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USING ELECTRO HYDRAULIC CONTROL SYSTEMS FOR BUILDING EARTH DAMS

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Lucrarea prezinta o aplicație a servomecanismelor electrohidraulice [1], [2] de reglare a poziției cu reactie prin laser, importanta în cresterea calității execuției barajelor de pământ din amenajarile hidroelectrice. Acest tip de servomecanism este fabricat de firma TOPCON-Japonia în construcție modulară, specifică tuturor tipurilor de utilaje terasiere de nivelare cu acționare hidraulică a organului de lucru (cupa sau lama). Aspectele originale ale lucrării constau în:
- simularea numerică şi identificarea experimentală a servomecanismului [3], [4];
- realizarea unui dispozitiv care reproduce în laborator condițiile de funcționare a servomecanismului hidraulic montat pe utilajul de nivelare.

The paper presents an application of the electrohydraulic servomechanisms [1],[2] used for regulating position, with laser reaction, important for improving operational quality when performing land dams in hydroelectric arrangements. This type of servomechanism is manufactured by the Japanese firm TOPCON, having a modular structure, specific for all the fluid powered land levelling equipment (with scoop or blade) The originality of the paper is due the following:
-numerical simulation and experimental identification of the servomechanism [3],[4];
-accomplishment of a device which reproduces in laboratory the operational conditions of the hydraulic mechanism mounted on the levelling equipment.

Keywords: servomechanism**,** dams**,** laser**,** hydroelectric

1. Introduction

Longitudinal dikes (Fig.1) which prolong transversal dams on riverbeds, are like land dams, the only difference being that transversal dams are parralel with the river flow. These dikes are permanent, being subject to the water action most of their lifespan, having the function of limiting the flooded area by generating an accumulation lake.

The dam body is made of land taken from loan pits near the dam. The ground must have a certain granulometry, with well defined proportions for

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particles of different diameters. For a good compaction, the ground must be set in layers of a certain thickness, so that compaction performed before is laid down the next layer to be evenly done on the entire breadth. If the optimum breadth is not observed properly, according to the type of compaction equipment it will lead to an overcompaction of the dam crowning, which may generate water flood and infiltrations through the dam body.

For preventing this, the authors propose to adjust the breadth of a ground layer before its compaction, by leveling it with a special equipment created for this operation, provided with TOPCON laser controlled modular systems, manufactured in Japan, or SPECTRA PRECISION or APACHE, manufactured in USA.

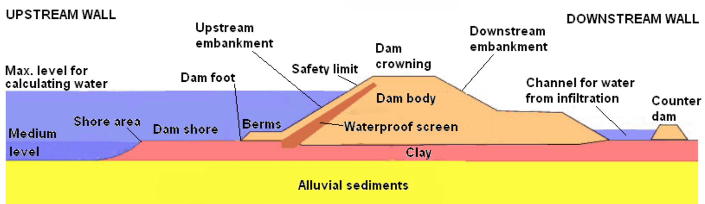


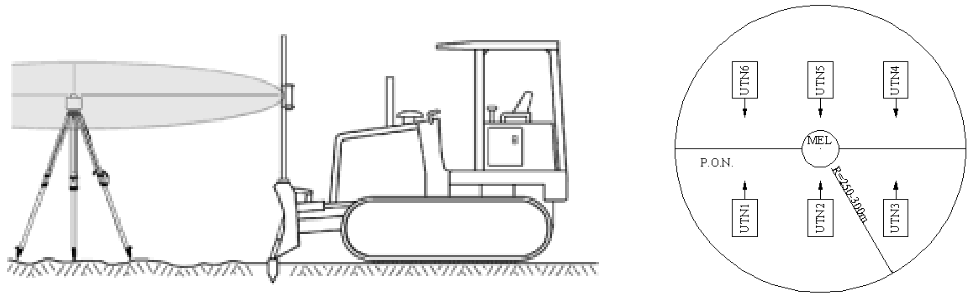
Fig. 1. Section through a dike.

The objectives of the paper are as follows: a brief presentation of the TOPCON laser controlled modular systems, created for the leveling equipment [5], a presentation of the device which simulates the operational conditions of TOPCON [6], the numerical simulation and experimental identification of the TOPCON laser controlled modular system mounted on the test device [8] which forms an electrohydraulic servomechanism for regulating the position with laser reaction [9].

