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Radiographic Techniques in the Explosive Component Facility at Sandia National Labs

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ABSTRACT

The Explosive Component Facility (ECF) at Sandia National Laboratory (SNL) is a state of the art facility for the design and testing of energetic materials and components. Two key elements of these capabilities are the flash x-ray machines. One is a six head, 150 KeV and the other is a six head, 300 KeV instrument.

One of the more interesting uses of the 150 KeV system has been to study the action and reaction of a linear shaped charge (LSC) while submerged in water. The submerged samples were viewed from the top to capture the interaction of one piece of LSC with another piece near by. Each LSC was covered by separate rubber coverings and affixed to a composite plate. Three heads, delayed by a specified time, were used to capture the time sequence of events in stop action. Side views of the LSC were done with and without the rubber coverings to examine the dampening effects of the cover. An end-on perspective was also captured by x-ray using one head and several time delays.

The debris scatter produced from a larger device has also been examined. The explosive used was in a pellet form initiated by a detonator and a timing lead. The x-ray radiographs show the particles from this device as they expand outward. Three x-ray source tubes were used in a large horizontal array, apertured to expose individual pieces of film. Another x-ray source was placed overhead and simultaneously exposed a film under the object.

Keywords: x-ray, LSC, explosives

1. ECF BUILDING

The Explosive Components Facility (ECF) is a key facility at Sandia National Laboratories (SNL) in Albuquerque, New Mexico and a focal point for consolidation of many explosives activities into a single site. The ECF is a designated User Facility. It is utilized by four technology groups: explosive technologies, neutronic components, batteries, and weapons evaluation.

The Explosives Technology Group is composed of three departments located in the ECF. These three departments have historically been charged with the development, characterization, and testing of all non-nuclear ordnance used in nuclear weapons. They provide a true cradle-to-grave responsibility for this ordnance.

The Explosive Components & Diagnostics Projects Department, 1554, develops unique diagnostics and conducts performance and exploratory tests of explosives and explosive components for a laboratory-wide customer base. This includes high-energy detonators, detonation transfer, precision timing and shaped charge devices as well as advanced components using semiconductor materials. These components support subsystem developments for commercial applications as well as weapon systems.

The ECF supports the DOE production and maintenance programs of the US nuclear stockpile such as in the following areas:

- Advanced development activities for explosive, neutronic, and power source (battery) components;
- Stockpile improvement programs through surveillance of component/weapon reliability;

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- Advanced disablement development for enhanced use control.

The ECF is newly constructed and outfitted. The building is structured with two basic wings: a northern wing and a southern wing. The north wing contains office spaces for design personnel and conference rooms. Two of these conference rooms are able to be secured for classified meetings if necessary. These meeting rooms are furnished with state-of-the-art presentation equipment including backlit projectors and computer controlled transparency viewers. The south wing contains explosive component conditioning chambers, chemical analysis labs and test and measurement labs. Devices may be characterized by many methods. They can have hi-speed projectiles launched at them by a gas gun, initiated by semiconductors and instrumented with laser interferometry. Lasers measure the velocity of particles or closure disks thrown by explosives by an instrument known as a Velocity Interferometer System for Any Reflector (VISAR). Hi-speed video up to two thousand (1000) frames per second and photometrics up to a million (1,000,000) frames per second are also supported by another department. X-ray diagnostics are used alone or in conjunction with the ultra high speed photography and/or VISAR analysis to fully track material from explosive devices.

1.1 X-ray lab

The X-ray Diagnostics and Testing Lab is in the south wing of the ECF and consists of a control room, a firing pad, an assembly room, a photometrics camera room and a darkroom. The control room is where the whole experiment is controlled and houses the instrumentation for the test. The electronic data is taken on high speed digitizing oscilloscopes that are controlled by a computer system. The computer sets up the digitizers, acquires the data and can be used to analyze it. This data can then be transmitted across our network system to the design engineer's own computer for further analysis or publication. The Photometrics cameras are set up in the camera room to look into the firing pad through viewing ports. These allow the cameras to be placed out of danger from explosive debris from the testing. They are then controlled from the instrumentation consoles.

