LA-UR- 95-3035

CONF-950750--42

Title: X-RAY SOURCE PRODUCTION IN FOIL IMPLOSION MACHINES

Author(s): M. Rich, and W. Matuska

Submitted to: IEEE/Pulsed Power Conf.,
Albuquerque, NM
July 1995

Los Alamos
NATIONAL LABORATORY

X-RAY SOURCE PRODUCTION IN FOIL IMPLOSION MACHINES

Marvin Rich and Walter Matuska
Los Alamos National Laboratory
P.O. Box 1663, Los Alamos, New Mexico 87545

A number of two-dimensional radiation-magneto-hydrodynamic foil implosion calculations are discussed which explore ways of producing warm x-ray sources (~60 eV) in a reproducible manner and which would permit close-in access to the source. The discussions include the effects of contoured electrodes on the foil implosion and source output, and of tapering the average mass distribution along the length of the foil. Primarily, source evaluation by jet formation and stagnation against a dense stopping block is treated.

INTRODUCTION

All long pulse width magnetic drive foil implosion machines, such as the Pegasus and Procyon machines at Los Alamos, must use large radius foils, (~ 5 cm radius). This necessity leads to a number of difficulties for production of soft x-ray sources with such systems:

a) An x-ray source consisting simply of the on-axis z-pinch will be relatively inaccessible and will be unusable for most applications because it will not be possible to place any required experimental apparatus close enough to receive adequate x-ray fluence.

b) The implosion of the foil is Taylor unstable, and the relatively slow collapse of the foil allows considerable time for the growth of large bubble and spike instabilities.

c) The strength and duration of the x-ray source may be very dependent on the mass perturbations of an initially highly wrinkled foil.

As a start toward determining whether some or all of these difficulties could be overcome, a number of two-dimensional Eulerian radiation-magneto-hydrodynamic calculations have been run in which axial holes in one or both electrodes of the machine permit the ejection of a plasma jet from the z-pinch region. This jet is allowed to stagnate against a dense stopping block, and the radiated power from the conversion of kinetic energy into internal energy is used as a diagnostic of axial energy production. Potentially, the jet along with the energy radiated out the hole in the electrode at all angles, could be used to raise the temperature in a small hohlraum, or the jet could be used directly to try to create a jet stagnation source. While the plasma jet and contoured electrodes permit the possibility of bringing an x-ray source out from between the implosion machine electrodes, the jet precludes looking axially into the hot z-pinch directly. It should be emphasized that other ways of obtaining an accessible x-ray source, such as looking diagonally off axis into the z-pinch or the construction of a small axial hohlraum, may prove to be the best methods for accessible source production, but these have not been investigated calculationally or experimentally as yet.

PEGASUS JETS

Though no experiments have been done to demonstrate that there can be a great deal of variability in jet strength depending on the initial foil perturbations (i.e. wrinkling), calculations for the Pegasus machine indicate that this will be so. Figure 1 shows problem P0, a configuration with two plane parallel electrodes, each having a 1 cm diameter hole on axis. Tungsten stagnation blocks were placed one centimeter from either hole in this calculation. As seen in the density contour plot of Figure 2, jets of imploded foil material exit each hole and stagnate against the tungsten blocks.

From the calculated radiated power curves shown in Figure 3, we see that there is a "weak" jet and a "strong" jet, where "weak" and "strong" refer to the relative magnitudes of the power curves obtained by integration over frequency of time dependent radial spectra produced by the stagnation of the jets against the tungsten stopping blocks.

CONTOURED ELECTRODES AND TAILORED FOILS

Studies of the effects of a contoured electrode in the single jet producing configuration, shown in Figure 4, were a continuation of the Pegasus work when radiation source development efforts were shifted to the higher energy Procyon machine, which permits access from one side only. The principle reasons for contouring the electrode without the axial hole were:

a) to position the hot portion of the z-pinch close to the axial hole where it would be most accessible or produce a stronger jet,

b) to try to reduce variations in jet strength (caused by instability growth in the foil) by compressing the imploding foil laterally,

c) and to determine if the pinch temperature could be increased by approximating a more spherical foil implosion than that of the usual cylindrical z-pinch, thereby producing a hotter source.

In order to begin an assessment of how sensitive jet production might be to foil perturbations when using contoured electrode configurations, two calculations, P1 and P2, were run which used an identical initial mass distributions along the foil but which differed only in that the orientation of the foil with respect to the electrode hole was reversed. The foil mass distribution was one matched to the Procyon test PDD1. Calculations corresponding to P1 and P2 with plane parallel electrodes and a single electrode hole have not yet been run, but must be done before final conclusions can be made. Figure 5 gives the average foil mass distribution used in the P1 calculation. It is seen that the foil is somewhat more massive toward the electrode hole. (In calculation P2, the foil distribution was reversed.) The powers radiated in the two cases at the stagnation plate are shown in Figure 6. The stagnation timing and peak power amplitudes differ in the two calculations, but not extremely. Having less mass near the electrode hole appears to create a faster jet, but having more mass there appears to provide a stronger jet.