2. Laser modular systems made for equipping the ground leveling installations

The leveling technology which uses laser, Fig.1, implies a leveling performed by a complex installation, equipped with laser controlled modular system, able to perform work from two passes, a rough leveling and a fine one at finish, with deviations from the reference plane of max. 2.5 cm on the entire leveled surface with a significant reduction of the tracking, transposition and materialization process during the leveling project.

The modular mechatronic system with laser, electronic and electrohydraulic components, which allows reaching this leveling technology may be mounted on any land leveling equipment whose work bodies, scoops or blades are hydraulically powered. It is conceived as an additional option of the land leveling equipment, which offers the possibility of leveling land automatically, without any human error regarding precision.



a) b)

Fig. 2. The laser leveling technology: a) mount the laser modules transmitter and receiver; b) automatic leveling after an optical leveling plan PON performed simultaneously by 6 land leveling equipments UTN.

In the classic acception, land leveling controlled by laser systems implies a modular system with the following structure:

The laser transmitter placed in the center of the surface to be leveled above a point with a known quote mark, on a tripod which may be adjusted vertically, emitting a laser beam in its rotation movement. This generates the laser reference plane or the optical refence plane (with programming options for the longitudinal and transversal slope in the forward direction) followed by the work body of the equipment during leveling. After setting the slope needed at leveling, the laser transmitter positions itself automatically.

The laser receiver, whose support is connected to the work body of the land leveling equipment, intercepts the laser fascicle generated by the laser transmitter and transmits altimetric information, namely the position of the work body accountable to the laser reference plane, to an electronic control and monitoring module, placed in the cabin of the land leveling equipment.

The electronic monitoring and control module which connects and amplifies the received laser information, compares it with a prescribed dimension specific for the leveling quote value, finds the error and emits a prompt for cancelling error, towards an electrohydraulic drive system.

The electrohydraulic system controlled by the electronic module has the role of driving the hydraulic cylinders of the blade for maintaining the work body in the leveling plane set by the leveling project, plane which is parallel to the laser reference plane.

In Fig.3. different types of land leveling machines equipped with modular systems may be noticed.

Fig. 3. Leveller and autograder equipped with laser controlled modular systems.

3. Device for simulating the real operational conditions of the laser module on the equipment

In Fig.4,a is shown the laboratory test device which simulates the real behavior of the TOPCON laser controlled modular system created for equipping the automatic land leveling machines in horizontal plane. Fig.4,b shows the mode of equalization of the device with the simulation model from AMESim.

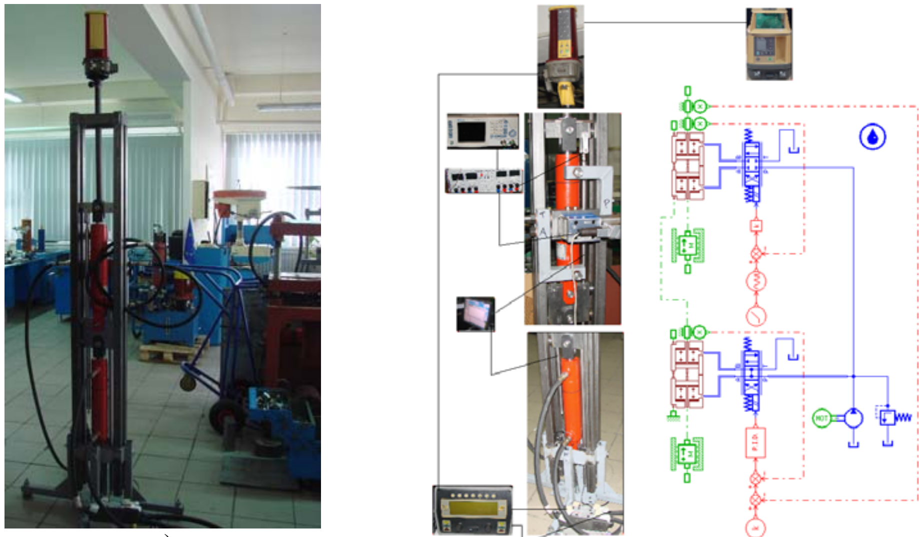
On the rod of the upper hydraulic cylinder is fixed the laser receiver which may move by the action of the upper cylinder, bottom cylinder or both. The device for testing the laser controlled equipment includes two electrohydraulic servomechanisms that simulate first the real behavior of the upward-downward hydraulic cylinders of the blade of the land leveling machine, and, second, the profile of the land to be levelled.

