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THE DECAY OF SOLITON AT THE CONTACT OF TWO "ACOUSTIC VACUUMS"*

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The authors of [1-3] examined the propagation of pulses in discrete mediums, in regard to which, in the absence of an initial deformation, it is impossible to introduce the concepts of the speed of propagation of infinitely small perturbations and the speed of sound. The tone carrier for such systems is solitons, which differ qualitatively from the corresponding classical case of the solitons of the Korteveg-de Vries (?) equation. In order to separate such mediums into a special class, the term "acoustic vacuum," emphasizing the absence in them of a fundamental concept of traditional acoustics – the speed of sound – was proposed.

Experiments in the transformation of pressure pulses in similar mediums are described in [3, 4], where a chain of spherical steel particles interacting according to Hertz's law served as an example of an "acoustic vacuum".

The present article describes the results of an experimental and numerical investigation of the passage of pressure pulses (solitons) through the contact of two "acoustic vacuums" – a chain of spherical steel granules with a diameter of 4.75 mm and a mass m_1 (AV-1) and a chain of particles with a diameter of 7.9 mm and mass m_2 (AV-2). The experimental scheme is analogous to the one described in [4]. Each of the chains was placed in steel tubes of the appropriate diameter, which were joined in such a way as to guarantee their contact. The parameters of the pressure pulses were measured in the incident, reflected, and transient waves with the aid of pressure sensors based on the TsTS-19, which were inserted into granules into which a slit had been cut. The signals from the sensors were recorded with the aid of S8-17 and S9-8 recording oscillographs (digital). The measurements in the incident and reflected waves were performed with the aid of a sensor placed in the 15-th particle before the contact, while the parameters of the transient wave were measured in a sensor placed in the sixth particle after the contact. The total number of particles in each system was 20. The pulse incident on the contact was excited in the corresponding system by the impact of a spherical piston of mass M (equal to the mass of the particles of the system through which the impact was conducted), moving with a speed equal to 1 m/sec. In this case a single soliton arises in it [1, 3].

The results of the experiments are given in Fig. 1, where (a) are the pressure pulses during impact of the piston $M = m_2$ before and after the contact (AV-2)-(AV-1): in an incident wave (lower beam, first pulse) and a wave reflected from a rigid wall, and (b) are pressure pulses during impact of a piston $M = m_1$ before and after contact (AV-1)-(AV-2): in an incident wave (upper beam, first pulse), in a reflected wave from the contact (upper beam, second pulse), in a transient wave (lower beam, first pulse), and in a wave reflected from a rigid wall. In the oscillograms the vertical scales are: upper beam – 32 N per large division, lower beam – 47 N/dev (Fig. 1a); upper beam – 9.5 N/dev, lower beam – 6.4 N/dev (Fig. 1b). The horizontal scale for both oscillograms is equal to 100 μsec/dev.

The numerical calculations were performed with the aid of the fourth-order Runge – Kutt method with monitoring of the laws of conservation of impulse and energy analogously to [1, 2]. The results of the numerical calculations corresponding in their formulations to the experiments are given in Figs. 2, 3. The average magnitude between the forces at the contacts of the particle into which the sensor was inserted was computed, since just this parameter is measured by the sensor at a mass of the piezoceramic much less than the mass of the particle.

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TABLE 1

Parameters	Experiment	Calculation
A_1, N	13 ± 1	29
A_2, N	8 ± 1	28
τ_1, μsec	34 ± 1	29
τ_2, μsec	37 ± 2	29
τ_{1-2}, μsec	460 ± 7	392

TABLE 2

Parameters	Experiment	Calculation
A_1, N	24 ± 2	33
A_2, N	6 ± 1	16
τ_1, μsec	15 ± 1	15
τ_2, μsec	21 ± 2	19
τ_{1-2}, μsec	246 ± 8	176
τ_{1-3}, μsec	927 ± 18	773

TABLE 3

Parameters	Experiment	Calculation
A_1, N	65 ± 4	64
A_2, N	43 ± 2	68
τ_1, μsec	26 ± 2	14
τ_2, μsec	16	14
τ_{1-2}, μsec	178 ± 2	167

TABLE 4

Parameters	Experiment	Calculation
A_1, N	69 ± 3	92
A_2, N	20 ± 3	56
τ_1, μsec	25 ± 1	25
τ_2, μsec	—	29
τ_3, μsec	—	35
τ_{1-2}, μsec	690 ± 10	605
τ_{1-3}, μsec	790 ± 30	727

