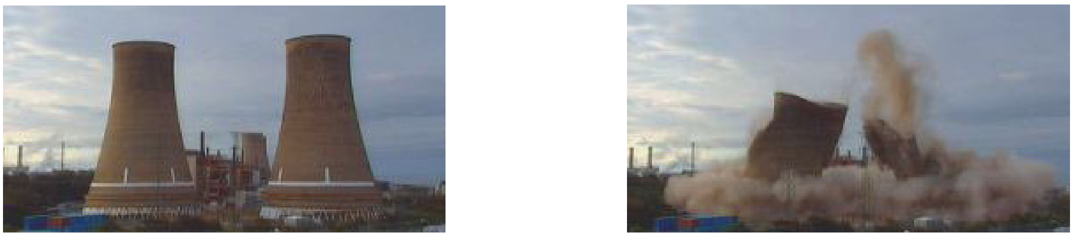
Suggested Topics for Explosion Engineering Projects

1 Explosive demolition in nuclear decommissioning

Nuclear plants were normally designed for a life of about 30 years (new designs have 40-60 year operating life). The decommissioning of nuclear power plants is referred to as nuclear decommissioning. The overriding issue in nuclear decommissioning is to ensure safety and protection of environment due to the possible presence of radioactive or fissile material in a nuclear facility that requires special precautions.

The best way for the demolition phase of nuclear decommissioning is to use explosives. 192 kilograms of explosives were used in the recently explosive demolition of the Calder Hall cooling towers (Figure 1).



(a) Explosive charges are placed under the towers. (b) Controlled collapse of each tower.

Figure 1. The cooling towers of the shut down Calder Hall plant at Sellafield, UK – the world's first industrial-scale nuclear power plant – was demolished using explosives on 29 Sept 2007 (from World Nuclear News).

2 Jetting angle, stand-off distance and detonation velocity for explosive welding

To generate jet at the welding front (Figure 2), an angle between the flyer plate and the bottom (base) plate must be formed. The angle is empirically determined at the range from 5º to 20º.

For the formation of a jetting angle, the plates must be separated by a specific distance (stand-off distance). To establish the proper stand-off distance, a lightweight spacer is placed between the plates. During the jet formation, these spacers will be expelled from between the plates; the spacers are commonly composed of foam or other lightweight materials.

To generate a successful weld, a sufficient amount of energy from the explosion is needed. The impact velocity of the flyer plate must be sufficient to generate an impact pressure of at least 10 times the static yield stress of the components, and it is estimated that the detonation velocity should be in the range from 1500m/s to 3500m/s.

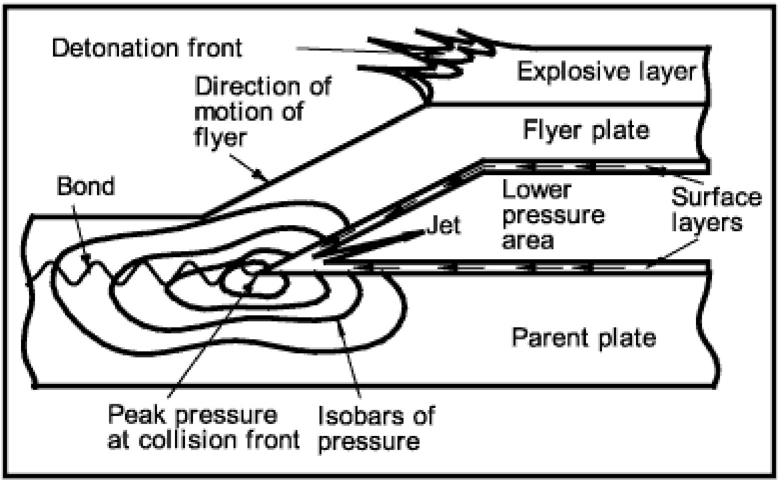


Figure 2, Welding front.

3 Shock expansion

What will happen when a shock wave undergoes a sudden expansion within a confined chamber?

A jet formed in explosive welding, as shown in Figure 3, is generated by a sudden expansion of shock wave in metal plates.

