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ISENTROPIC COMPRESSION UP TO 200 KBARS FOR LX 04, NUMERICAL SIMULATIONS AND COMPARISON WITH EXPERIMENTS

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Isentropic compression experiments and numerical simulations on LX-04 (HMX / Viton 85/15) were performed respectively at Z accelerator facility from Sandia National Laboratory and at Lawrence Livermore National Laboratory in order to study the isentrope and associated Hugoniot of this HE [1][2][3][4][5].

2D and 3D configurations have been calculated here to test the new beta version of the electromagnetism package coupled with the dynamics in Ls-Dyna and compared with the ICE Z shot 1067 on LX 04.

The electromagnetism module is being developed in the general-purpose explicit and implicit finite element program LS-DYNA® in order to perform coupled mechanical/thermal/electromagnetism simulations. The Maxwell equations are solved using a Finite Element Method (FEM) for the solid conductors coupled with a Boundary Element Method (BEM) for the surrounding air (or vacuum). More details can be read in the reference [6][7].

1.1 CONFIGURATION OF THE NUMERICAL SIMULATIONS

3D configurations, built with the TrueGrid® mesh generation program, has been used with a lagrangian description. The mesh resolution is presented Figure 1. The mesh resolutions on the side for the following parts are: the panel under the samples is 7.5

elements / mm, the LiF windows are 2 elements / mm, the samples are 4 elements/mm. A fine mesh resolution has been tested in 2D plane and 3D configuration.

The experimental configuration of the shot 1067 is presented Figure 2. The bottom of the cathode and anode are connected to a circuit with a capacitor bank. For the numerical simulations, the experimental current is an input data for the bottom of the square plain barrel.

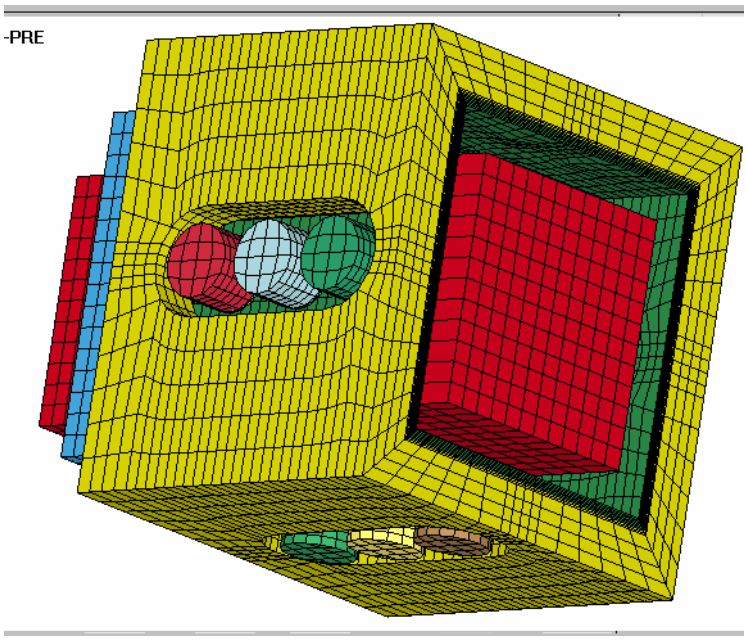

Figure 1 : mesh of the numerical simulations

1.2 MODEL DESCRIPTIONS

Steinberg constitutive law has been used for the metals [8]. Classical Gruneisen equations of state have been applied. The heat capacity and the thermal conductivity are needed to run the thermal solver.

The main assumptions are no phase change, no plasma, conductivity constant for the anode and cathode. The diffusion of the current could be taken into account, but has not been tested yet here. It is possible to take into account the conductivity change versus the temperature (resistivity equation of state), but has not been tested yet here. Further studies should take these into account.

