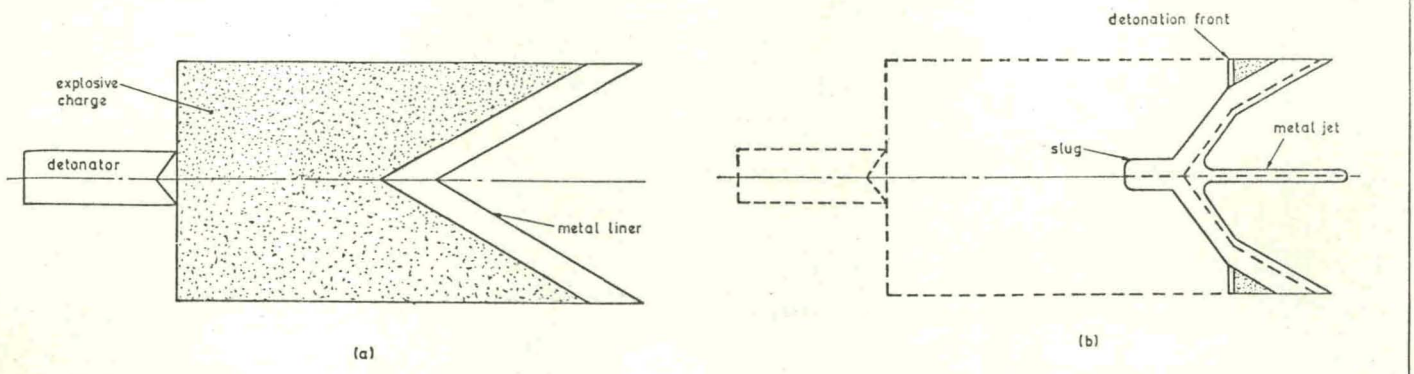


1 Hollow charge with metal liner. (a) Before explosion; (b) collapse of liner and the formation of a metal jet.

geometrical shapes such as flat surfaces, as in cladding, or cylindrical surfaces, as in welding tubes into a tube plate. Other applications have been, or are being investigated, e.g. lap welding, welding of tee junctions, spot welding, production of wire-reinforced composites, &c.

I. Mechanism of explosive welding

Many suggestions have been made regarding the mechanism of explosive welding. Philipchuk[1,7,8] and Zernow *et al.*[9] considered that it was essentially a fusion weld; Davenport,[10] Davenport and Duvall,[11] and Schmidtmann *et al.*[12] regarded it as a cold pressure-welding process; Boes[13] suggested that it was a form of friction welding, while Otto[14] concluded that it involved a shearing action. However, most of the workers in the field, such as Zabelka,[15] Pearson,[16] Hayes and Pearson,[17] Holtzman and Rudeshausen,[18] Cowan and Holtzman,[19] Wright and Bayce,[20] Holtzman and Cowan,[21] Bergmann, Cowan, and Holtzman,[22] Carlson,[23] Bahrani and Crossland,[24] and Bahrani, Black, and Crossland,[25] to mention but a few, have attributed the mechanism of explosive welding to the jetting action that occurs under oblique high-velocity impact.

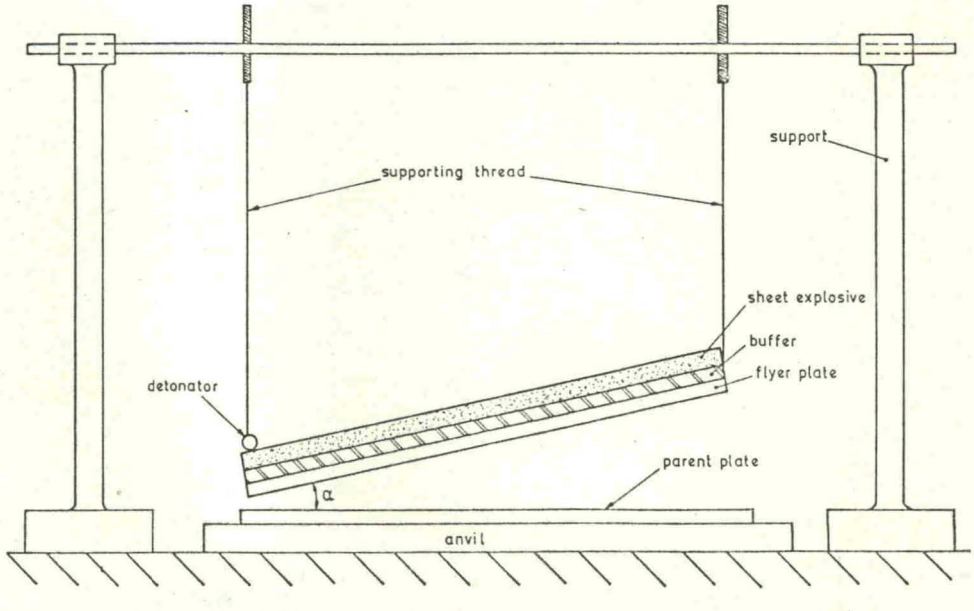
The formation of a metallic jet at the junction between two impacting plates is similar to the jet produced by the collapse of the conical or wedge-shaped liner in a hollow charge, as depicted in Fig. 1, which has been used as a weapon for defeating armour plate. The collapse mechanism and the theory of jet formation in such a case has been given by Birkhoff, MacDougall, Pugh, and Taylor.[26] When the charge is detonated the detonation wave moves down the explosive charge and when it reaches the apex of the liner it subjects the outer surface of the cone to very high pressure which causes its walls to collapse. The pressure produced in the metal in the region where the walls of the liner collide is extremely high, probably of the order of several hundred kilobars, which is much higher than the shear strength of the metal. Consequently, the material in the region of impact behaves as an inviscid fluid and the laws of fluid mechanics can be applied to the situation. It can be shown that the liner material divides into a high velocity 'metallic jet' and a slower-moving slug, as shown in Fig. 1. The high-velocity jet has remarkable powers of penetration. Though this jet behaves in a fluid-like manner it is probable that its temperature is below the melting point, but if it is trapped then the kinetic energy is converted to thermal energy and some melting will occur.

One of the arrangements for welding very commonly adopted is illustrated in Fig. 2. The top or flyer plate is supported with the minimum of constraint at a small angle of incidence, α, relative to the stationary or 'parent plate', which is supported on a relatively massive anvil plate. The top surface of the flyer plate is covered with a protective buffer such as rubber or polystyrene and above that is laid the sheet or layer of high explosive, which is detonated from the lower edge. The detonation of the explosive imparts a velocity V_P to the flyer plate, the magnitude of which depends on the ratio of mass of explosive/unit area to the mass of the flyer plate unit area. As shown in Fig. 3, the flyer plate collides with the parent plate at an increased angle of incidence, β, and it will be seen that

$$V_P = V_D \sin \varphi = V_D \sin (\beta - \alpha) \quad \ldots [1]$$

As the flyer plate collides with the parent plate it suffers a rapid retardation and an extremely high pressure is generated in both the flyer and parent plates in the region of impact S. As the pressure is very high compared with the shear strength of the materials involved, they behave for a very short interval of time in a similar manner to inviscid fluids and their behaviour can be treated by the laws of hydrodynamics.

It is convenient to bring the point S in



2 Set-up for explosive cladding.