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VARIOUS ISSUES IN THE FIELD OF SETTING NONSTATIONARY DYNAMIC PROBLEMS AND ANALYZING THE WAVE STRESS STATE OF DEFORMABLE MEDIA

Abstract: The paper considers the propagation of explosive loads in an infinite viscoelastic cylinder. The problem is posed in cylindrical coordinate systems. Using the Nave equation and the physical equation, a system of six differential equations is obtained. After a simple transformation, we obtain a spectral boundary value problem for a system of ordinary and partial differential equations with complex coefficients, which is then solved by the method of straight lines and orthogonal Godunov run with a combination of matrix differential equations solved by the new Mark method.

Key words: viscoelastic cylinder, Nave equation, stresses, deformation, ordinary differential equation, modified finite volume method, complex coefficients, S. K. Godunov method.

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Introduction

Explosive loads are distributed in the structure taking into account the physical laws of waves. Knowing the laws of the wave field allows you to more accurately choose a method for solving the problem and make a deep analysis of the wave stress

state. Various issues in the field of setting non-stationary dynamic problems and analyzing the wave stress state of deformable media are considered in [1, 2, 3, 4, and 5]. Stress waves of different nature propagate in the deformed body and interact with each other, which leads to the formation of new regions

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perturbations, stress and strain redistribution. When stress waves interfere, their intensities add up. They can reach values that exceed the ultimate strength of the material. In this case, the material is destroyed. After three or four times the passage and reflection of stress waves in the body the process of propagation of perturbations becomes steady, stress and strain are averaged, the body is in oscillatory motion. The mathematical description of this process is presented in the form of a system of partial differential equations that describe the physical process in question with a high degree of accuracy. In some cases, analytical techniques and methods for obtaining a solution tasks of ensuring complex safety of structures. It can be noted that solutions using analytical methods are more compact and visual. The latter allow us to study the physical processes occurring in the environment under consideration. However, they allow you to solve problems that are mainly of interest from the point of view of methodology, and also allow you to evaluate the reliability and accuracy of results obtained using numerical methods. Some analytical approaches and methods for solving non-stationary dynamic problems are considered in [6, 7, and 8]. When developing a mathematical model, it is very important to determine

the contact conditions of the "ground-pipeline" system. The result of numerical integration of the system of governing equations along with the adopted initial-boundary conditions (the system becomes closed) get the required dependencies: $\sigma_{ij}(x_i, t)$, $\varepsilon_{ij}(x_i, t)$, $V_i(x_i, t)$, $i=1,2$. For direct integration of the original system of differential equations of the second order partial differential mathematical model the authors used a modified finite volume method (method of S. K. Godunov).

Problem statement and solution methods.

According to the calculation scheme Fig.1 of the task, the pipeline is buried in an array of rocky rocks. At the initial moment of time, an elastic explosion wave is generated in a certain area of the array at a given distance from the pipeline, which later affects the pipeline system. Based on the regulatory requirements for the load range, let's assume that the explosive load should not destroy the rock mass. The value of the highest main stress is chosen as such a normative criterion of failure in the work. Therefore, the stress state equations of the system must be compiled for a range of loads that do not exceed the strength limit for rock formations.

