A TAXONOMY OF ELECTROMAGNETIC LAUNCHERS

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Abstract: The application of electromagnetic (EM) forces to the acceleration of projectiles has produced a bewildering array of electromechanical configurations. As electromagnetic launch (EML) technology matures, it becomes important to establish an unambiguous terminology to describe the various launcher concepts. During a September 1987 Workshop on Non-Railgun Accelerators hosted by the U.S. Army Armament Research, Development and Engineering Center (U.S. Army ARDEC), a consensus was reached on a taxonomy for EMLs. A refined version of that taxonomy is presented in this paper.

Background

In September of 1987, U.S. Army ARDEC hosted a "Workshop on Non-Railgun Electromagnetic Accelerators." During that workshop, the Accelerator Technology Working Group, chaired by the author, reached a consensus upon a taxonomy for EM accelerators based upon technology requirements. That taxonomy is offered here, with minor refinements, for the use of the EML community.

Method of Classification

Table 1 summarizes various distinctions or bases for classification discussed during the workshop. While it was agreed that each distinction was an important feature among certain EML technologies, none was felt to be dominant. However, the discussion evolved toward three basic features of virtually all EML's which were thought to be critical in terms of technology requirements. Those features are: 1) Armature Excitation, 2) Stator Field Control, and 3) Mode of Operation.

Table 1. EML distinctions

Coilgun	-	Railgun
Passive	-	Active
Noncontacting Armature	-	Contacting Armature
Pulsed dc Drive	-	ac Drive
High Impedance	-	Low Impedance
Distributed Drive	-	Base Pressure Drive
High Acceleration Ratio	-	Low Acceleration Ratio
Low Circulating Power	-	High Circulating Power

Armature Excitation

Armature excitation refers to the means by which the armature (moving conductor) current is established and/or

supplied. The armature current can be supplied directly by sliding contacts or plasma brushes, as in the case of the railgun and the original Mass Driver, or it may be induced as in an induction accelerator. In the case of armature excitation by induction, the source of the induced current is a rapid (relative to the launch time) change in flux linkage which may in turn be due to either a rapidly changing stator current (dI/dt) or a sudden change in mutual inductance between a stator coil and the armature (dM/dt). Armature excitation can also be provided by an on-board source of magnetomotive force such as a battery, capacitor, or superconducting coil, or it may be supplied by a persistent current established in a resistive armature prior to the launch. The working group also determined that cases exist in which armature excitation may be provided by some combination of these features.

Stator Field Control

Stator field control refers to the technique by which the stator magnetic field that interacts with the self-field of the armature to produce the desired acceleration is controlled in time and in spatial distribution along the length of the stator. Stator field control can be active or passive. Active stator field control is keyed to the instantaneous position of the armature. This can be accomplished by using brushes on the armature to commutate current into or out of individual stator coils (helical railgun) or armature position may be sensed externally and power switched to the stator coils using this information (Mass Driver). Stator field control may also be inherent as in the railgun where stator field distribution is keyed to armature position without commutation as in the superconducting quench gun.

There are also EML accelerator concepts in which the stator field control is entirely passive; i.e. designed into the accelerator and independent of actual armature position. An example of passive stator field control is a polyphase traveling wave induction accelerator.

Mode of Operation

The third EML feature is the mode of operation of the accelerator. The stator magnetic field can represent an advancing wavefront, as in the case of the simple railgun, or a receding wavefront, as exemplified by the quench gun or the DNA accelerator. As mentioned previously, a third mode of operation is the traveling wave, essentially an advancing wavefront followed by a receding wavefront. In this case, the magnetic wave can advance in a continuous manner, as in a polyphase ac system, or in a discrete manner, as in a switched system.

Conclusion

The EML taxonomy proposed here is based on functional requirements. The three EML features described here; Armature excitation, Stator field control, and Mode of operation; are the basis of the A-S-M classification system outlined in table 2. As an example of the use of the system, the original MIT-Princeton Mass Driver used direct armature excitation, active external stator field control and operated in the traveling wave mode with discretely switched coils. The appropriate classification is therefore A1-S1b-M1b.

Table 2. EML taxonomy

Armature Excitation	Stator Field Control	Mode of Operation
1. Direct	1. Active a. brush commutated b. external c. inherent	1. Traveling Wave a. continuous b. discrete
2. Persistent Current (resistive)	2. Passive	2. Advancing front
3. On-board MMF		3. Receding front
4. Induction a. dI/dt b. dM/dt		