TWO-DIMENSIONAL GAUGE INTERACTION EFFECTS FOR PLANE SHOCKS IN SNOW*

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*Supported in part by US Army Cold Regions Research & Engineering Laboratory

Terrestrial snow is a first-order simulant of comets and regoliths on icy bodies. The existing experimental database for shock waves in snow consists of high pressure data [1,2] with initial densities of 350 and 600 kg/m³ and low pressure data [3] with initial densities between 120 and 450 kg/m³. More work has been done in the low pressure region and a complete report is in preparation. As part of that effort, Ktech has used numerical modelling to develop a better understanding of the gauge interaction effects.

Figure 1 shows the geometry for the experiments and the calculations. A typical set of experimental records were presented in [3] along with a one-dimensional calculation without any stress gauges included. The experiments were done with gauges encapsulated in a variety of media ranging from bare carbon gauges to 0.4mm of mica on either side. In the present models we treat an intermediate case, encapsulation in plastic such as Kapton, Mylar or plexiglas modelled as a solid sheet of plexiglas.

The calculations were done on the Ktech MicroVAX II using PRONTO2D, a solid-dynamic finite element code [4]. The snow is modelled as a crushable solid whose pressure-volume response is determined by a user input function. The function used for the results presented was fit to limited experimental data of shock velocities and reflected shock velocities. There is no experimental constraint on the tensile behavior. The main deficiency of this model in its present configuration is that the unloading behavior is limited to a single modulus which is equal to the maximum compressive modulus. We have overcome this for the present application by using a slightly different constitutive model for shocks at about 5 MPa than for 12 MPa shocks. All other materials were modelled as linear elastic solids.

The essential features of our earlier one-dimensional models [3] are also seen in two dimensions. The snow responds to the impact of an aluminum flyer with a nearly flat-topped wave of very long duration (> 100 μs) even though the initial pulse width in the aluminum buffer plate is only about 20 μs wide. This is because the impedence of the snow is so low that the first pulse transmitted into the snow carries less than a percent of the momentum in the aluminum. Thus the aluminum acts very nearly like the infinite piston in the classical derivation of a gas filled shock tube.

Figure 2 shows stress contours at several times after the first shock begins to enter the snow. In Figure 2a after 47 μs the shock has not yet arrived at the gauge and the shock front is smooth rising to about 12 MPa and then falling slightly back toward the aluminum plate. After another 5 μs a strong interaction with the gauge is seen with a reflected shock amplitude of over 30 MPa at the center line (Figure 2b). Figure 2c shows the contours at 59 μs when the reflected wave, attenuated to 18 MPa, arrives at the aluminum-snow interface. Reflection there increases the stress to about 23 MPa at 60 μs, by which time the wave behind the gauge appears is undisturbed (Figure 2d). After a few more microseconds our calculation becomes unstable due to the large deformations in the mesh which accompany compression of snow to nearly the density of ice ($\rho/\rho_0 \sim 3$).

References: [1] A.A. Bakanova, V.N. Zubarev, Y.N. Sutulov and R.F. Trunin 1975, Sov. Phys. - JETP 41, 544-548. [2] E.S. Gaffney, 1985, pp. 119-148 in J. Klinger et al. (eds.) **Ices in the Solar System**, Reidel. [3] J.A. Brown, E.S. Gaffney, G.L. Blaisdell and J.B. Johnson, 1988, pp. 657-660 in S.C. Schmidt and N.C. Holmes (eds.) **Shock Waves in Condensed Matter 1987**, Elsevier. [4] L.M. Taylor and D.P. Flanagan (1986) Sandia Nat.Lab. Report SAND86-0594.

