**Calculation of stress and density based on measurements of shock propagation speed and projectile** **velocity.** According to (3.10.3), given the state (ρ(1), σ(1), *u*(1)) ahead of a shock, the state (ρ(2), σ(2), *u*(2)) behind it can be determined by measuring kinematic quantities only: shock propagation speed *D* and post-shock material velocity *v*\* in the laboratory frame (i.e., flow velocity behind the shock relative to the pre-shock medium). This possibility is very important because direct measurements of mechanical stress σ and internal energy *u* under rapidly changing conditions behind shock waves (the latter involving temperature measurement) are much more difficult to perform than velocity measurements.

*t*3

*t*1

*t*2

*t*4

δ*D*

δ*v*

*v*0

*v* = 0

**Fig. 3.11.3.** Schematic of plate impact experiment to measure impactor velocity and shock propagation speed in the target.

As an example, consider Hugoniot measurement in solids under shock loading in a plate impact experiment (Fig. 3.11.3). An explosively driven flat plate (impactor) made of the material to be studied hits a stationary target plate at a projectile velocity *v*0 (Fig.  3.11.4a). The velocity and pressure distributions along the impact direction at the instant of impact, *t* = 0, are shown Fig. 3.11.4b. Velocity is uniform within each plate, with a jump across the impact surface, while the pressure *px* = − σ*x* (compressive traction) is uniform and equal to *p*0 in both

*D* – 1*/*2 *v*0

− 1*/*2 *v*0

0



= *v* − 1*/*2 *v*0

*D* – 1*/*2 *v*0

А′

S′

S

1*/*2 *v*0



0

− 1*/*2 *v*0

1*/*2 *v*0

 = *v* − 1*/*2 *v*0

0

1*/*2 *v*0

*v pх*

*x*

*v*0

*рх*

*v*

1*/*2 *v*0

A

(*b*) *t* = 0

(*c*) *t* = 0

*v =* 0

(*a*) *t* = 0

1*/*2 *v*0

*v*0

1*/*2 *v*0

1*/*2 *v*0

(*d*) 

*D* – *v*0

А′

*v*

*v*0

0

S

*D*

A

*x*

S′

(*e*) 

А′

A

S′

*S*





*x*

*p*

*D*

*D* – *v*0

(*f*) 

0

**Fig. 3.11.4.** Shock waves in impactor and target.

plates. A discontinuity surface of this kind, across which the jumps in velocity and stress do not satisfy balance equations (in particular, shock jump relations (3.10.3)), is called an arbitrary discontinuity. Immediately after the impact, the discontinuity breaks down into two outward shock waves propagating in opposite directions along the impact axis.

The process can be conveniently analyzed in a reference frame (, *t*) moving at velocity *v*0 relative to the target, where the target and the impactor approach each other at velocity *v*0 (see velocities in the dashed-line box in Fig.  3.11.4*a*). When both plates are made of the same material, the process is symmetric about the impact plane (Fig. 3.11.4*c*). In this frame, the impact plane does not move (see Fig. 3.11.4*d*), the shock propagation speeds *D* are equal, and so are the velocity jumps (see AS and A′S′ in Fig. 3.11.4*d*):

[*v*] = 1*/*2 *v*0.

Figure 3.11.4*e* shows the velocity distribution at *t* = ** after the impact (** > 0) in the laboratory frame (*х*, *t*), where *х* is a Lagrangian coordinate, *v*=  + 1/2 *v*0, and the target is stationary before the impact. In this frame, the propagation speed of shock A′S′ is *D*, and the post-shock velocity of the target material is

*v*\* ≡ *v*\*(2) = [*v*] = 1/2 *v*0.

Fig. 3.11.4*f* shows the distribution of normal traction (*px* = −σ*x*) at the same *t* = ** after the impact, where a constant compressive stress (*px* = ) creates a "plug" between shocks *АS* (in target) and А′S′ (in impactor), which is at rest (= 0, ∂**σ***x/*∂*x* = 0) in the moving frame (, *t*).

The initial values of state functions (ρ(1), σ(1), *u*(1)) can easily be determined before the experiment. Thus, to find their post-shock values of density ρ(2), normal traction , and internal energy *u*(2), one needs to measure the projectile velocity *v*0 (which determines the velocity jump *v*\* across the shock in the target) and the shock speed *D* in the target. The velocity *v*0 and speed *D* can be found, respectively, by measuring the time τ*v* required for the impactor to travel the distance δ*v* between two arrival-time detectors in front of the target and the time τ*D* for a shock to travel the distance δ*D* between two arrival-time detectors embedded in the target (see Fig. 3.11.3). In experiments where electrical contactors (also called *shorting pins*) are used as detectors, an electrical circuit is closed at the instant any detector is hit by the impactor or a shock front, and the ensuing output current burst is recorded by an oscilloscope. The interval between the detected arrival times *t*1 and *t*2 is τ*v*, and the interval between *t*3 and *t*4 is τ*D*. Accordingly,

*v*0 = 2*v*\* = , *D* = .

Generally, δ*v* ~ δ = 5–8 mm, *v*0 ~ *D* ~ (5–10)×103 m/s, and τ*v* ~ τ*D* ~ 10−6 s ≡ 1 μs. Therefore, measurement of velocities on the order of 1 km/s requires time resolutions of about 1 μs.

*Отсутствует конец Главы 3.11*