The firing pad has been proof tested to one (1) kilogram of TNT equivalent of high explosives. The assembly room is a grounded room where the experimental object can be put together and moved to the pad. There is also a smaller stand-alone chamber within the control room that is rated for ten (10) grams of explosive charge to be used for smaller testing such as statistical programs.

The x-ray lab passed a readiness assessment in December of 1995 and became fully functional in April of 1996.

1.2 X-ray Layout

The x-ray systems currently installed in the ECF are commercially available from Physics International® (formerly Hewlett-Packard®) and are of 150 and 300 KeV output power ratings. Each system is complete and independent of each other and are permanently installed in the laboratory. The operational instrumentation consisting of the charging circuit, power supplies and timing control is located in the control room. The high voltage components are located above the explosive chamber in a separate room with controlled access. These items include the Marx style capacitor pulsars and the seventeen (17) kilovolt trigger amps. The output from the generators is cabled into the chamber and to individual electron source tubes. These x-ray tubeheads are typically mounted and arranged in a vertical, radial pattern and aimed at the device under test. The pulse of x-rays last seventy (70) ns and thirty (30) ns for the 150 and 300 KeV tubes, respectively. They can be delayed from each other within a hundred (100) ns and have a jitter of about fifty (50) ns. Exact timing of the radiographs can be obtained from signals fed into Hewlett-Packard® recorders. The medical type film is held inside a cardboard cassette placed within an aluminum holder in a curved plane to correspond with the head arrangement. Each head's output of x-rays are columnated by movable lead plates in order to not overlap images. In some cases these heads can be placed in a horizontal array or even a combination of directions. Debris from explosions could reach the heads so Plexiglas® or Lexan® sheets are typically placed in-between the experiment and the heads as shielding.

Radiological surveys have been done and indicate that there is no radiation escaping the explosive chamber when the x-rays are fired. This is true even when all six of the 300 KeV heads are fired at once. The camera portholes have two inches of Lexan® and also stop the radiographic effects. Interlocks prevent accidental exposures from both x-rays and explosives when the large blast doors are not closed and latched. External horns also warn of impending experiments.

A typical test will utilize DuPont Cronex® medical film with a single Quanta® intensifying screen placed behind it in the cassette. The film is then developed in a Kodak® automatic processor on site in the darkroom and can be duplicated using Kodak® duplicating film. We are also able to produce a paper image of the radiograph using hand processing. This paper image can then be made into view graphs, report pictures or digitized. The scanned image can then be manipulated if desired and

analyzed by mathematical software. The archiving and transmission of this digital file is much more efficient than older methods requiring hardcopies.

2. LSC TESTS

The 150 KeV x-ray system has been used recently to study the action and reaction of linear shaped charge (LSC) from overhead , "side-on" and "end-on" perspectives. The overhead views were taken while the LSC was submerged in water. Linear shaped charge is an explosive development that consists of a hollow chevron or "v" shaped tube that is then filled with an explosive powder. When it is initiated by a standard commercial detonator, it forms a "jet" of material outwards from the bottom of the "v". This jet is then used to slice through materials. The back side of the sheathing flies off at an angle as debris.

2.1 Submersion Tests

The action of the LSC covered with a rubber housing that was glued to a composite material substrate was radiographed while the assembly was submerged in a tank of water. This water simulated the actual conditions that the LSC and covers were to be used in. The water can dampen the LSC jet and cause the covers to move more than is normally expected. Three x-ray tube heads were used and were mounted on a wooden framework. The earliest timed head was placed at a vertical position and the others at forty-five degrees to either side. The columnation was accomplished by mounted Plexiglas plates with lead tape masking one exposure from the next. The film cassette was placed under the plastic tank which was set up on aluminum blocks. The cassette was also wrapped in plastic to keep water from being splashed on it and damaging the film. The sample plate was clamped to a pair of "L" shaped angle brackets. This same setup was used to radiograph samples that had the donor LSC and a second piece under it's own covering next to it. This was to determine if the detonation of the first piece would affect the placement or function of the second piece of LSC. The x-rays from each head were triggered at precise times by a pulse generator such that they represent a stop action photograph. In order to identify where things were in relation to each other, the rubber over the initiated LSC had small lead dots placed on the outside while the second cover had lead triangles on it.