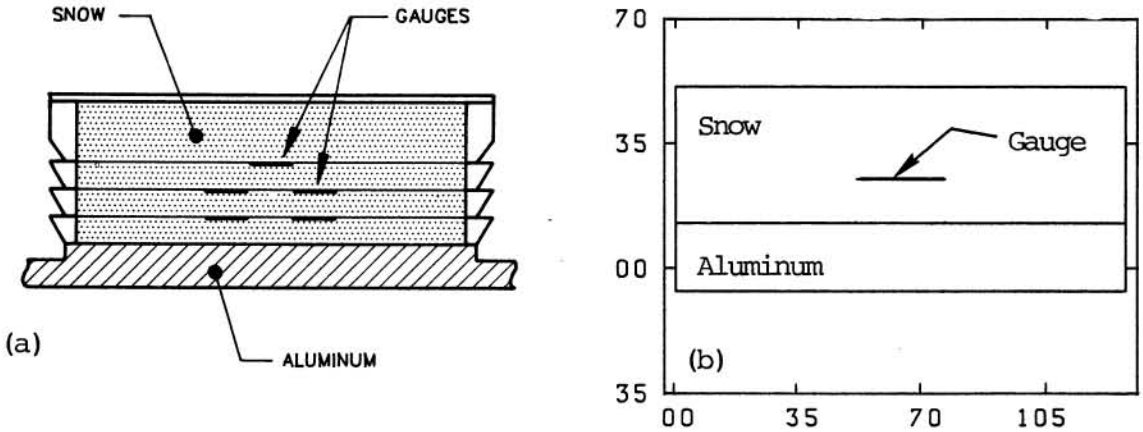

Figure 1. Geometric configuration (a) for experiment and (b) for calculations. Dimensions in mm.

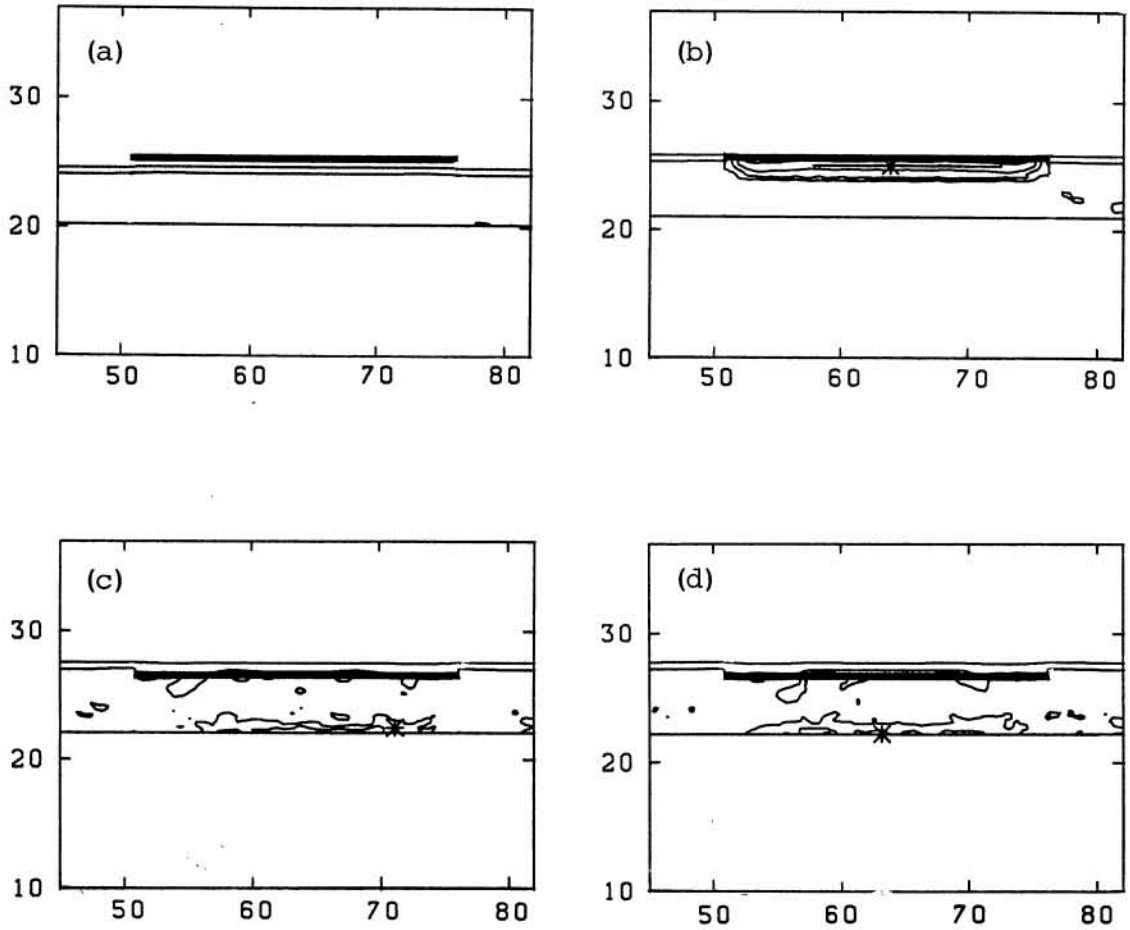

Figure 2. Stress contours for a plane shock in snow interacting with a stiff gauge package. Contour interval, 5MPa. Free-field shock amplitude, 12MPa. a) 47μs, b) 52μs, c) 59μs, d) 60μs. Dimensions in mm.