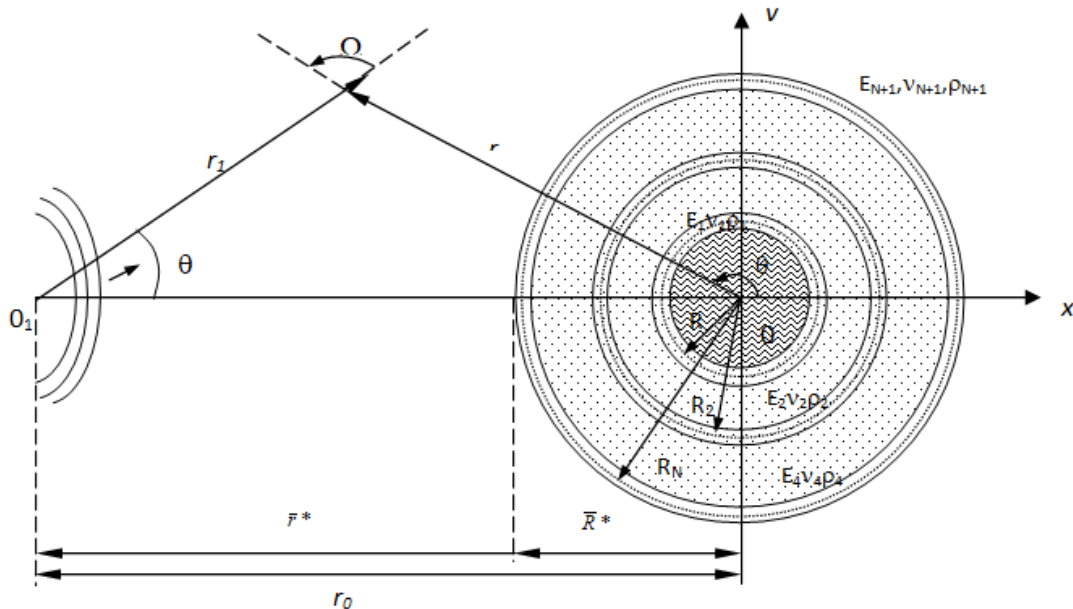


Fig. 1. Calculation scheme.

This condition is most fully met by the model of a homogeneous isotropic material that obeys the viscoelastic Hooke law for small deformations. We write a system of two dimensional equations of the linear theory of visco elasticity in the components of the displacement vector and the components of the stress tensor as;

$$\frac{\partial \sigma_{11}^{(k)}}{\partial x} + \frac{\partial \sigma_{13}^{(k)}}{\partial z} = \rho_k \frac{\partial^2 u_k}{\partial t^2};$$

$$\frac{\partial \sigma_{31}^{(k)}}{\partial x} + \frac{\partial \sigma_{33}^{(k)}}{\partial z} = \rho_k \frac{\partial^2 g_k}{\partial t^2}$$

$$\tilde{E}_k \frac{\partial u_k}{\partial x} = \sigma_{11}^{(k)} - \nu_k (\sigma_{22}^{(k)} + \sigma_{33}^{(k)}); \quad (1)$$

$$\tilde{E}_k \frac{\partial g_k}{\partial z} = \sigma_{33}^{(k)} - \nu_k (\sigma_{11}^{(k)} + \sigma_{22}^{(k)})$$

$$0 = \sigma_{22}^{(k)} - \nu_k (\sigma_{11}^{(k)} + \sigma_{33}^{(k)})$$

$$\frac{1}{2} \tilde{E}_k \left(\frac{\partial u_k}{\partial z} + \frac{\partial g_k}{\partial x} \right) = (1 + \nu_k) \sigma_{13}^{(k)}$$

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Here u_k are g_k the components of the mixing vector $\sigma_{11}^{(k)}, \sigma_{13}^{(k)}, \sigma_{33}^{(k)}, \sigma_{31}^{(k)}$ - components of the stress tensor, ρ_k - density ($k=1,2$). Moving to the polar coordinate system and entering dimensionless quantities included in the system (1), we finally get:

$$\begin{aligned} \frac{\partial \sigma_{rr}^{(k)}}{\partial r} + \frac{1}{r} \frac{\partial \sigma_{r\theta}^{(k)}}{\partial \theta} + \frac{1}{r} (\sigma_{rr}^{(k)} - \sigma_{\theta\theta}^{(k)}) &= \frac{\partial u_{1k}}{\partial t}, \\ \frac{\partial \sigma_{r\theta}^{(k)}}{\partial r} + \frac{1}{r} \frac{\partial \sigma_{\theta r}^{(k)}}{\partial \theta} + \frac{2}{r} (\sigma_{r\theta}^{(k)}) &= \frac{\partial g_{1k}}{\partial t}, \\ \frac{\partial u_k}{\partial r} + \frac{1-2b}{r} \left(\frac{\partial g_{1k}}{\partial \theta} + u_{1k} \right) &= \frac{\partial \sigma_{r\theta}^{(k)}}{\partial t}, \\ \frac{\partial \sigma_{\theta\theta}^{(k)}}{\partial r} + (1-2b) \frac{\partial u_{1k}}{\partial r} + \frac{1}{r} \left(\frac{\partial g_{1k}}{\partial \theta} + u_k \right) &= \frac{\partial \sigma_{\theta\theta}^{(k)}}{\partial t}, \\ b \left(\frac{\partial g_{1k}}{\partial r} + \frac{1}{r} \left(\frac{\partial u_{1k}}{\partial r} - g_{1k} \right) \right) &= \frac{\partial \sigma_{r\theta}^{(k)}}{\partial t}. \end{aligned} \quad (2)$$

