# PROPAGATION OF A SPHERICAL SHOCK WAVE IN SANDY SOIL

N. N. Gerdyukov, A. G. Ioilev, and S. A. Novikov

UDC 534.222.2+624.131

The behavior of sandy soil during camouflet explosion of a spherical explosive charge was studied in [1-5]. Measurements were performed by tensometric pressure sensors at relative distances greater than 0.5 $m/kg^{1/3}$ (stresses less than 5 MPa). It was noted that at relative distances greater than 1 $m/kg^{1/3}$ spreading of the shock wave front becomes noticeable, the wave beginning to degenerate into a compression wave. Use of piezoelectric pressure sensors [6, 7] allowed study of spherical explosive wave propagation in the pressure range of 0.02-150 MPa in poured sandy soil of natural humidity (initial density 1.54 $g/cm^3$, moisture content w = 3-5%).

The soil mass was loaded by spherical charges of 50/50 TG with masses q = 0.03, 0.05, 0.063, 0.1, 0.25, 0.36, and 0.92 kg. Stress measurements carried out normal to the explosion wave surface were made with piezoelectric pressure sensors in a titanium casing [6, 7] at relative distances $x_* = x/q^{1/3}$ = 0.1, 0.2, 0.4, 0.5, 0.63, 0.8, 1, 1.05, 1.27, and 2.54 $m/kg^{1/3}$. Measurement results averaged over several experiments are shown in Fig. 1 ($\sigma_n$, normal stress amplitude in incident explosion wave; 1, experimental data; 2, A = 0.42 MPa, n = 2.73; 3, A = 0.88 MPa, n = 2.18; 4, A = 0.59 MPa, n = 2.35; 5, A = 0.37 MPa, n = 3.13). The experimental data can be approximated by an expression of the form $\sigma_n = Ax_*^{-n}$ to an accuracy of 20-26%. The values of A, n, $x_*$ are given in Table 1 ($\gamma$ is the denstiy of the soil skeleton). Note that the exponent n increases with growth in $x_*$.

To estimate the amplitude of the normal stress in the incident wave upon camouflet explosion in sandy soil of natural humidity, over the entire interval $0.1 < x_* < 2.5$ $m/kg^{1/3}$ one can take a single set of parameter values: A = 0.42 MPa, n = 2.73, while in the near ($x_* < 0.2$ $m/kg^{1/3}$) and far ($x_* > 2$ $m/kg^{1/3}$) zones, the deviation from the experimental data increases to ~70%.

For comparison, Fig. 2 shows dependences of the same type, constructed with the experimental results of [2-4] (1, present study; 2, [2], w = 5-7%; 3, [3], w = 4-8%; 4, [2], w = 3-6%; 5, [2], w = 2-4%; 6, [4], w = 7-8%). Note that for sandy soil of low moisture content, despite the difference in measurement methods (in [2-4] tensometric pressure sensors and loop oscillographs were used for signal recording), the results are quite close. For increase in the sand moisture content to 5-7% and in sandy soil of natural composition [4] there is a quantitative difference in explosive wave attenuation, although qualitatively it is described by the same expression.

We will note that according to our measurements diffusion of the shock wave front already becomes marked at Smearing of the shock wave front was also noted in [2-4], but due to the low time resolution of the equipment used, this phenomenon was assigned to $x_* > 1$ $m/kg^{1/3}$.

TABLE 1

| Source | $\gamma$, $g/cm^3$ | w, % | A, MPa | n | $x_*$, $m/kg^{1/3}$ |
|---|---|---|---|---|---|
| [2] | 1,45—1,55 | 2—4 | 0,35 | 3.3 | 0.5 ... 2.5 |
| [3] | 1,42—1,48 | 4—8 | 0,45 | 3.3 | 0,8 ... 1,3 |
| | | 3—6 | 0,28 | 3.3 | |
| | | 5—7 | 0.6 | 3.2 | |
| [4] | 1.5—1,52 | 7—8 | 0.9 | 2.56 | 0.54 ... 2.2 |
| Present study | 1,48—1,5 | 3—5 | 0,42 | 2,73 | 0,2 ... 1,3 |
| | | | 0.88 | 2.18 | 0,1 ,.. 0,4 |
| | | | 0,59 | 2.35 | 0,1 ... 0,8 |
| | | | 0,37 | 3,13 | 0,6 ... 2,6 |

Arzamas. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, No. 2, pp. 10-11, March-April, 1993. Original article submitted February 19, 1992.

