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Study of the Compression of Dense Media Using Radiography of a Single Shock Wave

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by

J. Dapoigny
J. Kieffer
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STUDY OF THE COMPRESSION OF DENSE MEDIA USING RADIOGRAPHY OF A SINGLE SHOCK WAVE

by

J. Dapoigny, J. Kieffer, and B. Vodar

ABSTRACT

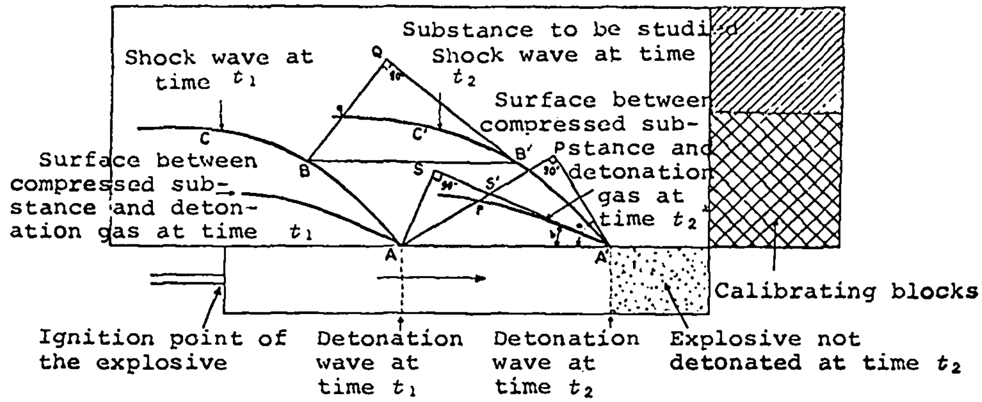
A method for studying the compression of dense media, using flash radiography and the shock wave produced by the lateral expansion of the detonation gases of an explosive is described. Quantitative results for polymethyl methacrylate are also given.

The usefulness of flash radiography for studying the compressibilities of dense media by shock waves is well known.[1-3] The method consists of experimentally determining the velocity, U, of the wave as well as the density of the medium, the pressure being calculated by Hugoniot's relations. One disadvantage of the technique described in the cited publications is that several x-ray pictures are necessary to establish the compressibility curve.

Various authors[4,5] have pointed out the interest of considering the shock waves generated by the lateral expansion of the detonation gases of an explosive for the study of compressibilities as well as wave-collision phenomena. After having obtained radiographs of such waves, as Schall and Thomer[4] did, we sought to extract as much quantitative data as possible from them. This report describes the basic ideas of such quantative research. Finally, we give a few results for polymethyl methacrylate.

A stick of explosive (Fig. 1) is initiated at its left end, and generates a shock wave in the medium. Because of damping, the wave front is curved (profile ABC), but because the flow behind the detonation wave is self-similar, the front of the shock wave is displaced without any deformation in the same direction, and occupies, at time t_2, position A'B'C'. The radiograph can therefore be taken at any stage of the phenomenon. Such a picture immediately yields the velocity of the wave at the point A of maximum shock strength. Considering two infinitesimally close instants of time, t_1 and t_2, the velocity of the wave at A is, indeed, proportional to the line segment, AP, the detonation speed, D, assumed to be known, being proportional to the line segment AA'. We therefore have the relation $U = D \sin a$. Because the density at A may, on the other hand, be determined as usual, one radiograph alone gives the pressure and volume in the head of the wave.

But the reasoning that led us to the velocity of the head A may be applied to any other point, B, of the wave (triangle BB'Q). All along the profile ABC the velocity is thus given by the expression $U = D \sin a$, a being the angle formed at the point



angle a	23°	26°	33°	37°	39°
$\frac{V}{V_o}$	0,86	0.86	0.76	0.72	0.71
U m/sec	3100	3500	4400	4800	5000
u m/sec	450	650	1100	1350	1650
P kg/cm²	11000	27000	57000	76000	86000

Fig. 1. The experimental configuration.

in question by the tangent to the profile ABC with the detonation axis ($a < \pi/2$). Because the density is easily measured all along this profile, we see that only one radiograph gives the entire compressibility curve starting from the maximum pressure achieved in A.