The first servomechanism contains a hydraulic cylinder similar to the one mounted on the machine, supplied from the hydraulic delivery block TOPCON depending on the level of detection of the laser reference plane, generated by a rotary laser transmitter TOPCON.

The second servomechanism consists of a hydraulic servocylinder controlled by a proportional valve with integrated electronics, by means of a data aquisiton system, a PC and the specialised soft TEST POINT.

The TOPCON electronic block receives electric signal from the laser receiver, placed on the rod of the upper cylinder from the device. The signal size varies depending on the level of detection of the optical reference plane, generated by the rotary laser transmitter. The prompt sent to the proportional valve of the TOPCON hydraulic kit is proportional with the detection level. According to this prompt, the rod of the bottom cylinder pulls or pushes the body of the upper cylinder in reverse direction to that of displacement of the cylinder rod.

The upper cylinder is controlled in close loop by means of a servocontroller. By means of a signal generator, it simulates various profiles for the uneven land. The two inductive transducers of linear displacement of the cylinders are connected by means of a data acquisition system to a PC where the TEST POINT program is installed.



a) b)

Fig. 4. Device for testing the TOPCON laser controlled modular system, a)photo device b) equalization of the device with the simulation model from AMESim.

4. Numerical simulation and experimental identification of the laser controlled modular system used for equipping the leveling machine in horizontal plane

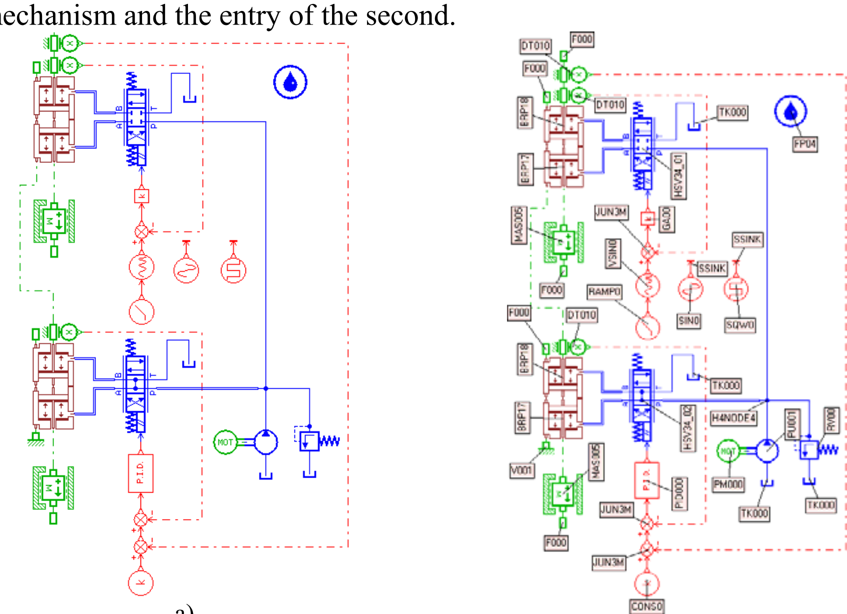
For the numerical simulation of the laser controlled modular system simulation in AMESim was used [7], namely the model shown in Fig.5 All the components of the simulation model are based on mathematical models of differential equations, validated by practice; the method of numerical integration of differential equations is automatically chosen. If the model is not correct or the inner and outer parameters are not properly determined, the program does not work, because the system of differential equations is incompatible or undetermined.

The simulation model represents an electrohydraulic servomechanism for regulating the position with laser reaction. It includes two inner regulation loops and an outer loop.

The first inner loop is set at the level of the hydraulic servomechanism of simulation for uneven land which is excited at entry with rectangular, sinusoidal signals, constant and variable.