1 - Steel304
2 - Copper
3 - Al6061T6

Units mm
a = 20
b = 3
c= 0.8
d = 6
e = 8.99
f= 4.33
g = 6.5
h1 = 9.12
h2 = 16.1
h3 = 23.14
i = 23
j = 30
l=13
m=4.496 (radius)
n=5.13
n=c+f

<u>Panel 1, 2, 3, 4</u>
Diameter 6
k top =0.491
k Bottom =0.722

<u>Panel 3 & 4</u>
Diameter 6
k top =0.4
k Bottom =0.6

<u>Windows</u>
Diameter 6
Thickness 3

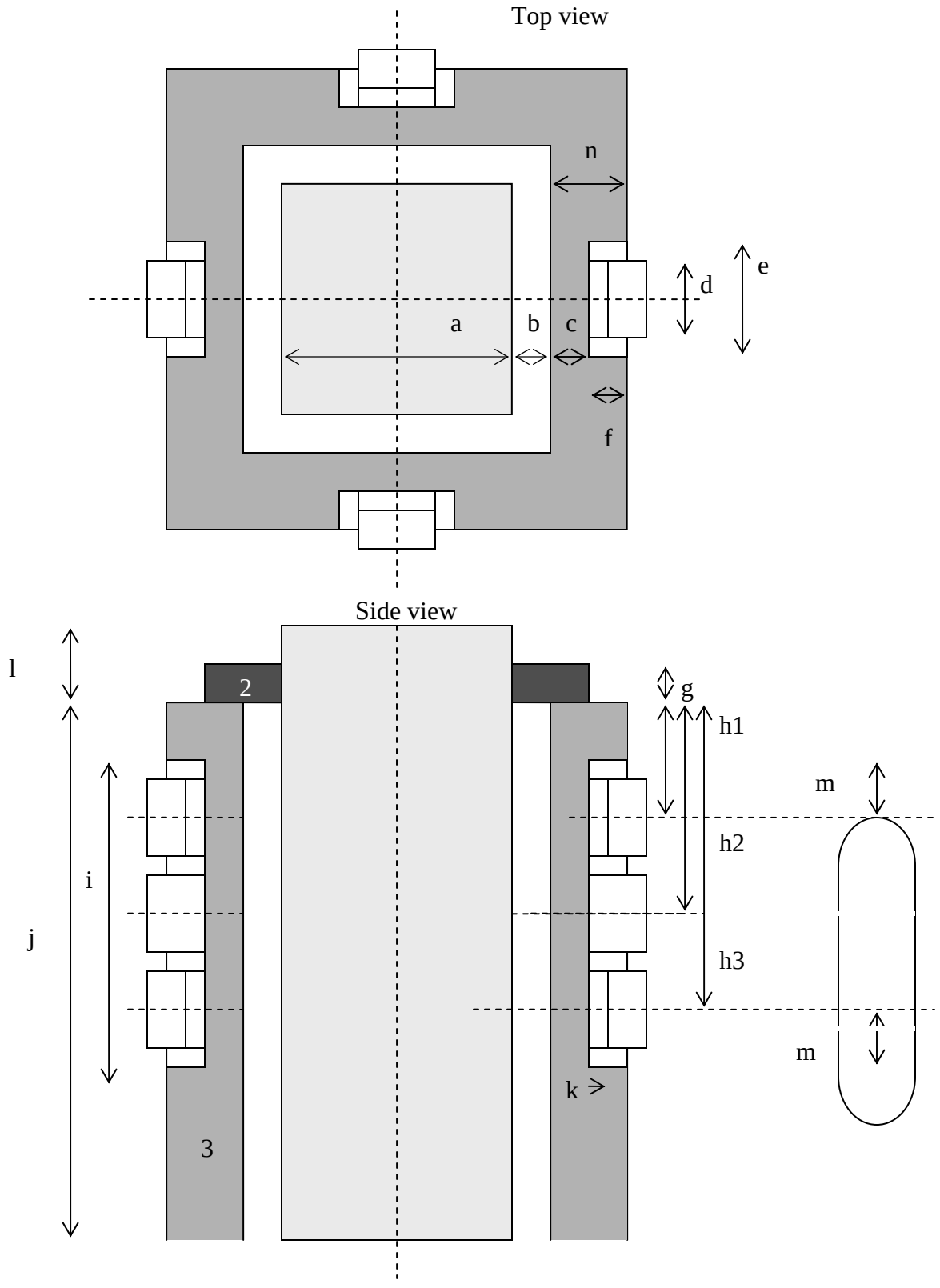

Figure 2 : Experimental configuration of the shot 1067

1.3 NUMERICAL SIMULATION RESULTS

The numerical results of the 3D configuration are presented Figure 3 and Figure 4.

