The Implementation of a Solenoidal Reluctance Linear Accelerator as a Trigger for Rail Accelerator

Jonathan Zhu, Samuel

In this report, we construct a solenoidal reluctance linear accelerator(SRLA) to give the initial velocity for the armature before the secondary acceleration. A primary accelerator(i.e. the trigger) would be favored if it gives a high existing speed and be easy-modified to an electronic control circuit, hence an EM accelerator becomes our potential alternatives. The result shows that a SRLA would be suitable for the rail accelerator.

Working Principle and Its Advantages

A SRLA is basically a counterpart for a rotary motor, but has its armature fired away. A typical SRLA consists of multiple coils arranged collinearly by a pipe inserted into each coil's bores. When a ferromagnetic slug enters the bore of a coil, the reluctance of the system is reduced dramatically since the ferromagnetic slug has a much lower magnetic permeability than air. Thus, a force is developed because of the change in reluctance of the system and the force try to reach a more stable position, in which the overall system has the same lower reluctance.[1] The metal slug will be accelerated towards the centre of the bore, however measurements must be taken to remove the magnetic field other wise when the slug passing through the centre, it will be pulled back to the centre again and keep oscillating since the system wants to reach a overall lower reluctance, hence capacitors are usually included.

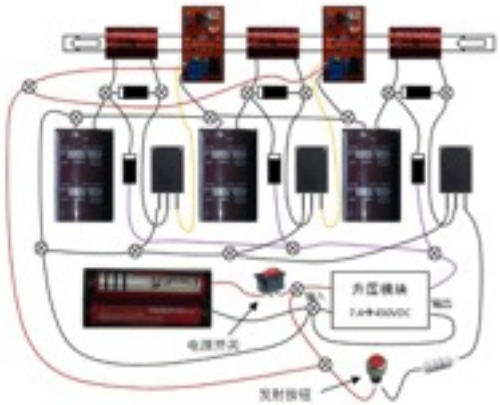
The reason for choosing a SRLA rather than a solenoidal magnetic induction linear accelerator is because of the armature. SILA required an armature composed of permanent magnets(e.g. NdFeB magnets) while SRLA only needs a ferromagnetic slug, hence a SRLA armature is easier to construct and have a better strength. Small scale experiment also reveals the generality of armature may play a vital role in appliance that requires high fault tolerance like military use, since SILA requires a uniform arranged magnetic pole.

Theoretical Calculation

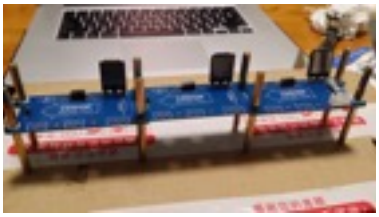
The popular ways of modeling a SRLA are means of Lagrangian model[2], or finite element analysis, for the purpose of this implementation, optimization was fulfilled using a coilgun finite element method software developed by Jonathan Filippi[4].

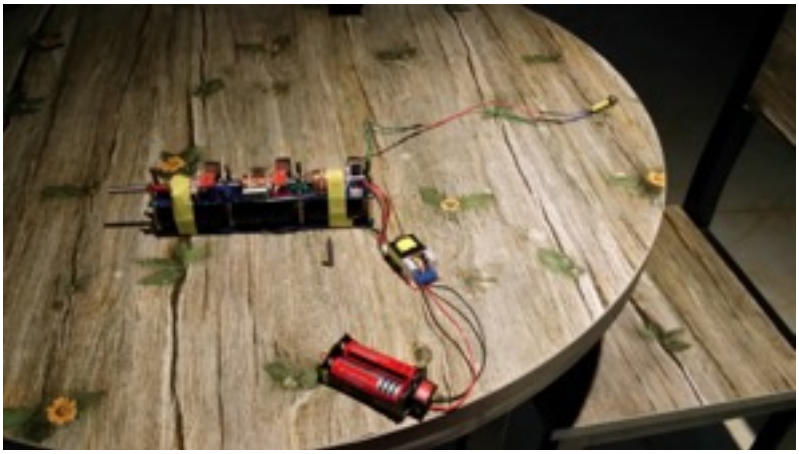
Implementation of the SRLA

The implementation of the SRLA is based on this figure:



