he concludes that steady state shocks cannot exist, and predicts that a single R-H curve will be obtained for all initial densities. Hofmann, et al, have shown, however, that with an energy-dependent equation of state the plate-gap model approaches the continuum steady-state model with increasing time and propagation distance.[51] The question is therefore not which model is correct but under what conditions is each model correct. Little experimental work has yet been done to establish the conditions under which each model is valid.

The picture of the process shown in Fig. 17, although qualitatively correct, is very much simplified. The R-H curves are, of course, energy dependent so that each value of V_0 has its own associated P-V curve. At lower pressures the collapse of pore space may not be complete. Moreover, many porous solids exhibit a finite elastic yield stress so that a pressure pulse propagates as two or more wavefronts.

A more accurate, though still qualitative, P-V diagram is shown as Fig. 18. The elastic limit is indicated by P_e and the pressure at which the pore space has completely closed is indicated by P_c. The two R-H curves above P_c are separated because of greater shock heating of the initially porous material. Partial compaction occurs in the region between P_e and P_c, and following compaction the relief curve is substantially steeper than the compaction curve.

Linde and Schmidt[72] and Herrmann[73] have proposed phenomenological models for the P-V relation of porous solids, including the elastic yield point and the compaction region. Although they require experimentally determined parameters, these models appear to fit existing data reasonably well. The region of partial compaction is least well understood, especially the release curves from a compressed state.

The pressures at which pore collapse is complete depend on the material. Boade has reported that compaction is complete in porous copper at pressures of about 21 kbar.[74] In tungsten the compaction pressure is about 100 kbar[75] and in iron it is 26 kbar.[76] Aluminum and graphite evidently compact at lower pressures, of the order of a few kbar.[72]

Other models intermediate between the two mentioned have also been employed. The simple snow-plow model assumes zero elastic strength (P_e) and compaction pressure (P_c), and assumes further that the compacted material is perfectly rigid.[77] This model is very amenable to analysis and gives surprisingly accurate results for shock attenuation in highly distended materials. A modification which allows finite elastic strength but maintains the assumption of perfect rigidity of the compacted material has also been used for approximate analysis.

The elastic strength and the elastic wave speed are both substantially reduced by porosity. Butcher and Karnes have reported that the elastic precursor amplitude varies linearly with distention ratio from about 9.5 kbar in iron of zero porosity to 1.5 kbar at a distention ratio (i.e. ratio of initial density of solid to initial density of porous solid) of 1.63.[78] The elastic wave velocity also varies linearly from 6.0 km/sec at zero porosity to 1.15 km/sec at a distention ratio of 2.37. These results seem to be typical for most porous solids investigated to date.

A third wave has been observed in copper by Boade.[74] The first travels with acoustic velocity with an amplitude of a few tenths of a kbar; the second travels with a velocity of about half the acoustic velocity and an amplitude of 1.35 kbar. These waves are followed by a third that carries the material to the peak pressure. The origin of the second wave is unclear; it may be related to a distinct stage of the compaction process.

The shock profiles observed in porous iron, graphite, and aluminum are not steady but continue to spread in the specimen thicknesses employed in the experiments.[72,76] The physical mechanisms for stress relaxation are not established; however, it is possible that the experiments are observing the transition from the plate-gap model to the continuum steady state model.

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