Railgun Experiments

By

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Summary: We have developed railgun system since 1986 for the research on hypervelocity impacts in space. Three railguns with barrel length of 95 cm, 165 cm and 186 cm are used for the experiment. 95 cm railgun has 10 mm square bore, 165 cm and 186 cm railguns have round bore with 13 mm diameter. Projectile is polycarbonate block and its mass is 1.0 – 2.0 g. A power supply is 6 mF capacitor bank. Total maximum energy is 300 kJ. The power supply is constituted by a 6 stage pulse forming network, a pulse transformer, a main switch and a crowbar switch. The current waveform may be controlled by varying the inductor of pulse forming network.
The highest projectile velocity achieved in our institute is 4.8 km/sec.

1. Introduction

In 1977, when the large homopolar generator at The Australian National University in Camberra became a practical operational machine, S.C. Rashleigh and R.A. Marshall chose a rail gun installation as one of research projects that made use of the generator's large current. A projectile which consists of a 12.7 mm cube of polycarbonate was accelerated to 5.9 km/sec at that experiment [*1*]. That was the beginning of recent researches of railgun, and after that experiment researches have been done mainly in U.S.A. (Los Alamos National Laboratory, Lawrence Livermore National Laboratory, University of Texas at Austin and so on) [*2, 3, 4*].

We have developed a railgun since 1986. The purpose of our railgun is the scientific research of hypervelocity impacts in space. We have three railguns with barrel length of 95 cm, 165 cm and 186 cm, and the maximum energy of the capacitor bank is 300 kJ. The present highest projectile velocity is 4.8 km/sec. The present paper describes the railgun barrel, the system of facilities, the diagnostics and the outline of our experiments.

2. Principle Of Railgun

Figure 1 shows the principle of the railgun. Basically the current flowing in the rails produces a magnetic flux density between the rails, and this magnetic field interacts with the current flowing in the armature. The resulting Lorentz force accelerates the armature together with the projectile along the rails. An aluminum fuse is set behind the projectile, and at the beginning of discharge an arc is initiated at the position of the fuse. Plasma plays the role of the armature.

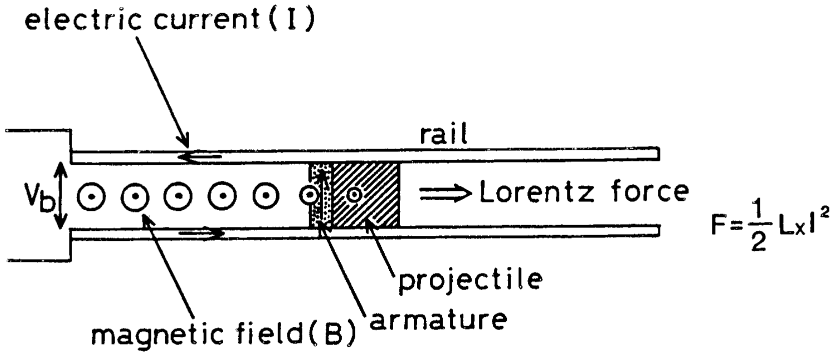

Fig. 1. Principle of railgun

3. Railgun

Three railguns with barrel length of 95 cm, 165 cm and 186 cm are used for experiments. 95 cm railgun has 10 mm square bore, and other railguns have round bore with about 10 mm diameter. Figure 2 shows 95 cm railgun and Fig. 3 shows 165 cm and 186 cm railgun.

Figure 4 shows the cross section of the railgun as one example. This railgun is 95 cm long, and the bore is 10 mm square. The rails are copper and their cross section is 15 mm × 20 mm. The insulators are transparent polycarbonate and fiber-reinforced plastic (FRP). Steel blocks support the rails and the insulators, and are compressed with 16 mm diameter bolts.

Four viton seals are placed between the rail and insulator to maintain bore vacuum and prevent leakage of the plasma armature.

The railgun is attached to a vacuum chamber as shown in Fig. 2. The inside of the chamber and railgun bore is evacuated to the order of 10 Pa with a turbomolecular pump and cryogenic pump.