The x-rays clearly show the LSC going off and the aluminum sheath material spreading out. By noting the edge of the composite material, the edge of the second cover and the image of the aluminum sheathed LSC under it, it is evident that these items of interest did not move within the six hundred (600) microseconds that the radiograph was taken in. This is well past the necessary time frame of the intended use. The radiographs also show a brass step gauge that is placed on the test subjects as a distance reference.

2.2 Side-on Tests

Side views of the LSC were done with and without rubber coverings to examine the dampening effects of the covers. For this series the LSC was placed on the same composite material. They were not submerged under water since the first series didn't provide evidence that it had any effect on the materials actions. The plates were then placed up on blocks of wood to align it with the film without interfering with the image. The three x-ray heads were placed in a vertical array and the film cassette was curved behind the sample. The cassette was protected by a Plexiglas® sheet. Timing of the pulses from the heads was designed to capture images that worked their way across the film.

The exposures without the covering show the outer sheath material being thrown off the back side in layers as the jet moves along the length of the LSC. By measuring the jet positions at different times and the angle of the sheathing, the velocity of the sheath can be determined. The x-ray set with the cover in place shows a radical slow down in the velocity of the sheath material relative to the speed of the detonation front. The height of the debris of the covered LSC test at about twenty-four microseconds versus about twenty-eight for the uncovered LSC test is noticably smaller.

2.3 End-on Tests

End-on exposures of LSC are typically difficult to get because the axis of the jet movement is in the direction of the x-rays and the film pack. For this set of exposures a single head was used and pulsed at different times for several samples. The three inch piece of LSC was glued to a plastic detonator holder and bent at a ninety degree angle approximately an inch from the end such that the det hung downward out of the view. This assembly was then taped to a composite plate and placed on a block of wood. Again the film was protected by Plexiglas®.

The x-rays of the LSC without the covering show the sheath material field moving outward very clearly with time. The sheath material movement appears symmetrical and uniform. The covered LSC radiographs show a much smaller and denser debris field.

3. DISPERSION TESTS

A set of radiographs were taken from a series of tests that examined the debris scattered from a device. It is important that the fragments from the device not damage adjacent components in the complete system. The explosive was a pellet pressed from powder and initiated by a detonator and a timing lead. This was all contained inside an aluminum housing that sat on top of a Alumina filled plastic simulation of a next assembly.

Four x-ray heads were used; three in a horizontal plane and the fourth mounted above the test unit vertically. The earliest timed head was orientated such that the detonator housing was perpendicular to it's axis. The other two heads were arrayed from there at forty-five and ninety degrees. The horizontal film cassettes were sandwiched between two pieces of two inch thick hi-density foam with a Plexiglas® sheet in front and placed normal to the x-ray stream. There was a set of apertures made up of Plexiglas® and lead tape to keep from exposing adjacent film packs. The vertical film cassette was placed under the device, a two inch thick foam holder, a second two inch thick piece of foam and ½ inch of Lexan®. The foam pieces also served as witness plates to capture debris for measurements. The vertical film was preexposed with the device in place in order to give a reference position for the debris.

The four x-ray views show the dispersion of fragments at various times. The flight of the setscrews used to hold the explosive device to the plastic simulator is clearly seen in the radiographs. From these "markers" most of the other large fragments can be traced to their final impact with the foam witness blocks. By tracing these fragments and their depth into the witness blocks, fragment average velocity, kinetic energy and momentum can be calculated.

4. SUMMARY

The capabilities of the new ECF building at Sandia are state-of-art in instrumentation and techniques. The X-ray Diagnostics and Testing Lab has the capacity to test and image large and small explosive components with the added techniques of VISAR and ultra high speed photometrics when needed. The radiographs produced from these sample tests highlight these capabilities. The lab is also embarking on the photo processing and digitizing of the radiographs into forms more usable to the experimenter for reports, archiving and analysis.

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