Disk EMG Application to Study the Equations of State of Materials

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Introduction: One of the problems of high energy density physics is to specify the equations of state (EOS) of materials under high pressures. Such pressures were obtained in the underground nuclear explosions. In those experiments the iron plate was driven to velocities 36...61 km/s. The impact of the plate moving with such velocity on the target produced the shock compression pressure 4,1…10,5 TPa in the studied specimens. In the non-nuclear gasdynamic experiments the steel plates and the shells were driven by the explosive projectile systems up to velocities of 23 km/s and the pressures to 1,8 TPa were achieved. It is difficult to get higher velocities of acceleration of heavy metals like iron and copper by purely gasdynamic methods. Therefore, in order to cover the pressure range ³ 1 TPa it would be of interest to consider a possibility of magnetic drive of the shells to velocities of 20-50 km/s.

1. Magnetic drive of the shells at RFNC-VNIIEF. To drive the shells to high velocities, the high-power explosive magnetic generators (EMG) have been developed and applied at RFNC-VNIIEF. They are cheaper than the stationary facilities and allow producing the load energy higher than the energy achieved at the best among the existing and designed stationary systems. On the way of EMG application in the experiments to study the high-speed drive of the shells and to produce pressures of ³ 1 TPa RFNC-VNIIEF has created and repeatedly and successfully tested the most powerful helical EMG (HEMG) that shapes the current pulse with the amplitude of 15 MA and characteristic rise time of 8 μs in the load at the stored energy of 30 MJ [2] and allows driving the aluminum shell to a velocity of ~ 10 km/s [3]; the disk EMG (DEMG) Æ 0.4 m with the electrically exploded unit of energy delivery to the load that allowed shaping the current pulse with the amplitude 31,5 MA and rise time of 4 μs in the experiment, driving a 50-gram aluminum shell to velocity of 12 km/s and providing a satisfactory symmetry of its convergence has been designed and successfully tested [4]; the DEMG Æ 1 m that made it possible to transfer the energy of more than 20 MJ to the liner with the mass of ~ 1 kg has been created [3].

2. Experiments with diameter 0.4 m. The DEMG Æ 0,4 m with the electrically exploded current opening switch on the basis of copper foil is used to drive the cylindrical liners. The application of the foil current opening switch (FOS) allows reducing the effective time of current rise in the loads to 1-2 mks. such device was used in VNIIEF in the experiments with DEMG at the currents 60-90 MA and power to ~10 TW [5]. In the experiments ALT - 1, 2 conducted jointly by VNIIEF and LANL in 1999-2001 the aluminum liners with a 50-g mass were driven to velocities 12 km/s. Further continuation of these works requires consideration of a possibility to design the systems with a 15-mudule DEMG Ø 0.4 m and to conduct experiment ALT-3 driving the cylindrical aluminum liner to a velocity ~20 km/s and checking a feasibility of shock-wave measurements in the reference specimens [7]. The diagnostics of efficiency of the liner-impactor efficiency will be determined due to the reading of the PDV system sensors [8].

3. Perspectives of achieving high velocities of impactors with the use of DEMG of 0.4 m diameter. It is possible to increase the velocity of the liner by increasing the number of disk elements and reducing the working area of the liner. The calculations with the 30-element DEMG Æ 0.4 m were performed to check these possibilities; in the calculations the heights of the liners were 50 mm and 20 mm. At this the nominal velocities of the liners were ~ 24 km/s and ~ 27 km/s, respectively. It is seen that the increase of the number of disk elements does not result in an effective increase of the liner velocity.

4. Capabilities of DEMG of 1.0 m diameter. High velocities of the impactors can be as well achieved with the use of DEMG with the disk elements of 1.0 m in diameter. Such DEMG has already

been applied to drive 50 g aluminum liners to velocities of ~ 15 km/s [9]. To evaluate a possibility of achieving high velocities, the calculations with the 15-element DEMG Æ1.0 m have been performed; in the calculations the height of the liners has been 50 mm and less. By installing the FOS at the radius bigger than the radius of a disk element and by increasing the voltage of operation of the explosive switch it is possible to increase the efficiency of the liner drive by the current of DEMG Æ1.0 m more than by a factor of 2.5 and to achieve the velocity of ~ 40 km/s. Reduction of the working surface of the liner makes it possible to achieve the velocity of ~ 50 km/s.

Conclusion. The experiments studying the drive of the liner systems by the EMG current pulses are overviewed. The expected parameters of the aluminum liner suitable for the exploration of the EOS of materials are described and confirmed by calculations concerning the liner drive to a velocity of ~ 20 km/s by the current of a 15-element DEMG Æ0.4 m in the joint VNIIEF-LANL experiment ALT-3. At the use of a 30-element DEMG Æ0.4 m the liner velocity can be ~24 km/s. Further increase of velocity to ~27 km/s is possible due to a reduction of the liner' working surface. The feasibility of application of the super-power 15-element DEMG Æ1.0 m to drive the liner of the ALT-3 system is estimated. The calculations demonstrate that the liner velocity of ~ 50 km/s can be achieved.

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