The second inner loop is set at the level of the servomechanism of monitoring with laser control which is similar to the TOPCON laser controlled modular system.

The outer loop of regulation is done between the exit of the first servomechanism and the entry of the second.



a) b)

Fig. 5. Model of simulation in AMESim for a TOPCON laser controlled modular system mounted on a testing device a) simulation model b) components simulation model.

In fig.6…12, some of the numerical simulations are shown as follows:

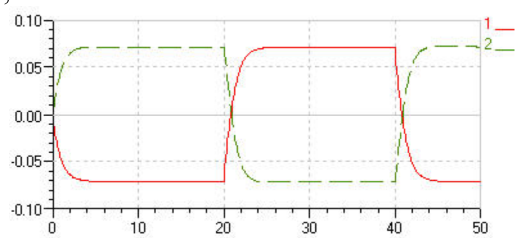


Fig. 6. The answer of the laser monitoring servomechanism at exciting the servomechanism which generates profile with rectangular signal.

In Fig.6, the servomechanism generating profiles of uneven land is excited with a rectangular signal with an amplitude of 0.14 m and a frequency of 0.05 Hz in an interval of 50 s.

1- Represents the displacement of the rod of the generator servocylinder [m].
2- Represents the displacement of the monitoring servocylinder rod and the body of the generator servocylinder [m].

By the algebraic sum of the graph from Fig.6, the curve 3 from Fig.7 results. In the terminology related to the operation of automatic land leveling after a horizontal plane, curve 3 represents the deviations of the profile of the levelled land from the optical horizontal reference plane.

These are present only in the zone of stage jumping last 2 s and have a max.value of 0.01 m.

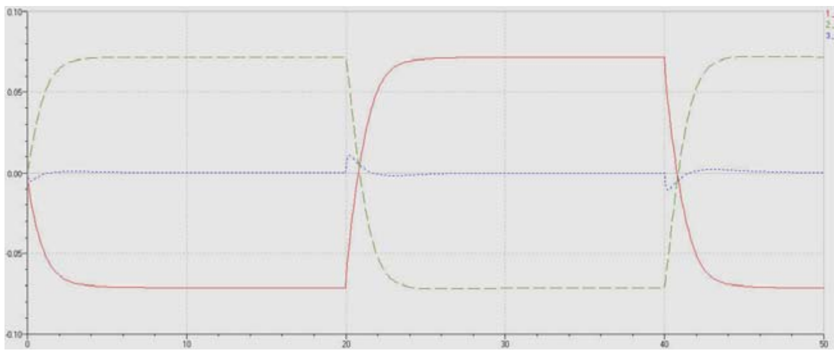


Fig. 7. Deviation profile leveled land from the optical reference plane.

In Fig.8, the servomechanism generating the profile of uneven land is excited with a constant sinusoidal signal with an amplitude of 0.14 m and a frequency of 0.05 Hz lasting 50 s. The meaning of the curves 1 and 2 is the same with that from Fig.6.

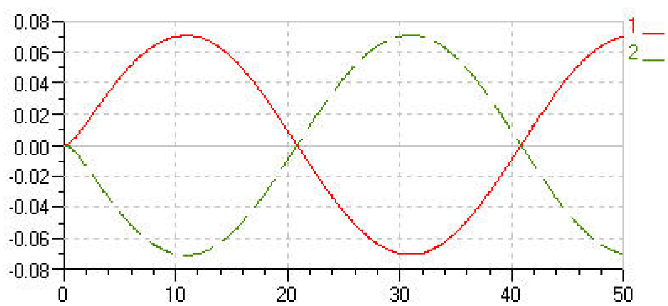


Fig. 8. The response of the laser monitoring mechanism at exciting it with constant sinusoidal signal.

By the algebraic sum of the graph from Fig.8, it results the curve 3 from Fig.9. with the same meaning as that from Fig.7. The errors are negligible with max.values below 0.002 m.