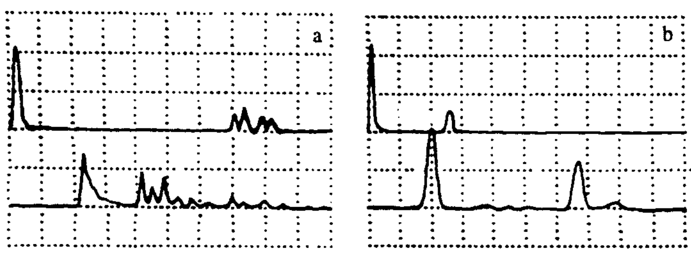

Fig. 1

Tables 1 and 2 present the pulse parameters corresponding to the experimental design for the incidence of a soliton on the contact (AV-1)-(AV-2) (Figs. 1b and 2); Table 1 presents the results of the experiments and the numerical calculations for beyond the contact (Fig. 2b), while Table 2 gives the results for before it (Fig. 2a). Tables 3 and 4 correspond to the case of the contact (AV-2)-(AV-1) (Figs. 1a and 3); here the first of them corresponds to the sensor readings and the calculation for beyond the contact, while the second is for before it. The experimental data of the tables are averaged over six experiments. The quantities A_1, A_2 are the amplitudes of pulses 1 and 2 (Figs. 2 and 3) measured in a single beam, τ_1, τ_2, τ_3 are the widths of pulses 1-3 at the half-amplitude level, and $\tau_{1\text{-}2}$, $\tau_{1\text{-}3}$ are the time intervals between the pulse maximums.

The results show that if the soliton falls on the contact from the AV-2 side (Figs. 1a and 3), then a reflected pulse is not recorded in it. At the same time the incident soliton forms in AV-1 an asymmetrical triangular pulse, which then breaks down into a sequence of solitons. This breaking-down is visible in Fig. 1a in the lower beam, where a pulse reflected from the wall in the form of a sequence of solitons is recorded.

In the case in which a soliton strikes the contact from the AV-1 side (Figs. 1b and 2), a reflected pulse and a pulse passing through to AV-2 are recorded in it. Since in this case all of the recorded pulses are close to solitons, it is possible to try to find their parameters on the basis of the laws of conservation of total energy and impulse. Indeed, it is possible write them in the form

$$p_0 = p_1 - p_2, \qquad E_0 = E_1 + E_2,$$
$$E_0 = \frac{p_0^2}{2m_{1\,\mathrm{ef}}}, \qquad E_1 = \frac{p_1^2}{2m_{2\,\mathrm{ef}}}, \qquad E_2 = \frac{p_2^2}{2m_{1\,\mathrm{ef}}},$$

where p_0, p_1, p_2 and the corresponding total energies are the parameters of the incident, transient, and reflected solitons. An expression for the effective mass of the solitons can be obtained on the basis of their parameters in the long-wave approximation: $m_{1\,\mathrm{ef}} = 0.27m_1$, $m_{2\,\mathrm{ef}} = 0.27m_2$.

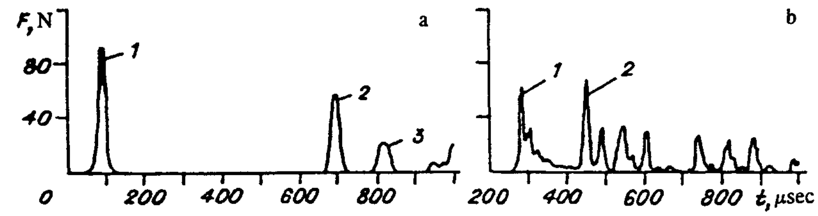

Fig. 2

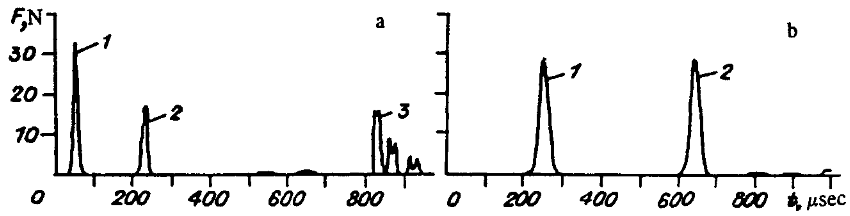

Fig. 3

From the conservation laws it is easy to determine the parameters of the transient and reflected solitons:

$$p_1 = \frac{2p_0}{1+k}, \qquad p_2 = \frac{1-k}{1+k}\,p_0,$$

where $k = m_1/m_2$.

The experimental and numerical calculations can be compared by taking into account the following dependence between the maximum compression force and the pulse in the soliton:

$$F \sim R^2\left(\frac{p}{m}\right)^{6/5}.$$

Here F is the maximum compression force; R and m are the radius and mass of the particles; and p is the pulse.

Comparison of the results of the experiments and the numerical calculations shows their qualitative agreement, good agreement between the time parameters, and a large divergence in the amplitudes of the pulses, which is caused by the presence of dissipation in the system and its not being taken into account in the calculations. The conservation laws permit correct evaluation of the parameters of the pulses when a soliton strikes the contact from the side of a light "acoustic vacuum," although there is no obvious unity in this picture of the break-down of the incident soliton into transient and reflected solitons.

Thus, a pattern, qualitatively different from the traditional acoustic case, of the interaction of a soliton with the contact of two acoustic vacuums is revealed.

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