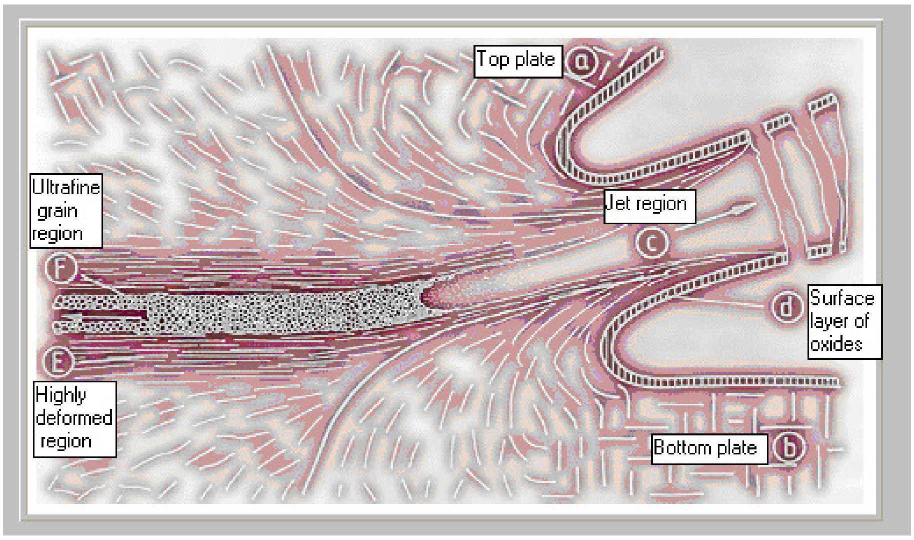
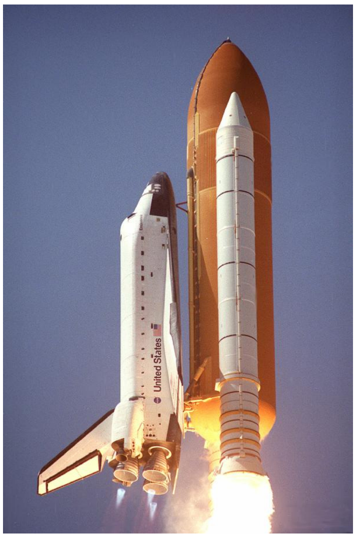
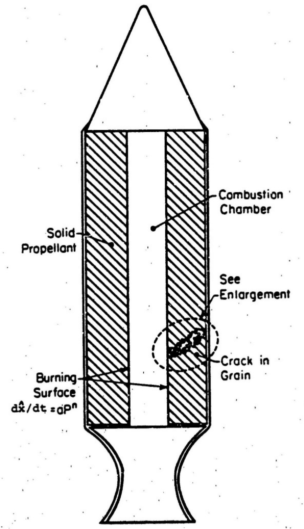


Figure 3, Jet formation in explosive welding.

4 Damage in solid propellants and its effect on deflagration-to-detonation transition



(a) NASA's space shuttle and solid rocket as a launching vehicle



(b) Solid rocket propellant with damage in the grain.

Figure 4, Damage in a solid propellant.

Thrust in a solid rocket arises from the pressurization of a vented chamber, where masses are injected from the combustion of the propellant. The combustion rate depends on the chamber pressure as well as the burning area.

The burning rate increases with the chamber pressure, and the chamber pressure increases with the burning rate. For this reason, relatively small defects can lead to catastrophic failure.

For example, a crack in the propellant as shown in Figure 4(b), causes an abrupt change in the surface area, and hence in the burning rate, which in turn causes an abrupt change in the pressure. A potential failure mode is a possible transition from deflagration (normal surface burning) to detonation (explosion), in which, perhaps due to pre-existing damage or compaction of the propellant, energy is released throughout a volume of the propellant, with fatal consequences.

5 Hot-spot ignition of condensed phase energetic materials

During the explosion, shock waves slam into the high-explosive, compress it with pressures up to 400,000 times that of the Earth's atmosphere, and cause it to release chemical energy which heats it to over 3,500°C. The heat releases power that approaches 10^{13}W/m^2 to sustain the shock wave, which travels as fast as 10^4m/s. All of these reactions occur within less than 10^{-6}s.

A crucial part for the above behaviours is due to voids, or defects, in high-explosive material. Voids in high explosives are an important part of the ignition process, because they enable the material to explode. Voids are small pockets—usually between 1 to 20 micrometers in size—either filled with air or, in some cases, a byproduct gas of the surrounding crystalline high-explosive grains or polymer binder. During the detonation process, the shock wave deforms and compresses the material, which then engulfs the area occupied by the voids. What remains are hot spots—small isolated regions of high explosive at a much higher temperature than the surrounding material. These hot spots are where ignition of the high explosive begins.

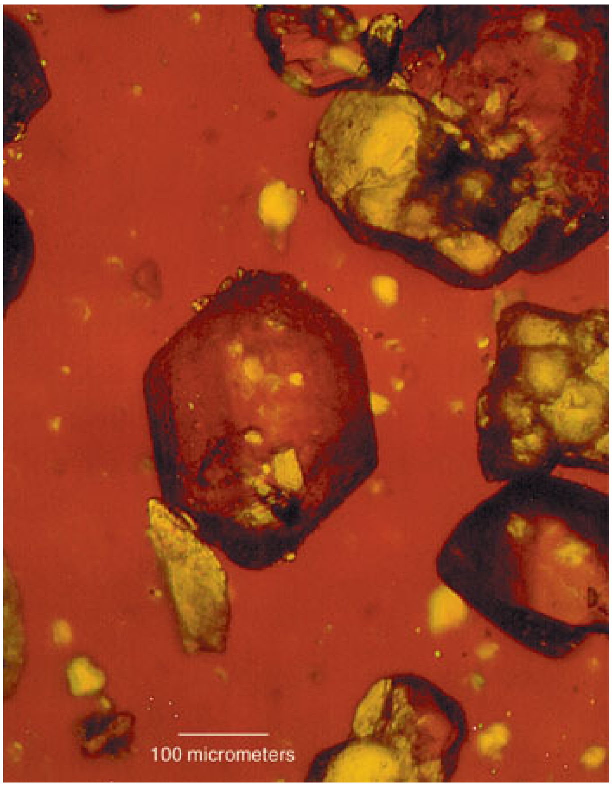


Figure 5. Defects, or voids, are an important component in a high explosive because they cause the material to ignite. This photomicrograph shows defects in a 150-micrometer HMX crystal. (from Science and Technology Review, Lawrence Livermore National Laboratory).

