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SIMULATION THE DYNAMICS OF A COMPOSITE CYLINDRICAL SHELL WITH A GAS-PERMEABLE LAYER UNDER THE INTERNAL IMPULSE LOADING

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Abstract. The results of numerical investigation of the processes of dynamic deformation of composite cylindrical shell protected inside with a cylindrically rolled packet of metallic woven grids are presented. Internal loading is achieved through the explosion of spherical charge. Mathematical model of metallic grids deformation suggested earlier is now provided with experimental diagram of dynamic compression in the direction perpendicular to the grid layers. In circumferential direction the value of effective elastic modulus is selected in series of calculations. Estimated data is compared with the experimental results. The existence of the gas-permeable cylindrical packet of grids leads to decrease of maximum circumferential deformation of the outer shell.

1. Introduction

For the purpose of providing the model of dynamic deformation of metallic woven grid packets [1, 2] with material functions and constants a series of dynamic and static experimental tests of industrial type grid 2-2-0.5 NU GOST 3826-82 were held at SRI of mechanics at NNSU. Figure 1 presents dynamic (1) and static (2) deformation diagrams of packets of grid under the test.

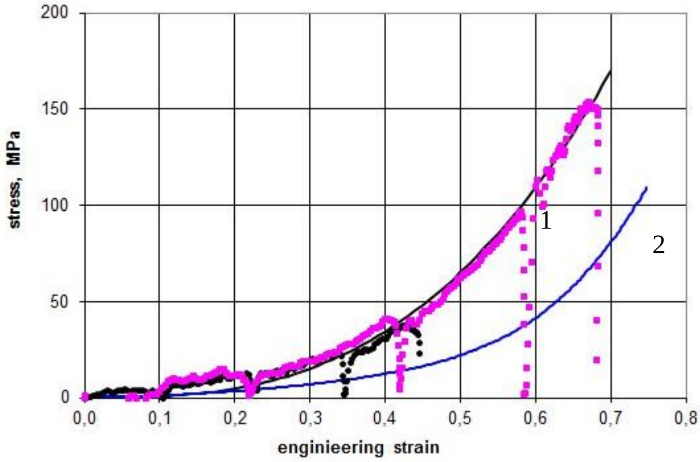

Fig. 1. Diagrams of static (1) and dynamic (2) deformation.

Loading and off-loading curves of dynamic diagram are marked by dots and its analytical approximation $\sigma = 467.6 \cdot \varepsilon^{2.845}$ is shown by solid line. Static diagram of compression [3] is

permeability factor in the direction normal to the grid layers β_{r_0} =0.64 and in the direction of the grid wires β_{z_0} =0.42. In the process of the packet compression, these parameters change proportionally ρ_2/ρ_{20} [1, 2]. The law of the grid compression is assumed in accordance with the dynamic diagram of compression (Fig. 1) presented in a table form together with the linear law of unloading with sound speed at the unloading equal to 3 km/sec. In circumferential direction elastic linking is supposed to be between the tension and deformation with the effective modulus $E_{eff}=1.2\cdot10^4$ MPa. While modelling the deformation process of the grid we do not take into account heat exchange effects between phases and interphase forces related to viscosity and attached gas masses.

Gas-dynamic loading of the shell with grid is fulfilled through detonation activity stimulation of the given charge with its geometric center and initiation point placed at the origin of coordinates of the computational domain (Fig. 2). The charge detonation process is calculated with the help of “ray model” [6]. The contact boundary between detonation products (DP) and air is not marked in the process of calculation. It is assumed that the mixture of these components obeys the perfect gas equation with varying index of adiabatic curve γ that depends on its current density $\rho:\gamma=1.25+1.45(\rho/\rho_{BB})$ where ρ_{BB} - original density of the charge. The charge initiation moment is taken as a countdown moment. At the upper and lower boundaries of the PD-air flow range, the conditions of “free outflow” are realized.

Calculation is carried out with the help of computer code UPSGOD in associated arrangement [7]. Characteristic dimension of square cells of the used difference cells is from 0.2 to 0.5 cm – for air, grid and body under load.

In experiments circumferential deformation of the outer layer of basalt-plastic shell body at the section z=0. Figure 3 presents calculated and experimental time scans of circumferential deformation of the outer shell at this section. Dotted lines show the calculation results of explosive loading for the composite shell without protection grid.