The experimental velocity of the “drive” (middle sample, interface panel / LiF) is retrieved with a good accuracy. A bump can be seen during the release, which is associated with the coarse mesh of the second LiF window. The pressure reaches about 200 kbars at the base of the panel. It seems to be higher at the interface between the panel and the LiF windows, Again, this should be related with a coarse mesh resolution of the LiF window.

Further numerical simulations using finer mesh resolutions are on-going to see the influence of the mesh resolution and the effect of the Ignition and Growth model for HE.

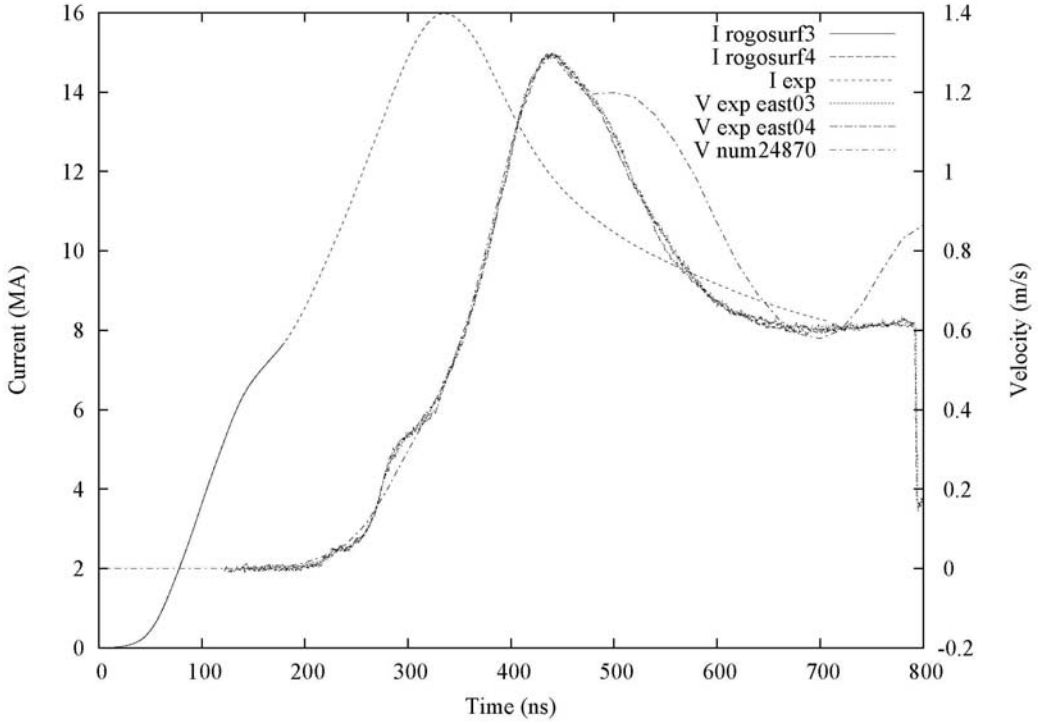

Figure 3 : Current and velocity versus time, Z Shot 1067 and calculations

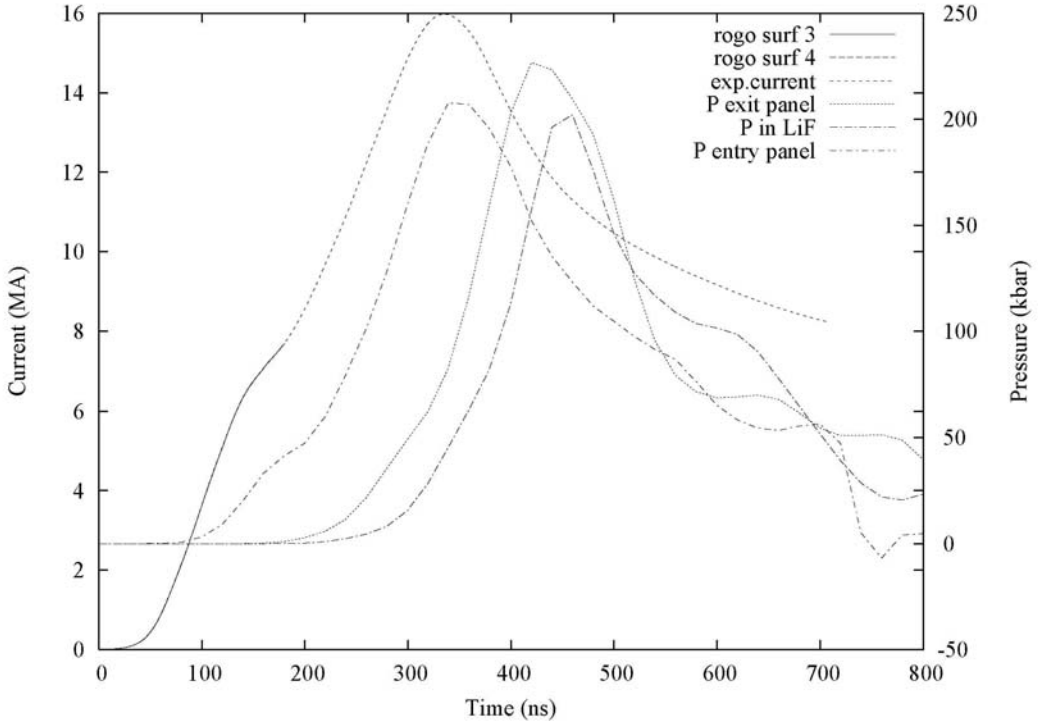

Figure 4 : Current and pressure versus time, Z Shot 1067 and calculations

* This Work has been performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48

References

[1] D.Hare, K.Vandersall, Isentropic Compression Data from SNL Z machine shot 1067, LLNL 2005

[2] D.Hare, D.B.Reisman, F.Garcia, L.G.Green, J.W.Forbes, M.D.Furnish, C.Hall, R.J.Hickman, The Isentrope of Unreacted LX-04 to170 kbars, Shock Compression of Condensed Matter - 2003, pp.145-148