Two additional calculations, P3 and P4, were run to determine whether modification of the average mass distribution along the foil length can be used to control or enhance source and jet formation. Masses of the initial and final half centimeter of the two centimeter long foils were increased and decreased, respectively, by ten percent, leaving the total mass unchanged, and creating a "tapered" average mass along the foil with the perturbations relatively unchanged. A table indicating the orientation of the foil mass distribution with respect to the hole in the electrode for problems P1 through P4 is given below.

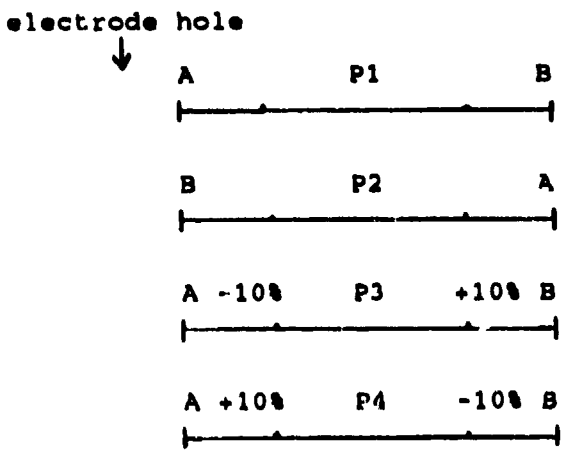
Figures 7 and 8 show the foil mass distributions obtained for problems P3 and P4. X-ray power outputs from the jet stagnations of problems P1, P3, and P4 are given in Figure 9. It is seen again that reducing the foil mass near the electrode hole (problem P3) produces an earlier but weaker power output, while increasing this mass (problem P4) delays the onset of the x-ray output and possibly increases the width of the power curve slightly. Additional work with tailoring of the average foil mass distributions is needed to provide a fuller and clearer picture of the usefulness of this procedure.

DIFFICULTIES

There are a number of difficulties with the work presented here as it presently stands. As mentioned previously, problems analogous to P1 and P2 using plane parallel electrodes must be run before we can fully assess the worth of contoured electrodes (let alone the determination of best contour designs). The present calculations were driven by a current wave form derived from a previous Procyon test rather than with a self-consistent circuit model for the Procyon machine. Such a circuit model did not exist when the work was done, but is necessary for assured self-consistency. The radiation-magneto- hydrodynamic code which was used has a number of defects, such as the occasional formation of unphysical hot spots in vacuum regions. While it is necessary that the code defects be corrected in order to have full confidence in calculated results, we believe that calculational trends and problem comparisons are reliable. Finally, because of the great scarcity of experimental data with which to check code reliability with respect to jet formation and stagnation, we cannot be truly confident in any of these calculations even to the point of whether weaker or stronger jets truly occur depending on foil perturbations.

DISCUSSION

While not yet definitive, the present work suggests that suitable contouring of electrodes in foil implosion machines can be of use in reducing the effects of foil perturbations and subsequent instability growth and in enhancing jet formation and stagnation. Some control over these processes can also be obtained by appropriate tailoring of the average mass distribution along the implosion foil despite the inability to control the initial perturbations in the foil. We are perhaps talking about ten to twenty percent enhancements in final x-ray source output. Again, before we can be fully confident in our results and conclusions, we must examine and resolve the problems mentioned above and have adequate experimental data with which to verify our computations. We feel that this paper starts to address the problems necessary to produce reliable and accessible soft x-ray sources using large radius foil implosion machines.



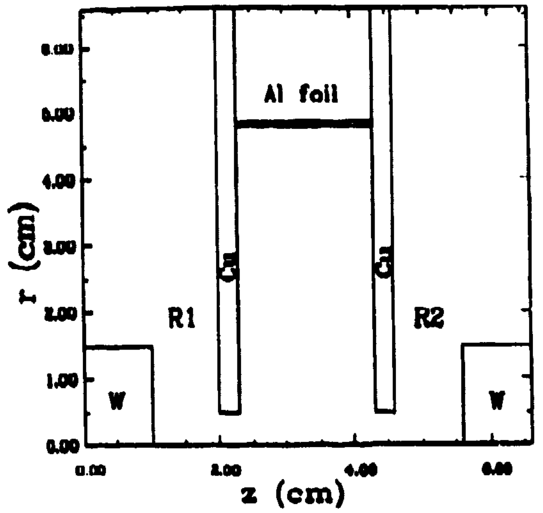


Figure 1. Pegasus machine configuration with 1.0 cm diameter holes in each electrode and tungsten stagnation blocks used to demonstrate calculationally the variability of jet strengths.