Here, $b = \frac{1-2\nu}{2(1-\nu)}$, ν - the Poisson's coefficient,

$\sigma_{rr}^{(k)}, \sigma_{r\theta}^{(k)}, \sigma_{\theta\theta}^{(k)}$ - the components of the stress tensor, u_{1k}, g_{1k} - the radial and tangential components of the velocity vector in the polar coordinate system.

System (2) can be written in matrix form:

$$\frac{\partial V_k}{\partial t} + A^M \frac{\partial V_k}{\partial r} + \frac{1}{r} B^M \frac{\partial V_k}{\partial \theta} = \frac{1}{r} Q^M V_k, \quad (3)$$

where $V_k = (u_k, g_k, \sigma_{rr}^{(k)}, \sigma_{\theta\theta}^{(k)}, \sigma_{r\theta}^{(k)})^T$ -matrix - column of unknowns, «T» - symbol of transposition. Matrix

differential equation (3) is solved by the new Mark method.

$$\begin{aligned} \left(\frac{1}{\Delta t}\right)^2 [m](q^{j+2} - 2q^{j+1} + q^j) + \left(\frac{1}{2\Delta t}\right)[S](q^{j+2} - q^j) + \\ + [k][\beta q^{j+2} + (1-2\beta)q^{j+1} + \beta q^j] = \beta F^{j+2} + (1-2\beta)F^{j+1} + \beta Fq^j \end{aligned}$$

Meaningful results and analysis.

The results of numerical simulation of the impact of a seismic explosion wave on a rock mass are presented below (figures 2). It should be noted that at distances greater than 140 Rzar, the effect of the charge length on the amplitude of the stress wave ceases when the charge length is greater than 40 r_{zar} [7]. It follows that when filling a well with a diameter of 76 mm BB with a density of 1100 kg / m³, the maximum amplitude of the stress wave will be reached when the charge length is 1.52 m, and the charge mass will be 7.6 kg. That is, a further increase in the mass of the charge "in depth" will not change the amplitude of the stress wave, and consequently the amplitude of the seismic wave at the measurement point. In the process of numerical simulation, the increase in the mass of the exploding charge occurs as a result of an increase in the number of simultaneously exploding charges in the deceleration stage.

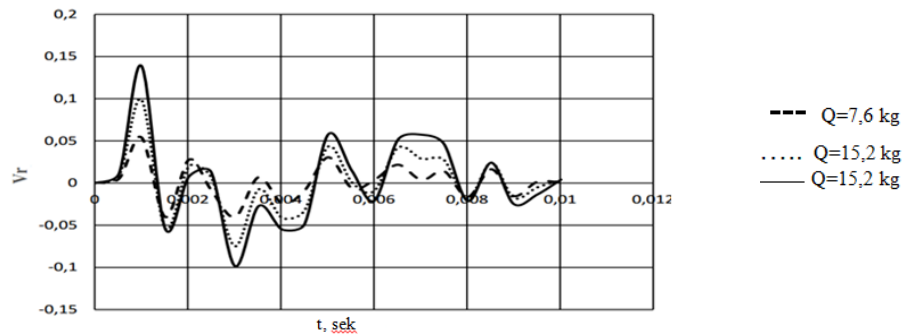


Fig. 2-Radial components of the displacement velocity vectors on the ground surface during the explosion of 7.6 kg, 15.2 kg and 24 kg charges

In the second phase, the proportionality between forces and displacement of the structure is broken, lost the elastic nature of the interaction and, with increasing external load in the third plot one can observe the slide relative to the underground structure of the soil[5,8]. Let's go back to the graph shown in

Fig.3. from This we can conclude that with increasing intensity (external load), the share of energy transferred from the ground to the underground structure decreases. Following this tradition, during the experiments, attention was also paid to the study of this parameter.