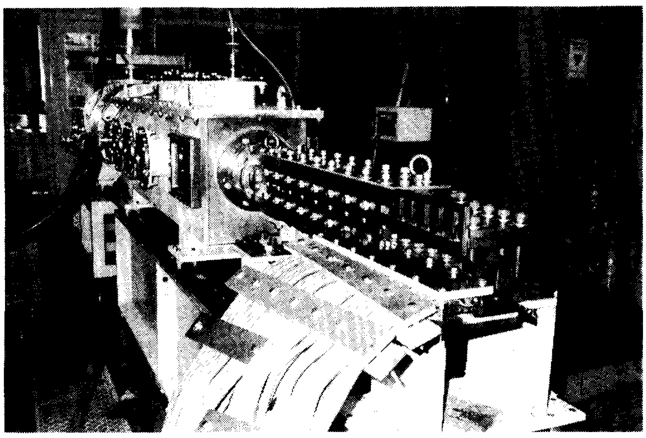

Fig. 2. 95 cm railgun attached to a vacuum chamber

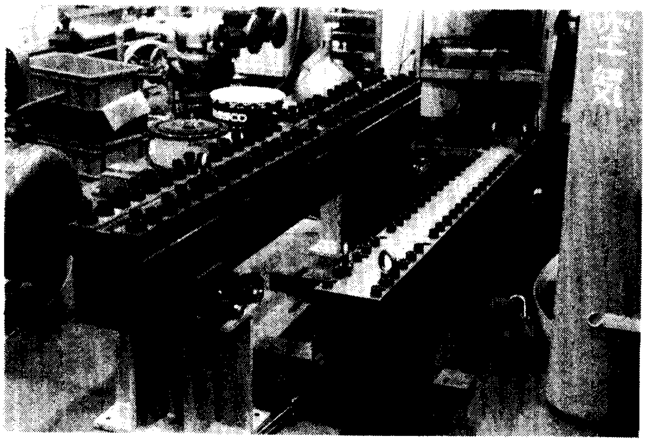

Fig. 3. 186 cm railgun (left) and 165 cm railgun (right)

