Developing and Analyzing Performance Tests on Magnetostrictive Actuators

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Introduction:

Magnetostrictors are alloys that undergo strain when they experience magnetic fields. These materials have many applications, one being the actuating material in electrical actuators. However, the actuator's performance as a function of actuating frequency and external load is dependent upon the magnetostrictive material being used inside the actuator. **The purpose** of my research was to quantify a magnetostrictive actuator's performance to identify its potential applications.

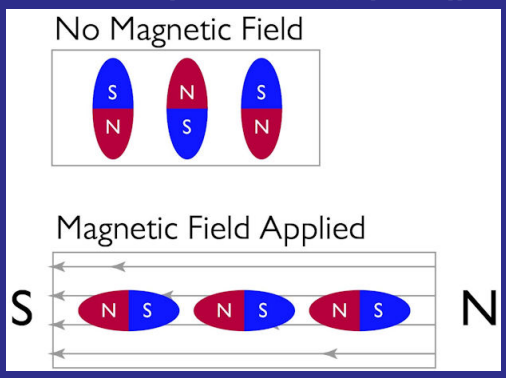


Image from Digital Engineering 247 (https://www.digitalengineering247.com/article/making-smart-materials-smarter-multiphysics-simulation/). The magnetic domains (red/blue ovals) are realigned by an applied magnetic field, resulting in elongation (and in some materials' cases, contraction) [1].

Methods:

1. I tested the performance capabilities of the actuator by putting it inside a deadweight apparatus.
2. I collected the actuator tip's displacement data via an oscilloscope at five different driving frequencies. Data was collected from all frequencies at each of eight different applied loads.
3. Data was exported to Excel where I calculated the RMS tip displacement for each frequency/load.

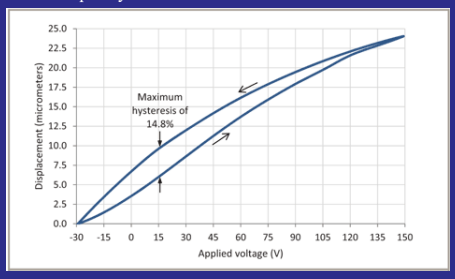


Image from Aerotech (https://www.aerotech.com/product-catalog/piezo-nanopositioners/piezo-engineering-tutorial.aspx). Exemplary hysteresis curve of a magnetostrictive actuator; a reversed magnetic field applied to the magnetostrictor shows the actuator tip does not follow the same displacement curve when bringing the magnetization back to zero [2].

Materials:

- Deadweight apparatus (~7 ft. tall aluminum structure)
- 8 Lead bricks (25 lb. each)
- Oscilloscope
- Photonic sensor (for micrometer scale displacement measurements)
- Voltage amplifier
- Function generator (generating desired driving frequencies)

Image from TdVib LLC (http://tdvib.com/sonic-actuators/). Pictorial representation of an actuator I tested [3].

Results:

Examining the actuator's performance under varied loads and frequencies allowed us to develop load lines. Load lines are the displacement vs. applied load curves for each driven frequency. Given the confidentiality of the research, raw data cannot be given. Examples of similar work are shown below:

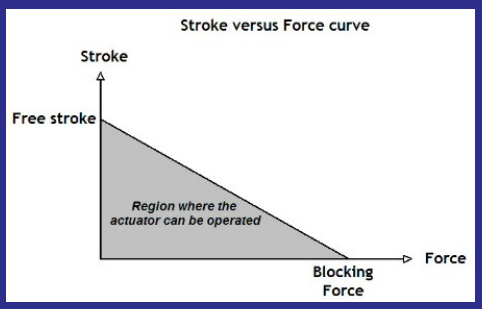
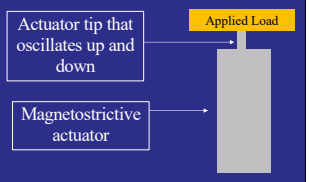


Image from Mircromechatronics, Inc. (http://www.mmech.com/noliacdefinitions). The plot above represents an exemplary actuator's displacement (stroke) vs. the applied load (force) [4].

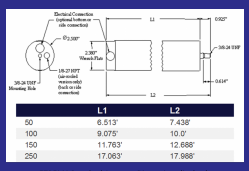
Block force: the applied load for which the actuator stops exhibiting any displacement and produces no mechanical work.



Discussion:

- The aluminum deadweight apparatus was not sturdy enough to support applied loads and thus produced noisy data.
- Higher driving frequencies made the applied load lose contact with the actuator tip temporarily, again producing noisy data.
- Load lines obtained from data were nonlinear.

Electrical energy fed into actuator → AC current passes through a solenoid and produced a magnetic field → Magnetostrictive material inside the solenoid elongates, producing mechanical energy



	L1	L2
50	6.513'	7.438'
100	9.075'	10.0'
150	11.763'	12.688'
250	17.063'	17.988'

ETREMA Standard Actuator Dimensions (inches)

Image from TdVib LLC (http://tdvib.com/sonic-actuators/). Diagram for electrical connection [3].

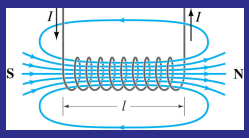
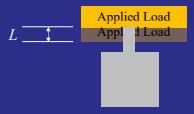


Image from Mini Physics (https://www.miniphysics.com/ss-magnetic-field-due-to-current-in-a-solenoid.html). A solenoid containing current produces a near-uniform magnetic field [5].



The magnetostrictor inside the solenoid elongates and contracts, pushing the actuator tip up and down against the applied load. Thus, mechanical work is produced.

Conclusions:

- This actuator's applications cannot yet be determined due to the unpredictable behavior.
- The deadweight apparatus must be replaced by a sturdier structure that will not itself vibrate.

Site Information:

- Naval Surface Warfare Center Carderock Division
- 9500 MacArthur Blvd, Bethesda, MD 20817
- Site mission: perform research, engineering, and testing for the U.S. Navy's ships and ship systems [6].
- Supervisor/mentor: Dr. Nicholas Jones
- My group's specialized goal: perform research in the field of magnetic materials and identify applications for these materials.

Acknowledgments:

I would like to thank Dr. Nicholas Jones for being my mentor and striving to expand my scientific interests. Thank you to Dr. Holtz, Dr. Merck, and College Park Scholars Science and Global Change program for imbuing me with climate change knowledge and scientific skepticism.

Bibliography:

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2. Anonymous. N.d. "Piezo Engineering Tutorial; hysteresis effects [https://www.aerotech.com/product-catalog/piezo-nanopositioners/piezo-engineering-tutorial.aspx]." *Aerotech.* Accessed 19 March 2020.
3. Anonymous. N.d. "Sonic Actuators [http://tdvib.com/sonic-actuators/]." *TdVib LLC.* Accessed 18 March 2020.
4. Anonymous. N.d. "Definitions; blocking force & free stroke [http://www.mmech.com/noliacdefinitions]." *Micromechatronics.* Accessed 17 March 2020.
5. Anonymous. 26 December 2015. "SS: Magnetic field due to current in a solenoid [https://www.miniphysics.com/ss-magnetic-field-due-to-current-in-a-solenoid.html]". *Mini Physics.* Accessed 19 March 2020.
6. Anonymous. N.d. "NSWC Carderock: What We Do [https://www.navsea.navy.mil/Home/Warfare-Centers/NSWC-Carderock/What-We-Do//]". *Naval Sea Systems Command.* Accessed 17 March 2020.