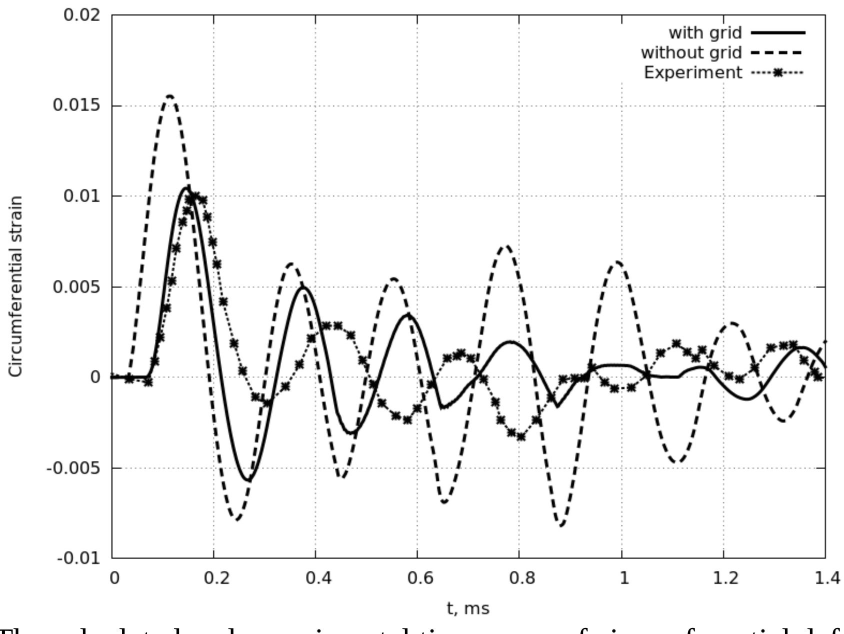

Fig. 3. The calculated and experimental time scans of circumferential deformation of the outer shell.

From calculation results, it can be seen that deformation processes in the packet of grids under the effect of explosion products are of oscillating nature and are followed by recurrent separations from steel inner shell in vicinity of the symmetry plane and succeeding new impact with it. The frequency of these oscillations is determined not only by rigidity of the packet of load carrying outer shells but also depends on rigidity properties of the grid presented in this model by E_{eff} .

The decreasing change of this parameter leads to decrease of rigidity of the packet of grids and reduction of its resistance to distribution processes in circumferential direction. Eventually it may result not in the reduction of deformations of the outer shell observed in the experiments but, on the contrary, to their increase. If E_{eff} changes considerably on the other side, we can observe quite different picture - the rigidity of the packet of grids is overrated. In this respect the chosen value of E_{eff} was preferential for this task. The difference of calculated and experimental oscillation amplitudes at the advanced level of interaction with explosion products can be attributed to the fact that in numerical model we did not take into account the supporting rods that were used in the experiments to keep the grid at the shell body and thus restricted its movement in the radial direction.

3. Conclusions

Generally, as it follows from the calculations the presence of protecting layers of woven grid packets leads to reduction of maximal circumferential deformation of the composite shell under consideration approximately by 30 %.

Acknowledgements

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References

[1] M.Kh. Abuzyarov, E.G. Glazova, A.V. Kochetkov, S.V. Krylov, V.I. Romanov, M.A. Syrunin. // *Problems of Strength and Plasticity* **72 (**2010) 120. (In Russian).

[2] E.G. Glazova, A.V. Kochetkov // *Journal of Applied Mechanics and Technical Physics* **53(3)** (2012) 316.

[3] A.N. Gorohov, D.A. Kazakov, A.V. Kochetkov, I.A. Modin, V.I. Romanov // *Problems of Strength and Plasticity* **76(3)** (2014) 251. (In Russian).

[4] A.I. Abakumov, C.N. Zaikin, V.Yu. Melzas, P.R. Nizovcev, G.F. Portnyagin, V.N. Rysak, V.P. Solovjev // *VANT* **3** (1993) 26. (In Russian).

[5] V.N. Rusak, A.G. Fedorenko, M.A. Syrunin, L.A. Sobol', A.V. Sukhanov, V.G. Popov // *Journal of Applied Mechanics and Technical Physics* **43(1)** (2002) 154.

[6] F.A. Baum, L.L. Orlenko, K.P. Stanyukovich, *Physics of explosion* (Nauka, Moscow, 1975)

[7] M.K. Abouzyarov, S.V. Krylov, E.V. Tsvetkova // *Problems of Strength and Plasticity*. **75(1)** (2013) 25. (In Russian).