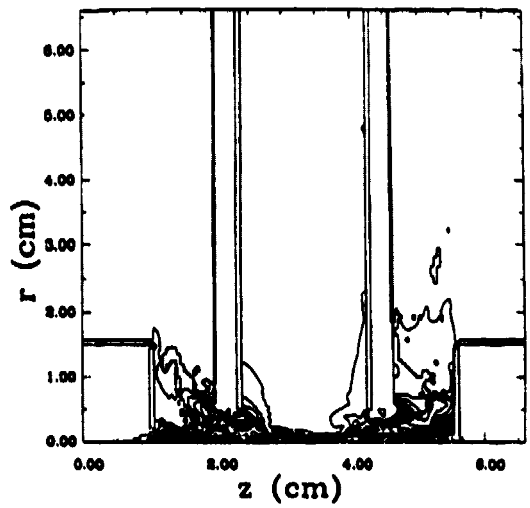


Figure 2. Density contour plot illustrating jet formation and stagnation in the Pegasus geometry of Figure 1.

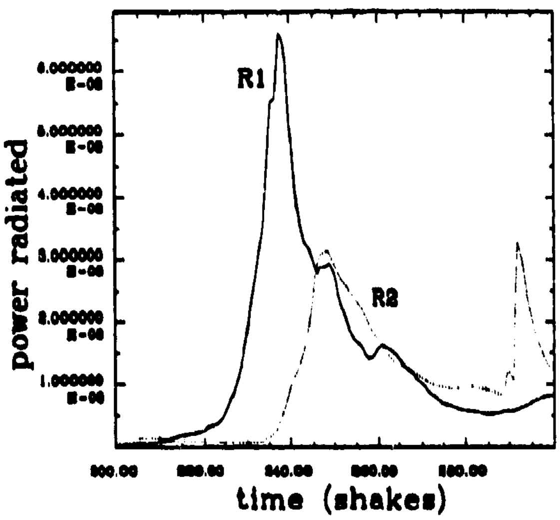


Figure 3. Calculated radial x-ray power outputs from the two jet stagnation regions of Figure 1 showing the unequal effectiveness of the jets.

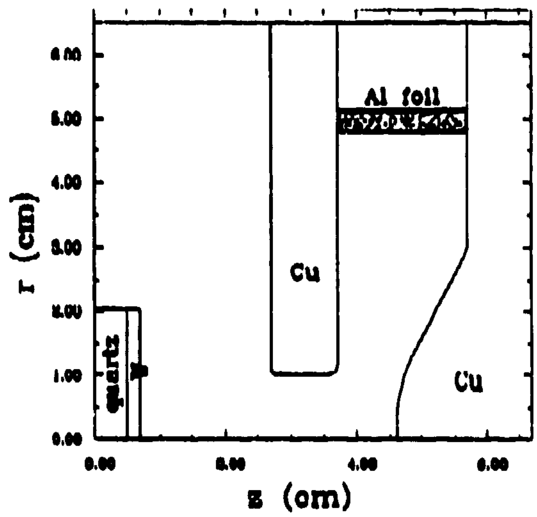


Figure 4. Configuration used in calculations for the Procyon test PRF0.

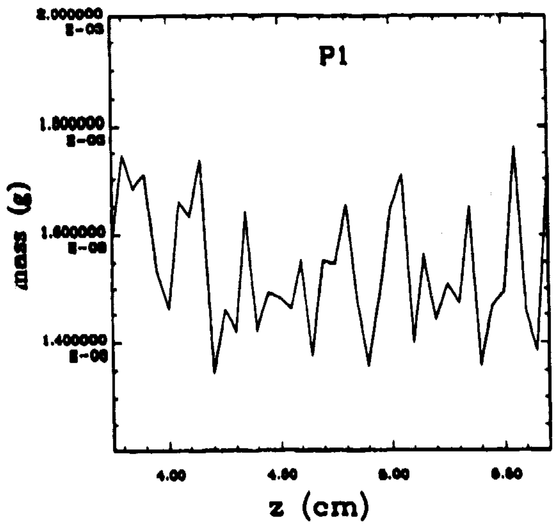


Figure 5. Mass distribution laterally along the aluminum implosion foil used in the Procyon calculations P1 and P2.