6 Shock and blast mitigation though the energy absorbing of granular materials

For a contact explosion shown in Figure 6, the shock pressures are in the range of 10,000 – 50,000 MPa depending on type of explosives.

Lightweight, highly compliant granular materials are known to exhibit excellent energy absorbing characteristics when loaded by blast or impact events.

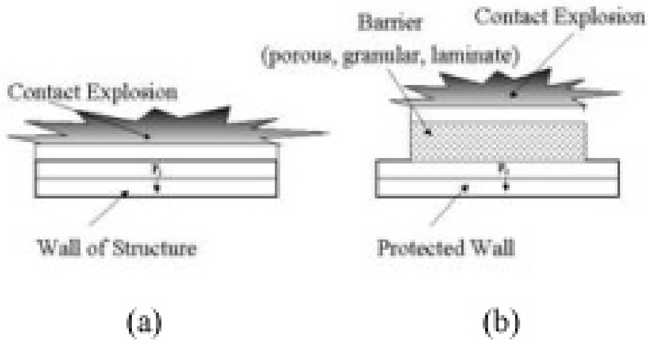


Figure 6. Blast loading due to contact explosion without protected layer (a) and with protected layer (b).

7 Material design for shock mitigation

Materials, such as metal foams, designed to absorb shock energy have microstructures that converts kinetic energy, totally or partially, into another form of energy through permanent deformation.

Closed-cell metal foams are made of separate cells which trapped gas inside the metal, as shown in Figure 7.

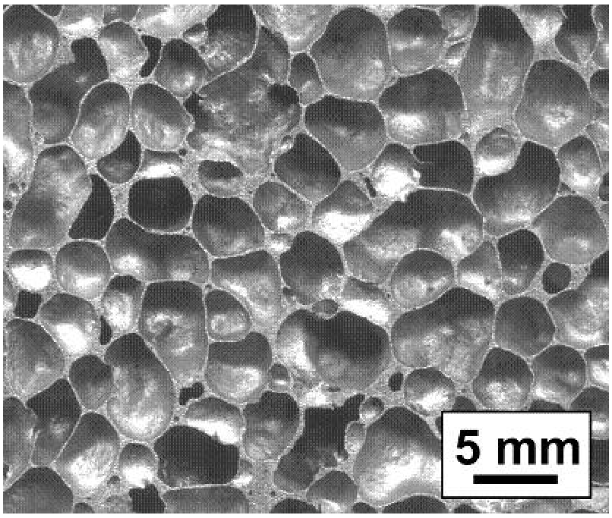


Figure 7. Microstructure of closed-cell metal foam (from Shinko Wire Company).

Closed-cell metal foam (Figure 8) can be used for energy absorption. Also, the closed cell foams normally have higher compressive strength due to their structures.

Figure 8. Foamed aluminium, size is around 0.1m. (from Wikipedia)

8 Stress waves scattered from a sudden debonded interface

A plastic bonded explosive (PBX) is an explosive material in which explosive powder is bound together in a matrix using small quantities of a polymer binder. The polymer binder tends to absorb shocks, making the PBX very insensitive to accidental detonation.

Debonding of particle/binder interfaces in a PBX, as shown in Figure 9, can significantly affect the macroscopic behaviour of high explosives and solid propellants. Hotspot may form from the localized sudden interface debonding, thus trigger detonation of high explosives under low-level loading during handling, transportation or accidental impact.

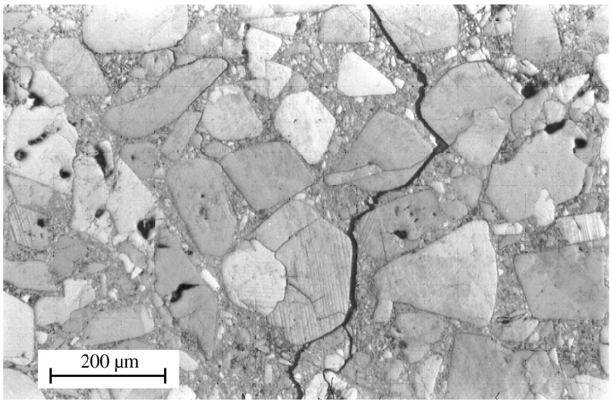


Figure 9. Microcrack propagation in a high explosive.