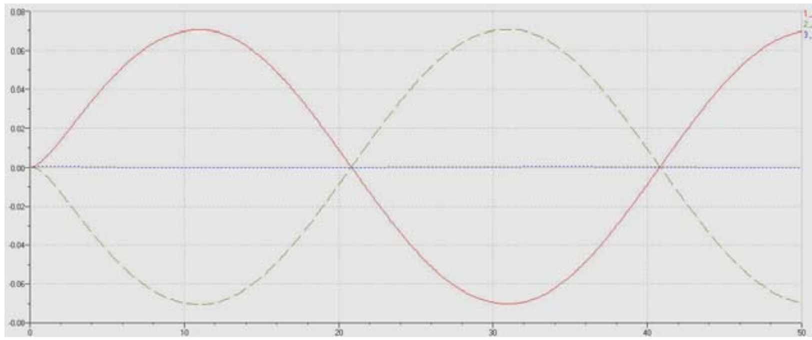


Fig. 9. Deviation profile leveled land from the optical reference plane.

In Fig.10, is shown a method for emitting in AMESim a sinusoidal signal with variable amplitude and frequency: over the sinusoidal signal with variable frequency and constant amplitude is superimposed a ramp signal, after this the two signals being composed. For the component signals, there is a model in AMESim but not for the composed signal.

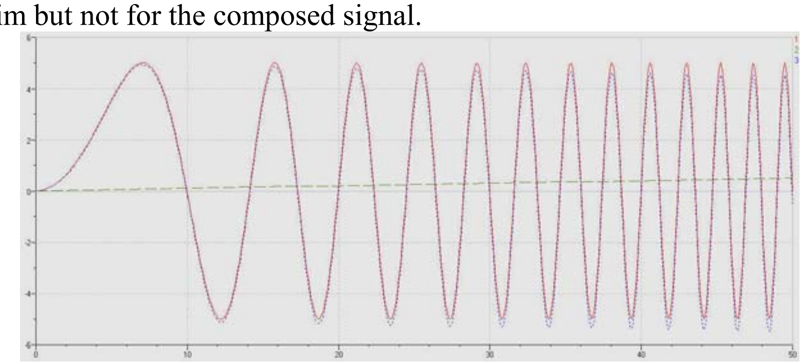


Fig. 10. The formation of a sinusoidal signal with variable frequency and amplitude.

The meaning of the curves from Fig.10. is the following: 1- sinusoidal signal with variable frequency max frequency 0.5 Hz and amplitude 0.1 m 2 – ramp signal sinusoidal signal with variable frequency and amplitude.

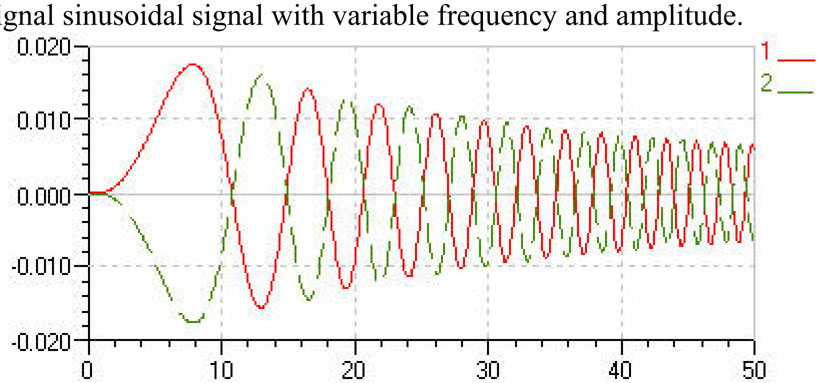


Fig. 11. The response of the laser monitoring servomechanism at exciting the servomechanism generator of profile with variable sinusoidal signal.

In Fig.11, the servomechanism generator of uneven land profile is excited with a variable sinusoidal signal of the shape shown in Fig.10 with an amplitude of 0.14 m and a frequency of 0.05 Hz lasting 50 s. The meaning of the curves 1 and 2 is the same as that shown in Fig.6.

By the algebraic sum of the graph from Fig.11, it results the curve 3 from Fig.12, with the same meaning like that presented in Fig.7. The errors are negligible with frequencies below 0.8 Hz and a maximum value of the deviation of 0.004 m.