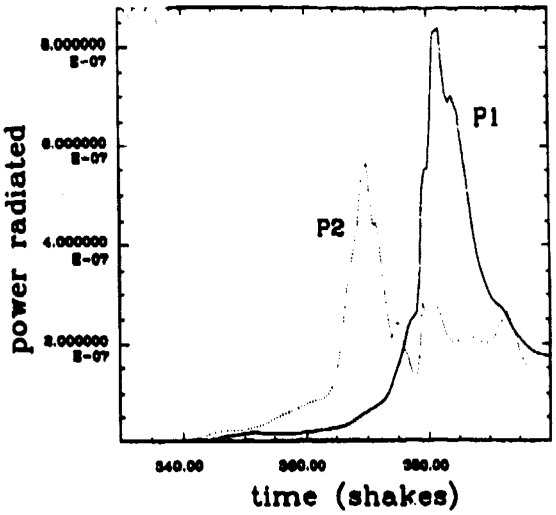


Figure 6. Radial x-ray power outputs from the jet stagnation region for Procyon calculation P1 using the foil mass distribution of Figure 5 and from calculation P2 in which the orientation of the foil mass distribution was reversed with respect to the electrode hole from that of P1.

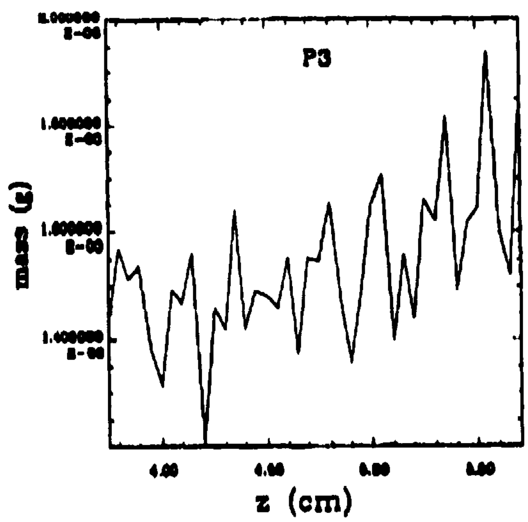


Figure 7. Foil mass distribution used in problem P3 in which the masses of the left half centimeter of the foil (nearest the electrode hole) were decreased by 10% and the masses of the right half centimeter were increased by 10%.

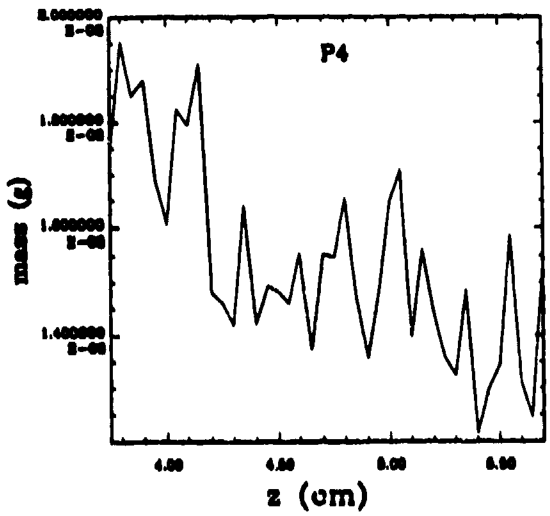


Figure 8. Foil mass distribution used in problem P4 in which the masses of the left half centimeter of the foil (nearest the electrode hole) were increased by 10% and the masses of the right half centimeter were decreased by 10%.

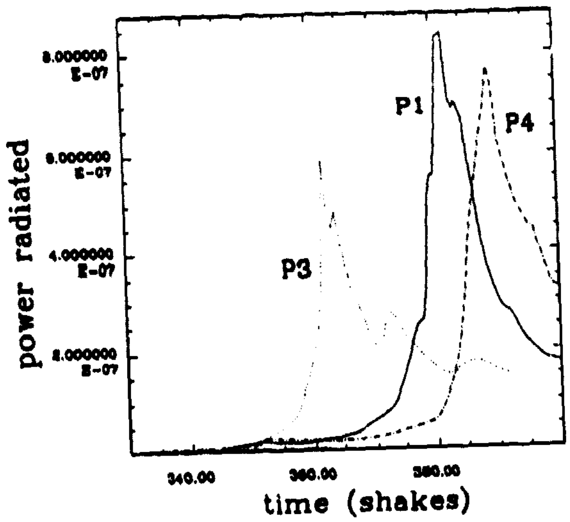


Figure 9. Comparison of the radial x-ray power outputs from the jet stagnation regions of problems P1, P3, and P4.