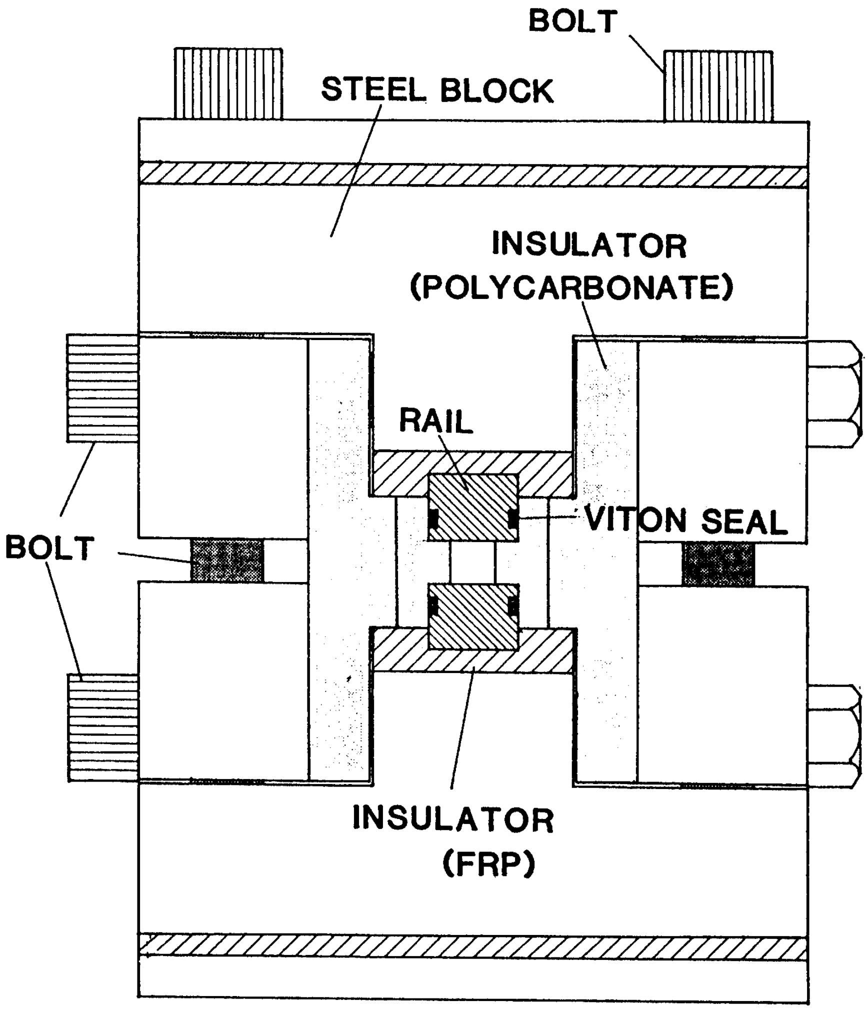

Fig. 4. Cross section of 95 cm railgun

4. Projectile

Figure 5 shows the projectiles for the railguns, the projectiles are cubic or rectangular polycarbonate blocks which have 10 mm square cross section. For the round bore railguns, the projectiles are cylindrical blocks with 10–13 mm diameter. An aluminum or phosphor bronze fuse on the back side of the projectile seeds the plasma armature. The projectile mass is 1.0–2.0 g and the fuse mass is 0.3 g.

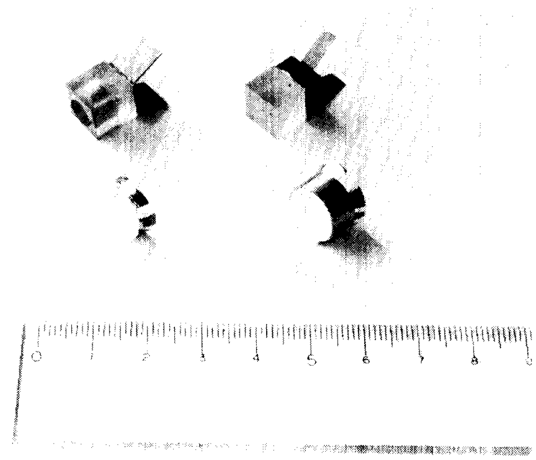

Fig. 5. Projectiles

6. Power Supply

The power supply consists of a 6 stage pulse forming network, a 4:1 pulse transformer, an ignitron switch and a crowbar ignitron (Fig. 6).

Each stage of the pulse forming network has a 1 mF capacitor bank and inductor. Individual inductance may be varied from 0 μH to 24 μH. The waveform of the current can be controlled by varying these inductances.

A 4:1 pulse transformer is placed between the pulse forming network and the railgun. It increases the current fed to the railgun.

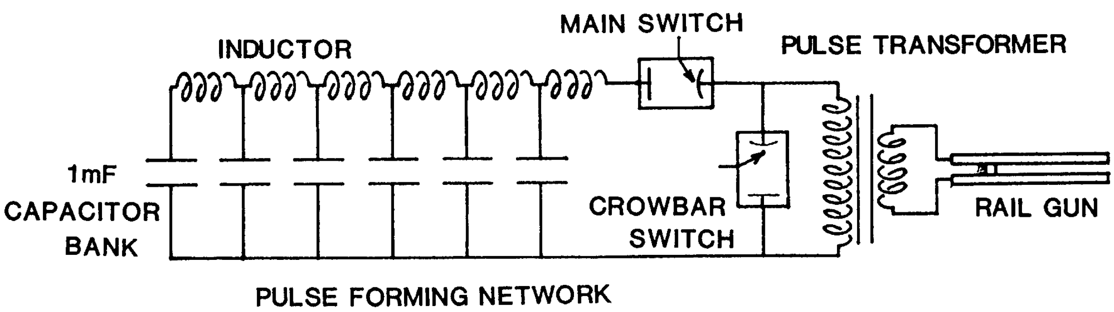

Fig. 6. Circuit diagram of power supply

7. Diagnostics

Total current is measured at the breech, and voltage between two rails are measured at the muzzle and breech (Fig. 7). The product of the current and breech voltage is the power supplied into the railgun, and the product of the current and the muzzle voltage is the joule loss of the plasma armature. Total current is measured with a Rogowski coil, and for voltage measurement two rails are shunted by 1kΩ–resistor that is linked through a current transformer. The current transformer measures the current flowing in the 1kΩ–resistor, and the voltage between two rails is calculated from the current.