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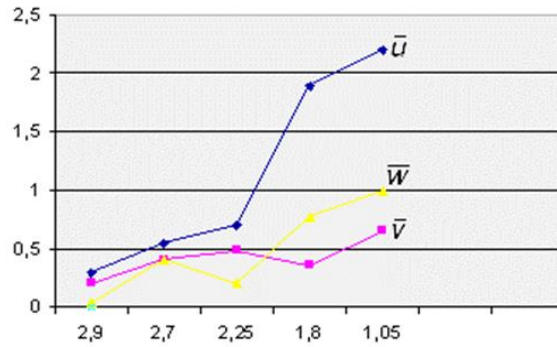


Fig. 3. Dependence of the relative displacement of soil and structures on the coefficient of " pumping " energy η

$$\eta = \frac{E_{COOP}}{E_{2p}}$$

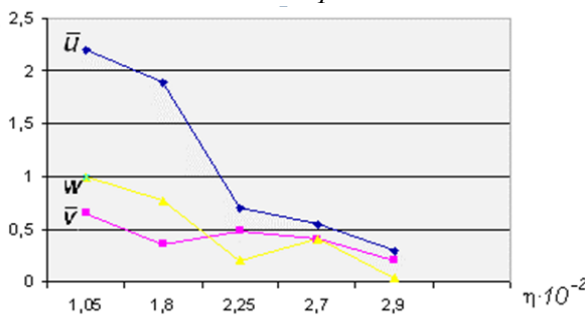


Fig. 4. Dependence of the relative displacement of soil and structures on the coefficient of " pumping " energy η

The first-corresponds to the stage loaded underground structures, when the relationship between the forces and the relative movement of the structure is linear. In this case, the soil is compacted, and elastic and viscous properties of the body are revealed, but not plastic.

$$\eta = \frac{E_{COOP}}{E_{2p}}$$

the material of the underground structure and the surrounding soil differ sharply, the physical picture is very complicated, there is movement of the underground structure relative to the ground under dynamic (seismic) influences. As a result, the interaction reduces the vibrational energy in the dynamic system "ground-underground structure" and therefore this parameter is increasingly attracting the attention of experimental researchers. For rice.3 and Fig.4 shows the dependence of the values of relative displacements ($\bar{U}, \bar{V}, \bar{W}$) of the movement of an underground structure relative to the surrounding ground. From here it is not difficult to notice that the relative displacement of the structure occurs in all mutually perpendicular directions in space. This shows that the coefficient n decreases slightly with increasing intensity. With increasing intensity of seismic vibration, the total amount of kinetic energy

received by the structure increases, but the ratio decreases. In the process of interaction, when the strength properties of

Conclusions

1. A mathematical model of the interaction of seismic and explosive waves with an oil pipeline in rocky ground environments is obtained, taking into account the contact interactions "soil-pipeline" and "pipeline-liquid".
2. Calculation schemes based on the method of S. K. Godunov have been developed that implement numerical integration of solving equations of a mathematical model describing the interaction of seismic and explosive waves with an underground oil pipeline.
3. Analysis of numerous studies of the seismic effect of explosions shows that the rate of vibration of the rock mass depends on almost all parameters of drilling and blasting operations, and to the greatest extent, the rate of vibration of the array is determined by the mass of the charge in the deceleration stage, the deceleration interval and the scheme of exploding charges [9]. It is known that with an increase in the number of deceleration groups and the deceleration time, the intensity of vibrations in short-time explosion decreases.

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