The actual building, however, is developed on a much more compact circuit board produced by CGShop™:



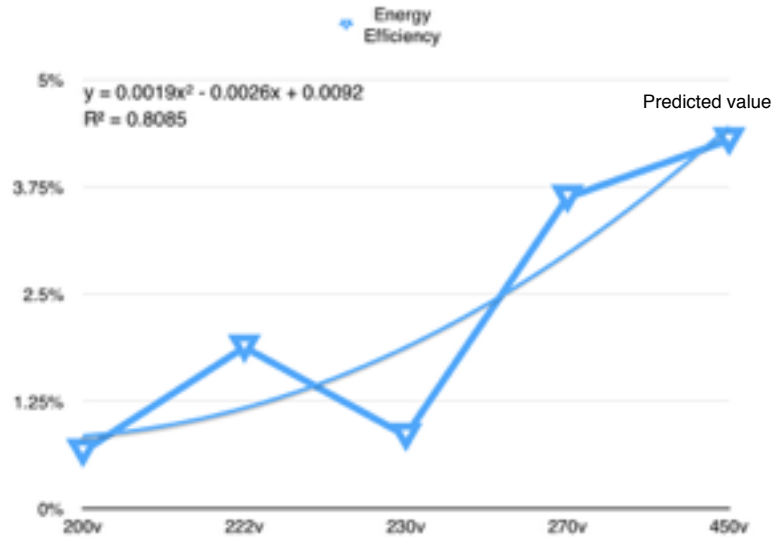


Trajectory Analysis

The initial video was filmed under both 720P&240fps and 1080P&120fps condition via iPhone 6s, and it was analyzed by Premiere Pro 2014cc.

The following data is necessary for the figure:
projectile's mass: 7.10g total capacity: 3000μF

No.	Distance Traveled	Existing Velocity*	Energy Efficiency	voltage
I	0.836m	33.44m/s	3.6303%	270v
II	0.836m	14.33m/s	0.6666%	200v
III	0.33m	19.8m/s	1.8826%	222v
IV	6.9m	13.8m/s	0.852%	230v
scale: 3.8cm≙0.5cm			Ek/Ec i.e. mV^2 / CU^2	



Mathematically, polynomial tendency forecast is employed to predict the maximum existing velocity,which would be 55 m/s at 450v, reaching an efficiency of 4.3%, at the designed maximum voltage(however this voltage is not recommended for safety issue).

* The existing velocity is calculated in the following:

I. A scale is first established by comparing the length of picture presents in the computer and the super-red-insulating -tape stick(1.7cm long) on the barrel.

I. The video is filmed with the standard of 720P&120fps and 720P&240fps, i.e. the frequency of frame taking is 120Hz and 240 Hz respectively. For a single shot, it stands for 1/120s or 1/240s.
II. Frames are counted when the slug leaves the barrel and stops when a noticeable trace of the slug is recognized.
III. The existing velocity is then calculated using this formula:

$$V_{Ex} = \frac{s \cdot k}{\frac{n(frames)}{120}}$$

k is the scale factor, n is the number of frames counted, s is the distance measured on the computer screen, 120 could be replaced by 240.

Conclusion

Based on above implementation and testing, we believed that multi-stages SRLA would be a suitable device to accelerator the armature before it enters the rail, it is also convenient to adapt an electronic control circuit. Hence, we choose SRLA as our rail accelerator's primary accelerator.

Reference List

[1]*Design of a Reluctance Accelerator*
D.A. Bresie and J.A. Andrews
Center for Electromechanics, The University of Texas
[2]*A Simple Unified Physical Model for a Reluctance Accelerator* G. William Slade, IEEE
[3]CG Shop at taobao.com
[4]Coilgun Simulator Jonathan Filippi *F.M.Technoligies* at http:\\www.cool-science.tk