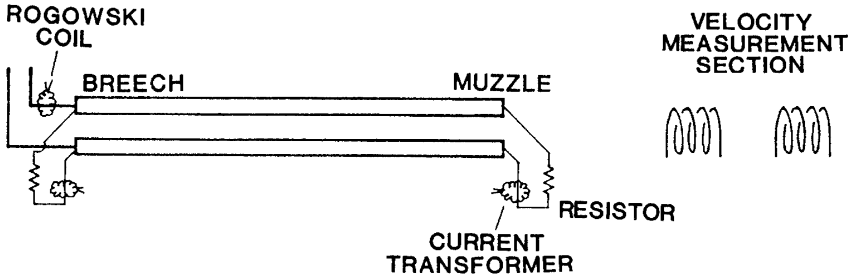

Fig. 7. Diagnostics

For measurement of projectile velocity, two sensors are placed along the trajectory of the projectile. When the projectile pass the sensor, it produces signal. The velocity is calculated using the time between the two signals and the distance of the sensors.

Some kind of sensors are used for the velocity measurement.

magnetoflyer	When the projectile including a small magnet passes through a coil, the coil produces a signal.
X-ray	A X-ray tube and a scintillation probe are used. When the projectile pass before the X-ray tube, it obstructs X-ray and output from the scintillation probe decreases.
wire gate	Wire is stretched on the trajectory of the projectile, and current flows in the wire. When the projectile cut the wire, current is also cut off.

8. Results

Figure 8 shows the railgun in operation.

Figure 9 shows the results of one shot, total current fed into the railgun, breech voltage and muzzle voltage. In this case, the capacitor bank was charged to 7 kV, and total energy was 147 kJ. The discharge duration was 1 msec and the peak current was 500 kA. Figure 10 shows the relation between the charging voltage of the capacitor bank and the projectile velocity. The highest projectile velocity was 4.8 km/sec at the charging voltage of 10 kV.

In our facilities, the projectile collides with a target in a vacuum chamber. Figure 11 shows a crator on an aluminum target by projectile velocity of 3.7 km/sec.

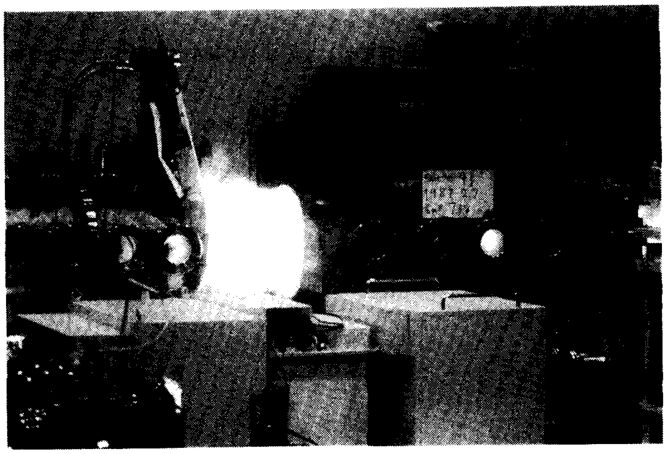

Fig. 8. The railgun in operation

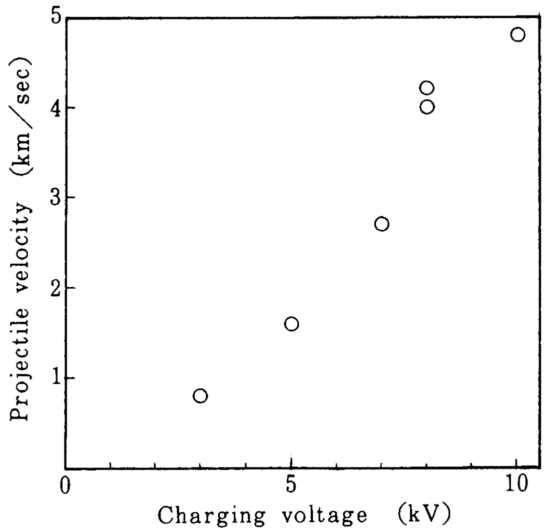

Fig. 10. Projectile velocity versus charging voltage of the capacitor bank

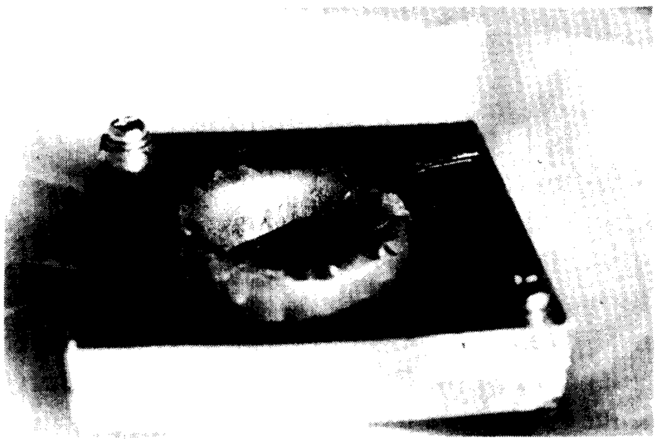

Fig. 11. An crater on an aluminum plate by projectile collision for velocity 3.7 km/sec.