However, it is often difficult to measure the density accurately at the wave front A because of the near-zero displacement of the compressed substance. It is therefore interesting to observe that at this point the particle velocity, u, may be experimentally determined. The radiographs (Fig. 2) show the interface between the compressed substance and the detonation products. Figure 1 then shows that the particle velocity is proportional to the length of the line segment, AS', and consideration of the triangles ASA' and AS'A' leads to the value $u = D \sin b / \cos (a-b)$. With U and u known, Hugoniot's relations give the pressure and volume at A. The particle velocity may, of course, be calculated in the same way all along the interface, but it is important to note that, except at A, we are dealing with particles that are a certain distance behind the wave front, and that therefore it is not possible to obtain the pressure and volume at a point other than A by this method.

Figure 2 shows the radiograph of a lateral wave in polymethyl methacrylate, and Fig. 3 gives the compressibility curve. We see that the results obtained from two different negatives agree well, as do the maximum points calculated from the measurements of the velocities U and u.

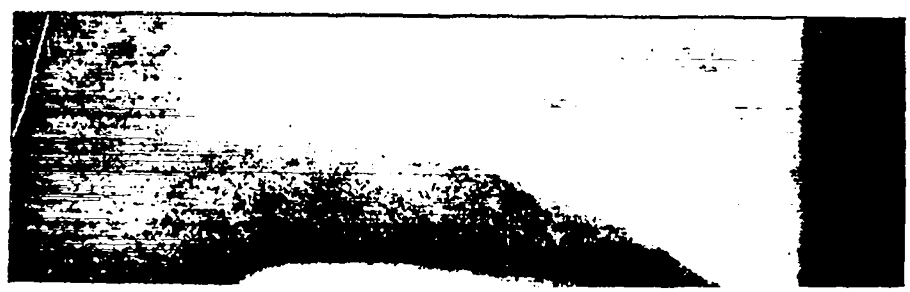
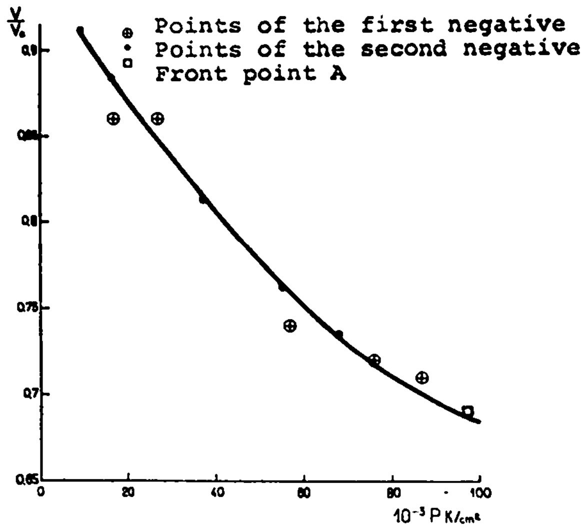


Fig. 2. Radiograph of a laterally produced shock wave.



angle α	22°	26	31°	34°	36°	40°
$\frac{V}{V_0}$	0,91	0.894	0.812	0.762	0.735	0.69
U m/sec	2992	3500	4120	4450	4650	5100
u m/sec	270	400	770	1060	1240	1600
P kg/cm²	9550	16 500	37 500	55 600	68 000	97 000

Fig. 3. Compression curve of polymethyl methacrylate.

REFERENCES

1. R. Schall, Z. Ang. Phys. 2, 252 (1950).
2. J. Dapoigny, J. Kieffer, and B. Vodar, Compt. Rend. 238, 215 (1954).
3. J. Dapoigny, J. Kieffer, and B. Vodar, J. Rech. C.N.R.S. 6, 260 (1955).
4. R. Schall and G. Thomer, Z. Ang. Phys. 3, 41 (1951).
5. Sam Katz, Stanford Research Institute, personal communication.