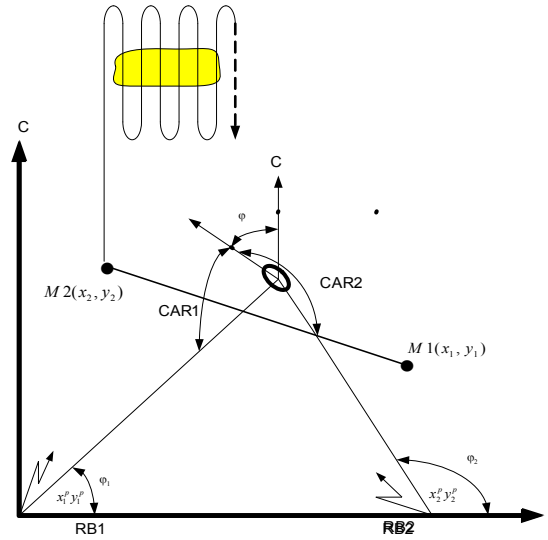

Fig. 6. Generalized scheme of flight along a predetermined path

The line of predetermined path (region $M\,1(x_1, y_1)$, $M\,2(x_2, y_2)$).

$$Y = x(y_2 - y_1)/(x_2 - x_1) - x_1(y_2 - y_1))/(x_2 - x_1) + y_1,$$

$y = \mathrm{tg}(\varphi_1)x$ is the radio ray of 1 pendulum;

$y = \mathrm{tg}(180^o - \varphi_2)x + x_2^r$ is the radio ray of 2 pendulum.

Currently review and analysis of the existing UAV shows the presence of a wide range of devices. All of them are divided into two basic types: the type

of aircraft and helicopter. To solve this problem, of course, helicopter is the most applicable type. Analysis of device parameters showed acceptability of UAV "Monolith", which is the development of the company "Erkar", director and chief designer of SKB "Erkar" Y. T. Leshchenko.

This is the apparatus of vertical take-off and landing. The horizontal speed of the UAV is up to 50 km / h. The flight range – up to 5 km. The maximum duration of the flight – 2 hours. Maximum take-off weight of the device – 13.2 kg. The actual load – 2 videocameras (wide and with narrow-angle) with a total weight of 2 kg. The machine uses the Korean system of radio control of aircraft models. The management is manual, remote. The device is ready to flight and runs in the sky for 5 minutes.

The unit is installed by German engine ZDZ-80. Motor weight – 1.8 kg, power – 8 h. p., maximum turns are 8000. The engine has been modified in the laboratory of SKB "Erkar".

It is proposed to create a search engine irregularities in the ground, using the above discussed devices.

IV. Conclusion

The necessity of solving the problem of detecting irregularities in the ground is shown. A brief review of existing hardware search irregularities in the ground is given. The principles of action and non-contact sensor design of seismic reception are considered. A device for search irregularities in the ground built on the consideration of the Principles is proposed. The structure of search engine irregularities in the ground with the placement of sensors on unmanned aerial vehicles is considered.

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А. П. Козлов, О. С. Юрченко. Пристрій безконтактного аналізу неоднорідності ґрунту
Показано необхідність вирішення проблеми виявлення неоднорідностей в ґрунті. Наведено короткий огляд існуючих технічних засобів пошуку неоднорідностей в ґрунті. Розглянуто принцип дії і конструкція датчика неконтактного прийому сейсмосігналів. Пропонується пристрій для пошуку неоднорідностей в ґрунті, побудований на розглянутому принципі. Розглянуто структуру системи пошуку неоднорідностей в ґрунті з розміщенням датчика на безпілотних літальних апаратах.
Ключові слова: неоднорідності ґрунту; система пошуку; безпілотний літальний апарат.

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А. П. Козлов. А. С. Юрченко. Устройство неконтактного анализа неоднородности грунта

Показана необходимость решения проблемы обнаружения неоднородностей в грунте. Приведен краткий обзор существующих технических средств поиска неоднородностей в грунте. Рассмотрены принцип действия и конструкция датчика неконтактного приёма сейсмосигналов. Предлагается устройство для поиска неоднородностей в грунте, построенное на рассмотренном принципе. Рассмотрена структура системы поиска неоднородностей в грунте с размещением датчика на беспилотном летательном аппарате.

Ключевые слова: неоднородности грунта; система поиска; беспилотный летательный аппарат.

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