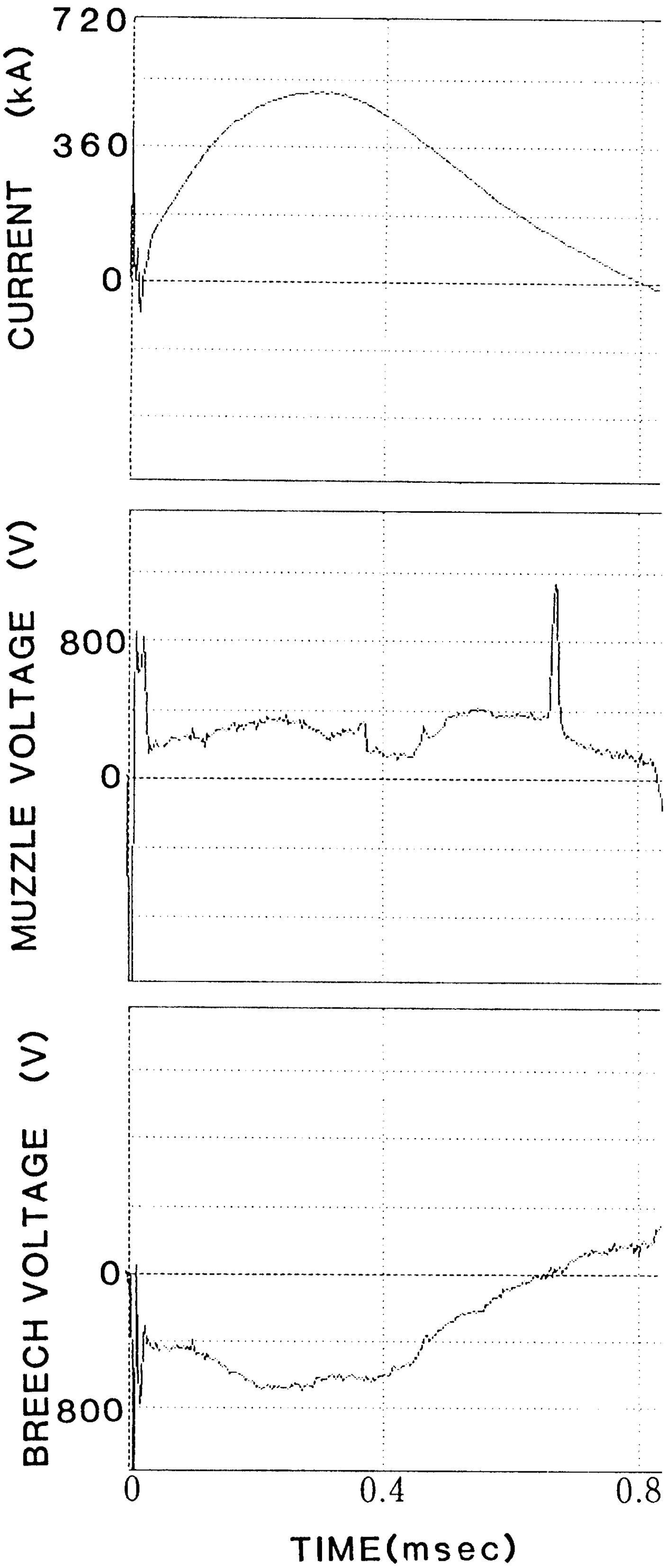

Fig. 9. Total current, breech voltage, and muzzle voltage of one shot

9. Conclusions

Our railgun system has 6 mF, 300 kJ capacitor bank, and three railguns with barrel length 95 cm, 165 cm and 186 cm. The highest velocity of our railgun is 4.8 km/sec. The railgun facility is now available for the research of hypervelocity impacts by space debris.

References

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