[3] D.B.Reisman, J.W.Forbes, C.M.Tarver, F.Garcia, R.C.Cauble, C.A.Hall, J.R.Asay, K.Struve, M.D.Furnish, Isentropic Compression of LX-04 on the Z Accelerator, Shock Compression of Condensed Matter - 2001, pp.849-852

[4] D.Hare, K.Vandersall, F.Garcia, J-P.Davis, C.Hall, J.W.Forbes, Isentropic Compression Data on LX04 at 150 Celcius using the Z Accelerator,

[5] D.E.Hare, How to Plan and Analyse an Isentropic Compression Experiment (ICE), September 2004, LLNL, UCRL-TR-206486

[6] P.L'Eplattenier, "Introduction of an Electromagnetism Module in LS-DYNA", presented at the Ohio State University workshop on Magnetic Metal Forming, Columbus, OH, May 19, 2005, available at http://mse-gsd1.eng.ohio-state.edu/~glenn/Mini_Symp/LSTC_Pierrre

[7] A.Lefrancois and P.L'Eplattenier, M.Burger, Isentropic Compression In A Strip Line, Numerical Simulations And Comparison With Gepi Shot 268, LLNL report, February 2006

[8] D.J.Steinberg, S.G.Cochran, M.W.Guinan, A Constitutive Model for Metals Applicable at High-Strain Rate, J.Appl.Phys.51,1498 (1980)