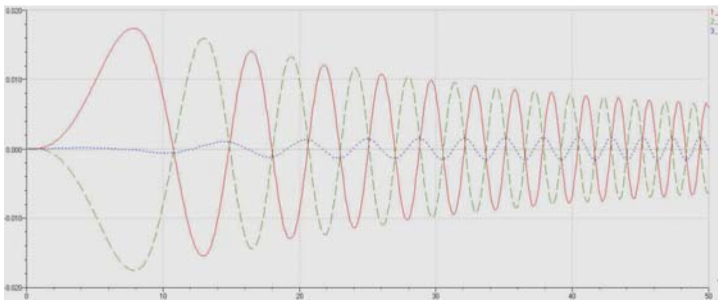
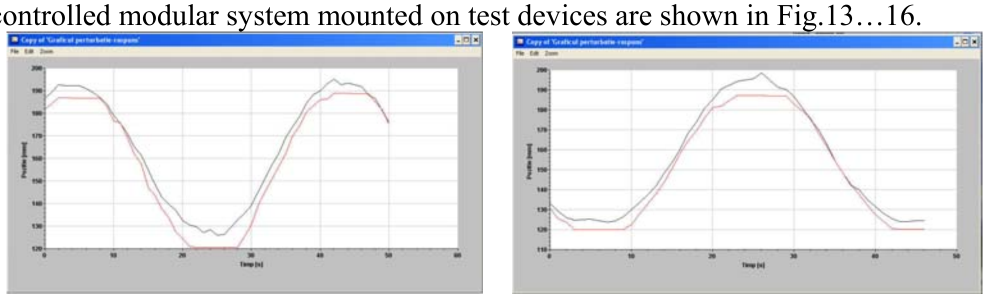


Fig. 12. Deviation leveled land profile from the optical reference plane.

The results of the experimental identification of the TOPCON laser controlled modular system mounted on test devices are shown in Fig.13…16.



a) b)

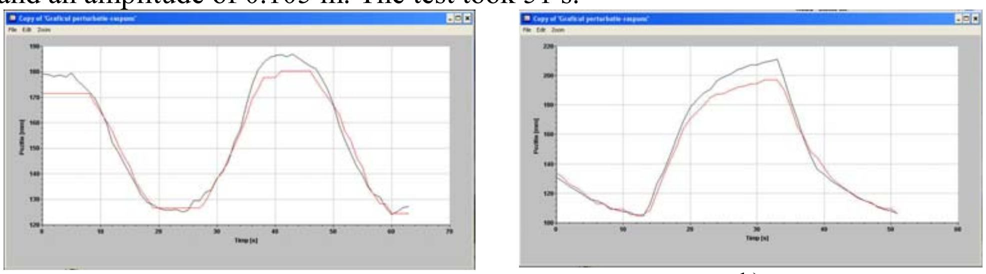
Fig. 13. The answer of the laser monitoring mechanism at the excitation of the servomechanism generator of constant sinusoidal signal profile.

In Fig.13.a) is shown the dynamics of the laser control hydraulic monitoring system when at the entry of the hydraulic mechanism generator of uneven land profiles is applied a constant sinusoidal signal with a frequency of 0.025 Hz and an amplitude of 0.072 m. The test took 50 s and proved a proper dynamic of deplacement of the monitoring servosystem (red) towards the generator of uneven land profile (black)

The graph from Fig.13, b were obtained by repeating the test with the same frequency of the sinusoidal signal of excitation 0.025 Hz but with a higher amplitude 0.080 m The test took 46 s and the results show a proper behavior of the monitoring servomechanism with laser control.

In Fig.14,a is shown the dynamic of the monitoring hydraulic servosystem with laser control, when at the entry of the hydraulic servosystem generating uneven land profiles is applied a constant triangular signal with a frequency of 0.025 Hz and an amplitude of 0.060 m which takes 63 s. The test proves the proper work of the laser controlled servomechanism.

In Fig. 14,b is shown the dynamic of the hydraulic servosystem with laser control when at the entry of the hydraulic servomechanism generator of uneven land profiles is applied a constant rectangular signal with a frequency of 0.025 Hz and an amplitude of 0.105 m. The test took 51 s.



a) b)

Fig. 14. The response of the laser control monitoring mechanism at the excitation of the servomechanism generator of profile with triangular signal: a)rectangular; b) constant.

