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Hydrodynamic Liner Experiments Using The Ranchero Flux Compression Generator System

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Introduction

At Los Alamos, we investigate materials at solid density under extreme conditions of, for example, high pressure or strain. To further these studies, we develop pulsed power techniques for driving high energy imploding liners. We have developed the Ranchero explosive-driven magnetic flux compression generator (FCG) system to perform such physics experiments at very high energy and in remote locations. Our first charter is to support the development of the Atlas capacitor bank¹, which will deliver up to 30 MA to hydrodynamic liners once completed in 2001. The basic unit of the Ranchero system is a coaxial FCG that is simultaneously initiated along its axis, has an armature expansion ratio of 2:1, and is 1.4 m long. We performed initial system tests using coaxial modules 43-cm long^{2,3}, and are finalizing the design and development of our 1.4 m detonation system. This development met with unexpected difficulties, and is a subject of another paper in this conference⁴. The 43-cm module, combined with the 2.4 MJ capacitor bank at our high explosive pulsed power facility, has the capability of delivering ~40 MA to a load of ~5 nH. Coupled with a fuse opening switch (FOS), the system will generate a good approximation of Atlas waveforms with 5 nH in the load and transmission lines, and this allows us to begin preliminary Atlas related tests before the 1.4 m module is completed. In this paper, we describe the work we have done to develop the capability along with the design of our first imploding liner experiment.

Ranchero Development Tests

Early development tests examined a variety of module parameters^{2,3}, and more recent tests have focused on testing features needed to power Atlas-like loads. Our final test of the generator by itself used the same end output configuration tested earlier for Atlas work, and added the inductance of an Atlas power flow system. The current generated in this test is given in figure 1. With our 12 mF capacitor bank charged to 19 KV, we can deliver 4.5 MA initial current to the ~56 nH generator. With a load of 4.5 nH plus ~0.5 nH hook-up inductance, the generator developed 39 MA. Earlier tests indicate that we have ~1.3nH residual inductance in the FCG, and including that with the 5 nH load, we have an energy of 4.8 MJ. Because of its over-all similarity, we consider this test as a baseline for modeling future tests. In particular, we used the current (I) and dI/dt data from this shot to establish an FCG model that can be used in self-consistent calculations involving time-varying circuit elements. To establish the model, we derived an inductance

Figure 1. Current delivered to a 5 nH static inductance load.

curve from our Raven 1-D MHD code, then used the data to establish a companion resistance function. Within the limits of reproducibility, these two curves specify a model for the module for all similar applications, even if neither one is completely accurate. The subsequent step in using the 43 cm module to power liner loads was to develop a FOS to isolate the liner from the high current associated with initializing the FCG field and early flux compression.

Fuse Development

We have chosen FOS parameters for a variety of high explosive pulsed power systems in the past using our CONFUSE computer code^{5,6}. With the generator model obtained as described above, we applied the

Figure 2. FCG and load currents on fuse development test. The right-hand curve is expanded and on arbitrary time scale.

code to choose fuse dimensions for the first system test. Our first experiment was designed conservatively, avoiding any fuse performance limits that would lead to fuse failure and not test the rest of the system. In the system, we have ~ 2 nH inductance in the fuse hardware, and an additional 3 nH in the transmission line and dummy load that mocks up an imploding liner test. Experimental results are shown in figure 2. Load isolation switches in the system were closed relatively early to avoid high voltage problems that could arise from overestimating fuse opening time. However, the fuse performed much

as expected and the load pulse of 29 MA resulted. This current is enough to perform preliminary Atlas tests and many physics experiments, and can be improved substantially by optimizing the fuse design and closing switch time. The fuse for the test shown in figure 2 was 50 μm thick, 2.7 m wide, and 0.3 m long, and CONFUSE suggests that a fuse 50 μm thick, 3.5 m wide, and 20 cm long would provide some improvement. A careful comparison of the results to CONFUSE predictions left some unanswered questions that may be related to either the fuse or generator models. As a result, we will conduct our first liner test with a fuse of the same dimensions as those used for this test, and further compare results after the test.

Liner Design and Preliminary experiment

The system for our first liner test is shown in figure 3. The conical

transmission line section emulates an Atlas transmission line. Two high voltage clamps allow us to assemble the load with access to both ends of the liner, then install that sub-assembly onto the pulsed power section. These clamps further allow diagnostic access to the inside of the assembly via small optical fibers. At 30 MA, the linear current density in the return current path outside the liner approaches 1 MA/cm. Because of this high current density and the close coupling between the current in the liner and return path, there are no cutouts allowed in the return conductor. It is made as thin as possible to allow maximum penetration of x-rays to diagnose the liner, and is 5mm thick in our initial design. The only operational change between the FOS test and the first liner test is to close the load isolation switches 2 μs later than on the test of fig. 2. This will remove some of the low current foot

from the curve, but should not run sizeable risk of overvolting the transmission lines. The curves should be very similar to those in figure 2, with two exceptions. The liner load inductance has increased above our 5 nH goal, and the liner dynamics will further decrease the peak current. We expect to see peak generator current of ~ 26 MA, and a liner current between 20 and 25 MA on the first test. The test will use a 3mm thick aluminum liner, which is twice the thickness of our eventual goal. This liner will move more slowly ($\sim 0.7\text{cm}/\mu\text{s}$) than our eventual plans, but will be easier to diagnose on this initial test where many diagnostics are also being tested.

Conclusions

We have developed a system for driving hydrodynamic liners at currents approaching 30 MA. Our 43 cm module will deliver currents of interest, and when fully developed, the 1.4 m module will allow similar currents with more total system inductance. With these systems we can perform interesting physics experiments and support the Atlas development effort.

References:

- ¹R.K. Keinigs, W.L. Atchison, R.J. Faehl, V.A. Thomas, K.D. Mclenithan, and R.J. Trainor, One-and Two-Dimensional Simulations of Liner Performance at Atlas Parameters.
- ²J.H. Goforth, et al, Ranchero, A High Flux Compression Generator System for heavy Liner Experiments, Seventh International Conference on Megagauss Magnetic Field Generation and Related Topics, August 5-10, 1996, Sarov (Arzamas-16), RUSSIA.
- ³J.H. Goforth, et al, The Ranchero Explosive Pulsed Power System, (Proceedings of the Eleventh IEEE International Pulsed Power Conference), Baltimore, Maryland 1997, p. 573, Cooperstein and Vitkovitsky eds.
- ⁴D.G. Tasker, et al, Optimizing the Ranchero Coaxial Flux Compression Generator, P. Miller, Naval Air Warfare Center, Weapons Division, China Lake, California.
- ⁵J.H. Goforth, et al, Performance of the Laguna Pulsed Power System, (Proceedings of the Sixth IEEE Pulsed Power Conference), Arlington, Virginia, 1987, p. 445, Turchi and Bernstein eds.
- ⁶R.E. Reinovsky, I.R. Lindemuth, J.H. Goforth, R.S. Caird, and C.M. Fowler, High Power Switching and Pulse Shaping, (Proceedings of the Megagauss Fifth Conference), Nova Science Publishers, Inc. 1990, p.453, Titov and Shvetsov eds.