0021-8944/93/3402-0161$12.50  

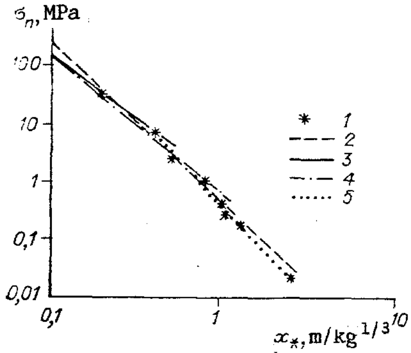


Fig. 1

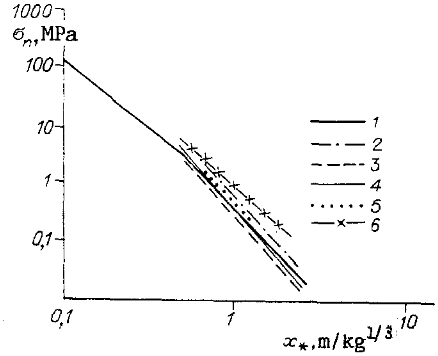


Fig. 2

## LITERATURE CITED


1. V. D. Alekseenko, S. S. Grigoryan, A. F. Novgorodov, and G. V. Rykov, "Some experimental studies of soft soil dynamics," Dokl. Akad. Nauk SSSR, 133, No. 6 (1960).
2. G. M. Lyakhov, Fundamentals of Explosive Wave Dynamics [in Russian], Nedra, Moscow (1974).
3. S. S. Grigoryan, G. M. Lyakhov, and P. A. Parshukov, "Spherical explosive waves in soils as determined by stress and deformation measurements," Zh. Prikl. Mekh. Tekh. Fiz., No. 1 (1977).
4. G. V. Rykov and A. M. Skobeev, Stress Measurements in Soil under Short-term Loading [in Russian], Nauka, Moscow (1978).
5. A. A. Vovk, B. V. Zamyshlyaev, L. S. Evterev, et al., Soil Behavior under Impulsive Loading [in Russian], Naukova Dumka, Kiev (1984).
6. S. I. Bodrenko, N. N. Gerdyukov, Yu. A. Krysanov, and S. A. Novikov, "Use of quartz pressure sensors in studies of shock wave processes," Fiz. Goreniya Vzryva, No. 3 (1981).
7. N. N. Gerdyukov, A. G. Ioilev, and S. A. Novikov, "Action of explosive loading on soft soil," Zh. Prikl. Mekh. Tekh. Fiz., No. 2 (1992).


# PRESSING THIN-WALLED TUBING FROM POWDERED MATERIAL


S. E. Aleksandrov and L. R. Vishnyakov



UDC 621.762


The technique of pressing through a matrix (extrusion) has been widely used to produce bars and tubes from metallic powder [1]. Theoretical studies of this process in various apparatus have been carried out in [2-15].

A solution was obtained in [3] by means of the characteristic method without use of the continuity equation, not allowing determination of the density distribution without additional assumptions or experimental data. Approximate solutions of the equations of the plastic flow theory were given in [2, 6, 9]. In those studies it was assumed that the material followed Green's yield condition. In [2-6] the problem is solued by the method of planar cross sections. We consider flow in a matrix and a container. The system of ordinary differential equations obtained is solved numerically. In [5, 7-9] the finite element method was used to analyze nonsteady extrusion. A rigid-plastic model with cylindrical yield condition was obtained in [4]. In that study it was assumed that densification occurred only in the container, while in the matrix the material flowed in an uncompressed state. Extrusion without consideration of friction on the matrix walls was considered in [11]. Flow was assumed to be radial. It was shown in [12, 13] that in some cases the material must remain rigid in the container while compacting in the matrix. In those studies conditions were derived under which a flow was realized for the process of bar extrusion. Methods involving analysis of the energy of extrusion were used in [10, 14, 15]. In [10] the velocity field was assumed radial, while in [14] the planar section method was used. In [15] flow in both container and matrix was considered.

Extrusion of bimetallic tubes and bars (in which case the external material has the form of a tube) was considered in [9, 16-18]. The planar section method was used in [9, 16, 17], while the finite element method was used in [18].


Moscow. Kiev. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, No. 2, pp. 12-19, March-April, 1993. Original article submitted February 12, 1992.




0021-8944/93/3402-0162$12.50