At all tests presented in Fig.13-14, the inductive transducers of linear displacement of the hydraulic cylinders were set in such a way that the two graph are superimposed for noticing easily the dynamic behavior of the hydraulic servomechanism with laser control.

For the test from Fig.15, which uses constant sinusoidal excitation signal, the inductive transducers of linear displacement of the hydraulic cylinders were set as to offer information regarding to the real direction of displacement of the cylinders.

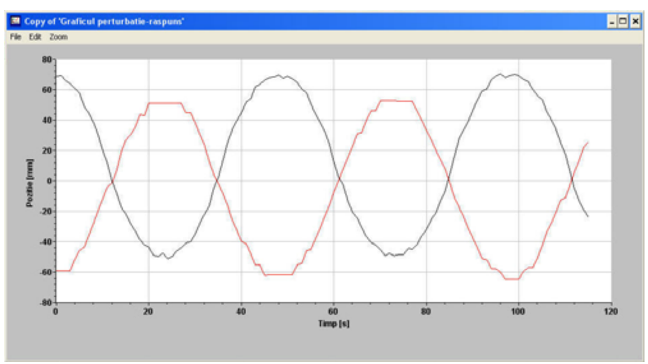


Fig. 15. The response of the laser monitoring servomechanism at the excitation of the servomechanism generator of profiles with constant sinusoidal signal.

In Fig.15, it is shown the dynamic of the hydraulic system with laser control when at the entry of the hydraulic mechanism generator of uneven land profiles is applied a constant sinusoidal signal with a frequency of 0.020 Hz and an amplitude of 0.120 m. The test took 120 s.

In Fig.16, it is shown the dynamic of the hydraulic monitoring system with laser control at the excitation of the mechanism generator of variable sinusoidal signal with a frequency of 0.010…0.100 Hz and an amplitude of 0.115…0.034m. The test took 694 s.

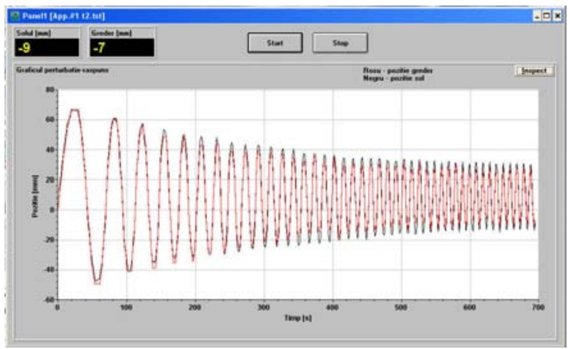


Fig. 16. The response of the laser monitoring servomechanism at the excitation of the servomechanism generator of profiles with variable sinusoidal signal.

5. Conclusions

The laser leveling of the land layers laid down when making the dam and the land dikes from the hydroenergetic setups represents a safe and efficient solution for providing optimum breadth with maximum errors of 2.5 cm on the entire surface of the laid layer. This kind of leveling performed before compaction of each land layer provide a proper and homogenous compaction of the dam and represents an optimum solution for reducing infiltrations and falling of the crowning which may lead to water flood like in Fig.17.

The laser controlled modular systems like TOPCON or similar ones are not present in enterprises not even for the most modern land leveling machines. They may be mounted on any type of hydraulic power land leveling machine, no matter the degree of wear or origin.

The assembly of these type of equipment with laser control like TOPCON which appeared lately in Romania, is performed by TOPCON trained personnel and not by the manufacturers of the leveling machines.

The dynamic and stationary characteristics obtained by a comparative test of a TOPCON laser controlled modular system, fixed on an autograder which performed an automatic leveling and then on a test device connected to a stand adequately equipped for electrohydraulic drives are comparable.

The test device realized at INOE 2000 IHP allows pre regulations for according the parameters of the laser controlled modular system with those of the machine on which it will be mounted.

If a fault appeans during the use of the machine equipped with laser controlled modular system, by means of the test device may be found which component of the system does not provide anymore the required operational parameters- the laser transmitter, the laser receiver, the hydraulic block or the electronic block.

Fig. 17. Example of water flood over a dam, January the 1st 2006, Sherman Island.

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