Performance of a Hexagonal, Segmented Railgun

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Electromagnetic acceleration
Principle of a Railgun

Railgun force law:

\[ F = \frac{1}{2} L' \cdot I^2 \]

- Electric energy: \( E_{el} \approx 10^6 \cdots 10^8 \) Joule
- Current: \( I \approx \) Megaampere
- Power: \( P \approx \) Gigawatt
- Acceleration time: \( T_{accel} \approx 10^{-3} \) s
- Velocity: \( v \geq \) several km/s
Railgun Applications

Satellite launch

Military

Research tool

Micro meteorites

Taylor test
Railguns @ ISL

RAFIRA

PEGASUS

SR\3-90

SR\3-60
Projectile Impact

Payload projectile

\[ M = 600 \text{ g} \]
\[ V = 1460 \text{ m/s} \]
\[ E_{\text{kin}} = 0.6 \text{ MJ} \]
The SR\3-60

3 Segments á 75 cm
Length: 225 cm
$E_{\text{Electric}}$: 450 kJ
Velocity: $\leq$ 300 m/s

Material: GRP
Length: 55 mm
Height: 28 mm
Weight: 90 g
Simple Railgun $\rightarrow$ Segmented Railgun

Capacitor banks

Rails

Segment 1  Segment 2  Segment 3

split up
Advantages of a Segmented Railgun

- Reduced ohmic resistance (shorter rails) → reduced heat losses
- Straight forward partitioning of the energy supply
- Built in flexibility, segments can be added or removed
- **Mechanical advantages**: shorter railguns are easier to produce and handle
- **Different segments** might use **different brushes**
- Possibility to increase the velocity limit for solid contact railguns
Sequential vs. Overlap Setup

Sequential:

S1

S2

S3

225 cm

Overlap:

S3

S2

S1

75 cm
Comparison: Sequential -- Overlap

Sequential, 6 kV, 102 m/s

Overlap, 7 kV, 143 m/s
Magnetic Fields

Sequential

Overlap

⇒ Overlap configuration has larger magn. field strength inbetween rails
Lorentz Force in Projectile
Overlap Setup

3 brushes:
- complex magnetic field inside the projectile
- Frontmost brush contributes very little to acceleration

Summary:
- Stronger magn. field strength
- Uneven distribution of forces
- Development of torque

Overlap setup better (faster)?
Velocity scales linearly with capacitor voltage

Velocities for both configurations are comparable

In this velocity regime both configurations are comparable

The overlap configuration is more compact
Summary and Outlook

There is a large experimental railgun program at ISL

Recently, two segmented railguns were set up and used for experiments

One segmented railgun was used to change the spatial arrangement of rails

Simulations with respect to the magnetic field distribution were made

(Surprisingly) the sequential and overlapping configuration achieve similar velocities

Currently we focus on:

- Multishot capability
- Magnetic Field investigations (University Vilnius, Lithuania)
- Micrometeorites (University of New Brunswick, Canada)
- High energy, large velocity (US-Navy, FH Gelsenkirchen)