EVALUATION OF TARGET OPTIONS FOR ADVANCED RADIOGRAPHY FACILITIES

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Abstract

Initial results indicate that electron beams hitting targets used to generate x-rays during multipulse operation in advanced radiography facilities will generate plasma plumes which will disturb the electron beam during subsequent pulses. This, in turn, potentially can degrade the x-ray spot quality generated by the subsequent pulses. If this concern is substantiated, new facilities such as the Advanced Hydrotest Facility (AHF) will need a provision for mitigating this effect. One such provision involves moving the target with sufficient velocity that any plasmas formed are carried adequately far from the electron beam that they do not disturb it. We report the various approaches which have been considered and present data showing the maximum target rates which can be achieved with each approach.

1 DYNAMIC TARGET DEVELOPMENT

Development of a dynamic target delivery scheme required study of several relatively mature technologies. Those investigated as candidates include high velocity fly wheels, shape charge jets, and two types of high performance guns (burning propellant and compressed gas driven versions or as they are better know two-stage light gas guns). All of the systems investigated offer their own distinct advantages relative to the others; however, each also has its own particular weakness when compared to the design requirements for the intended application. DARHT (Dual Axis Radiography Hydrodynamic Test facility) and AHF (Advanced Hydrodynamic test Facility) require high dose X-ray pulses at very fast repetition rates. The energy deposited in target materials to create these high X-ray doses causes it to vaporize and ionize leaving a hole. Fresh material must be positioned in its place before the next X-ray pulse can be delivered from the system. The primary function of a dynamic target is to fulfill this material replacement need.

The problem statement used for determination of suitability for a given solution can be simply stated as followed:

- Deliver fresh material to the interaction area before the next pulse is required.
- Suppress or redirect the evolved plasma out of the electron beam path to avoid disturbance of beam focus.
- Use materials of the proper cross section (high Z) to maximize the radiation dose for a given energy input.
- Deliver the target material to the same location every time the system is operated.
- Deliver the same amount of material to the interaction region for every X-ray pulse.

All of the normal methods for accelerating materials to high velocities were considered. Explosively driven flyer plates (plates of material propelled in a direction normal to the plate surface) while providing adequate velocity, are not orientated properly with respected to the electron beam without extensive development of current technology. Electrically driven rail guns were also determined not provide the necessary velocity.

The flywheel offers a significant advantage over all of the other methods because it does not need to be synchronized with other hardware in the system or the object to be flash X-ray photographed. The velocities required to deliver fresh material to the interaction region may be greater than can be obtained with existing materials or composites. The best speeds are on the order of 3mm/μsec velocity at the tip of the rotor. With development, the technique might reach a value of 4 mm/μsec which could be adequate to replace material for subsequent pulses. Flywheels, by their nature, store large amounts of energy. Figure 1, shows that the flywheel stores the greatest amount of energy of the approaches considered.

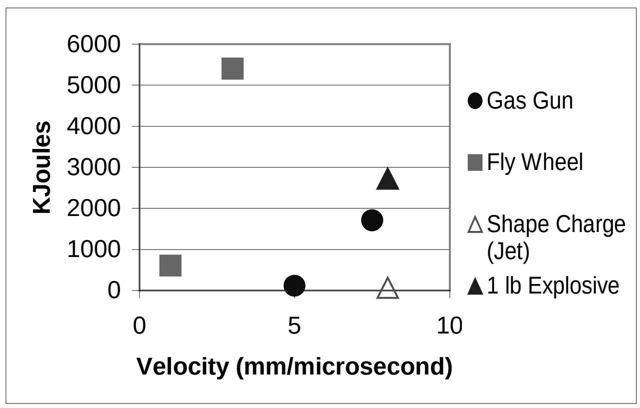

Figure1: Comparison of energy for different dynamic target approaches.

Introduction of stress risers in the surface by punching holes in them with an electron beam introduces the potential for failure and instant release of this energy. If a flywheel concept is chosen, care will need to be taken to provide for adequate containment in case such failure occurs. The need to manage the destabilizing effects of the ion / plasma plume generated during beam interaction with the target will require an additional technique for plasma management since fly wheels do not provide the 8 mm/μsec velocity calculated to be required for such plasma management through target motion alone.

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Shape charged jets offer the advantage of a very short cycle time for the total operation of injection of the target material. They also can reach the required velocities. The explosive is mounted relatively close to the electron interaction region and could be used to deliver material on demand under conditions where only a few microseconds pretrigger. This distinct advantage is mitigated by the fact that the jet of material expelled from the explosive is not of a constant cross section. Dimensions as small in thickness as 1millimeter (which is the thickness of tantalum currently required) are very difficult to obtain with this method. The density of the jet is normally on the order of 90% of solid density. Variability in the size of this material jet from shot to shot as well as along it's length in a particular stream of material makes delivery of a constant X-ray dose more difficult. This issue could be investigated through experiment along with contained management of debris generated by the blast. Experiments are currently being designed to evaluate the precision with which a jet can be placed in both time and space, the uniformity of the jet that can be achieved, the management of the gases from the explosion, and the management of the shock wave from the explosion. At this time, this is one of the two approaches that can potentially deliver the necessary velocity.

