Energetic and Materials Research at the Cavendish Laboratory

Plate-Impact

- The Cavendish Plate Impact Facility is a single-stage, 50 mm bore, light gas gun capable of achieving projectile velocities in excess of 1 km s^{-1}.
- Samples can be compressed to stresses approaching 40 GPa.
- Environmental chambers allow for both heating and cooling of samples.

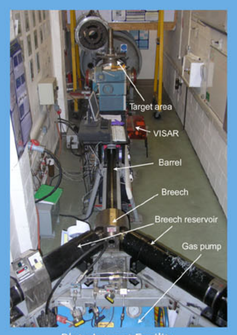


Plate Impact Facility

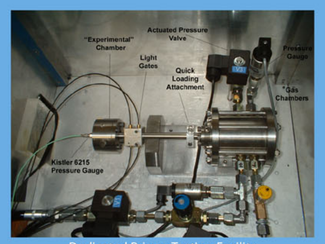
Laser Shock


Laser Shock Apparatus

- The Cavendish laser shock facility is primarily concerned with the ignition of secondary explosives.
- An Nd:YAG laser (200 mJ pulse) is focused onto a thin metal film (of order 5 μm) forming a plasma, propelling the remaining film forwards as a laser flyer (~6 km/s).
- Impact on a secondary explosive can cause a shock to detonation transition.

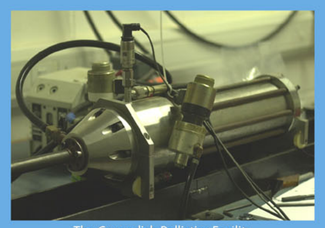
Energetics

- The Cavendish Energetics Laboratory enables small-scale testing of energetic materials including:
  - Synthesis of novel energetic compounds.
  - Several armoured chambers enable testing such as small-scale gap tests.
  - Dedicated primer testing facility.
  - Spark ignition apparatus.



Dedicated Primer Testing Facility

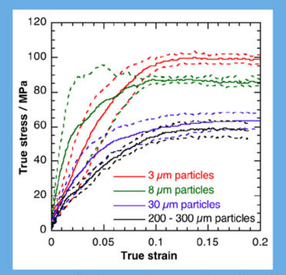
Ballistics


The Cavendish Ballistics Facility

- The flexible Cavendish Ballistics laboratory centres around a single-stage light gas gun capable of achieving projectile velocities approaching 1 km s^{-1}.
- A wide range of barrel geometries and different target chambers enable optimum diagnostic location.
- Typical testing includes
  - Classic and Symmetric Taylor Impact
  - Ballistic performance of composite panels
  - Novel experimental designs requiring dynamic loading

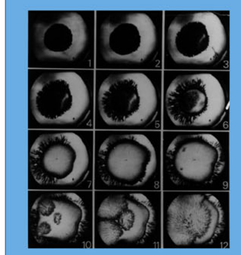
Hopkinson Bar

- The Cavendish Hopkinson bars allow for compressive, tensile, and torsional loading at strain rates of ~10^3 s^{-1}.
- A wide range of bar impedances is employed, including low impedance polymer bars.
- Environmental chambers allow for both heating and cooling of samples .



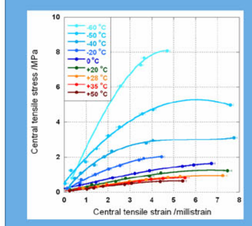
Stress-strain behaviour for a polymer-bonded composite under compressive loading, as a function of particle size, at a temperature of -60 °C and strain rate of ca. 3700 s^{-1}.

Drop-Weight


Initiation of deflagration in PETN (5.5 μs interframe time)

- The drop-weight facility has been used to study the initiation of deflagration in a wide range of explosives.
- Allows for compressive loading at a strain-rates of ~10^3 s^{-1} for ms time periods.
- An instrumented lower anvil allows for the force-time response to be accurately captured
- A rotating-mirror (AWE C4) camera enables through-sample photography over relatively long time scales.

Thermo-Mechanical Testing

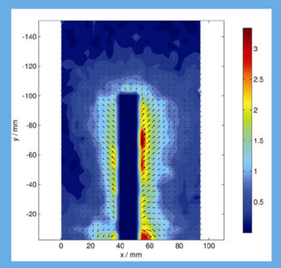


Tensile failure in a polymer composite as a function of temperature.

- Screw driven Instron testing machine to investigate low strain-rate properties.
  - Optical techniques; Moire Interferometry, fine grid, Digital speckle pattern interferometry.
- Environmental chambers allow for both heating and cooling of samples .
- Measurement of thermal properties; conductivity, diffusivity, heat capacity, using a variety of techniques.

Novel Experimental Techniques

Case Study: ballistic impacts in sand
A sand target is seeded with a layer of x-ray opaque particles. Flash radiographs capture the position of these particles before and during an impact process. Digital Image Cross-correlation enables the magnitude and displacement of internal deformations to be tracked.



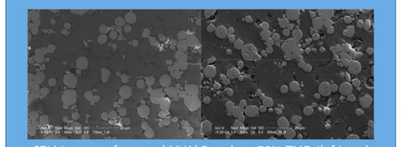
Penetration of flat nosed rod into sand bed (deformation map). J. Addiss PhD Thesis

Measurement Diagnostics

- State-of-the-art experimental diagnostics exist in each laboratory, however several are interchangeable between facilities, including:
- **Velocity Interferometry**
  - Point VISAR (up to 4 points)
  - Het-V/PDV
- **Piezoresistive gauges**
  - Stress measurement
  - Strain measurement
- **High speed Imaging**, from fast framing cameras and high speed video
  - Ultra 8
  - Ultranac 501 (framing and streak)
  - Suite of Imacon 790-792
  - Imacon 675 streak (0.3 ns / mm)
  - Phantom 4
- **Flash X-radiography**
  - 150 keV, 70 ns duration (2 head)

Characterisation and Preparation

- Sample preparation facilities;
  - Precision machining capabilities
  - Lapping and Polishing facilities
  - Vacuum depositions of metallic films
- Density and Sound speed measurements.
- Microscopy – Optical, AFM, SEM, TEM, STEM, ESEM, and ion beam lithography
- Additional University Facilities
  - Thermal analysis (DMTA, DSC).
  - Computed X-Tomography.
  - Laser particle sizing
  - X-ray diffraction

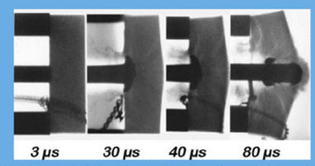

SEM Images of pressed Ni/Al Powders. 75% TMD (left) and 90% TMD (right).

Fracture and Shock Physics Group

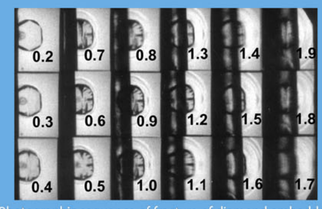

Members of the Fracture and Shock Physics group enjoying the 15th SCCM conference in Hawaii.

- Extensive historical expertise in materials testing and shock physics.
- Comprehensive reference database and library facilities
- Excellent portfolio of international collaborators, both academic and industrial.

Examples of High-Speed Imaging



Flash X-ray images of penetration of steel rods (four separate experiments) through borosilicate glass. From Bourne et al. J. Phys. IV France 7(C3) 157-162.



Photographic sequence of fracture of diamond embedded in PMMA subjected to shock loading. From G. Willmott PhD thesis.

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