The other approach which can deliver the 8mm/μsec thought to be necessary for plasma management is a light gas multiple stage gun. Figure 2 shows a series of experiments indicating that necessary velocities have been achieved by a number of organizations using a number of gun designs.

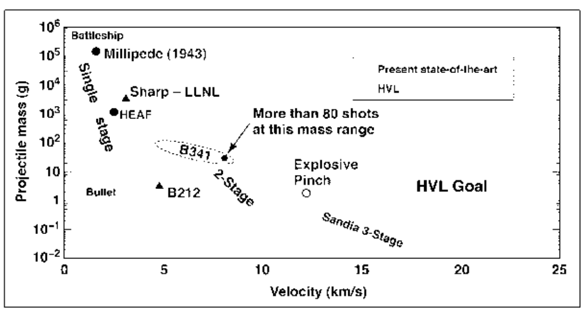

Figure 2: Experience of several organizations with high velocity guns. [1]

Research guns are currently under development (see HVL Goal in Figure 2) seek to double this velocity. An advantage of gas gun systems is their ability to deliver a predefined target geometry. Target projectile shape is defined before the gun is loaded and therefore can be well controlled. This ability allows the amount of material to be act[i]ed upon by the electron beam to be kept constant from pulse to pulse and hence a more constant X-ray dose from the system could be expected. The final selection criteria which makes the compressed gas version of the gun more attractive than the propellant style gun is the issue of the uniformity of powder charges from lot to lot of powder produced by the manufacturer. Compressed gas versions of the gun minimize barrel fowling, cleaning issues, and lot variability is removed from the list of potential problems causing jitter in the operation of the gun system. Propellants are also very susceptible to temperature effects. Cold powder charges burn at different rates than those that are ignited when the powder is hot before ignition.

The compressed gas version of the two-stage gun is currently favored over an explosively driven version. Calculations have been performed with a basic two-stage system. The strategy chosen for this calculation was to select a standard baseline firing configuration and evaluate timing of critical events. Gas gun parameters that might affect launch times were compiled along with narrow ranges of these parameters within ranges where they can be controlled. Assuming the use of explosively driven valves, these calculations indicate that a total system jitter for a gun capable of delivering a projectile at a rate of 7.5mm/μsec will have an uncertainty in delivery of that projectile of 2-3 μsec. This uncertainty or "jitter" defines the length of target necessary to assure that target material is hit by the accelerator electron beam at the appropriate time.

Stability of the gun from a shot to shot perspective is greatly a function of the ability to measure accurately temperature, pressure, and wear in the gun barrels. Precise instrumentation for measurement of these parameters is readily available. Since the target projectile never leaves the barrel, it is fully constrained in all directions except down the axis of the gun bore, allowing accurate positioning of the target relative to the electron beam to be only a function of velocity. Utilization of a gas gun does force certain limitations on the overall systems capabilities. The total gun cycle time is on the order of 5 milliseconds and little adjustment can be made to modify the flight time or speed of the target projectile after the gun has begun to operate at the pre-selected parameters. Leakage of gas around the projectile is also of concern because it may affect the electron beam. Theoretical and experimental work is planned to alleviate the concern in these areas. Testing of this type could be done on existing guns and scaled to fit flash X-ray criteria. It should be noted that at the time of this publication target material experiments are still in progress to determine if the target material plasma and ion interactions with the beam are a real concern or of negligible effect to the overall system performance. The basic gun operating values satisfy the requirements for delivery of a dynamic target, but it remains to be demonstrated that targets with geometry leading to required x-ray generating properties can be moved by gas guns to the required velocity.

2 CONCLUSIONS

An evaluation has been started to determine the best method to deliver a fast moving target normal to the electron beam in proposed rapid multipulsed radiography facilities. Rail guns, flyer plates and fly wheels were

[1]Raymond Finucane Lawrence Livermore Laboratory – private communication

considered and eliminated from further consideration they fail to deliver the necessary velocity of 8 mm/μsec, or in the case of the flyer plate, do not provide the target material properly orientated with respect to the electron beam. Both gas guns and explosively driven shaped charges have the potential for delivering the necessary velocity. Experiments are currently underway to address remaining concerns with each approach and to minimize the risk associated with fielding the one which is chosen for implementation.

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