Case Study 2: Needleless Injection

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Today’s focus

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http://www.energy.ca.gov/2015publications/CEC-500-2015-089/CEC-500-2015-089.pdf

The Broad Challenge

Replace traditional drug injection (using needles) with needle-free injections

In 3 mins in a group of 2 or 3 come up with 3 benefits and 3 problems with not using needles

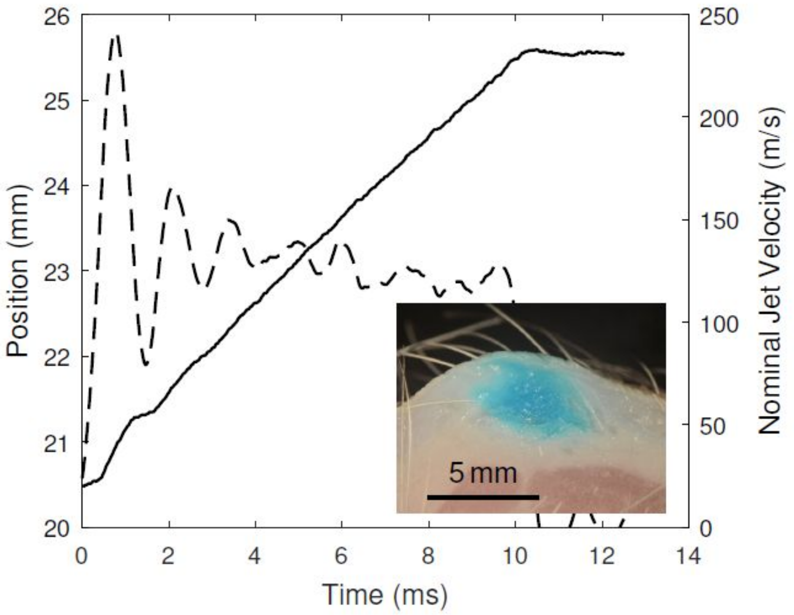


Fig. 10. 50 μL injection performed using the portable amplifier with the large injector and 300 μL ampoule from [5]. It has been controlled to remain near the surface, using a 75 % duty cycle and 10 ms duration. The piston position (solid line) and nominal jet velocity (dashed line) for the injection are shown.

Ruddy, B., Dixon, A. W., Williams, R. M. J., & Taberner, A. J. (2017). Optimization of portable electronically-controlled needle-free jet injection systems. IEEE/ASME Transactions on Mechatronics, 22(5), 2013-2021. doi:10.1109/TMECH.2017.2725345

The Broad Challenge

3 benefits and 3 problems with not using needles

The More Specific Challenge

Once you have decided to use needle-free injection then you have to decide how to do it.

In 3 mins, in a group of 2-3 come up with 3 different ways of creating the pressure and flow required.

(> 100 m/s stream of liquid drug that can penetrate skin using nothing but its own momentum)

The More Specific Challenge

In 3 mins, in a group of 2-3 come up with 3 different ways of creating the pressure and flow required.

The Really Specific Challenge

Once you have decided to use an electromagnetic actuator, you need to know what parameter are important to design for.

In 3 minutes in a group of 2-3, come up with 3 important things to consider if you were designing an electromagnetic actuator for needle-free injection

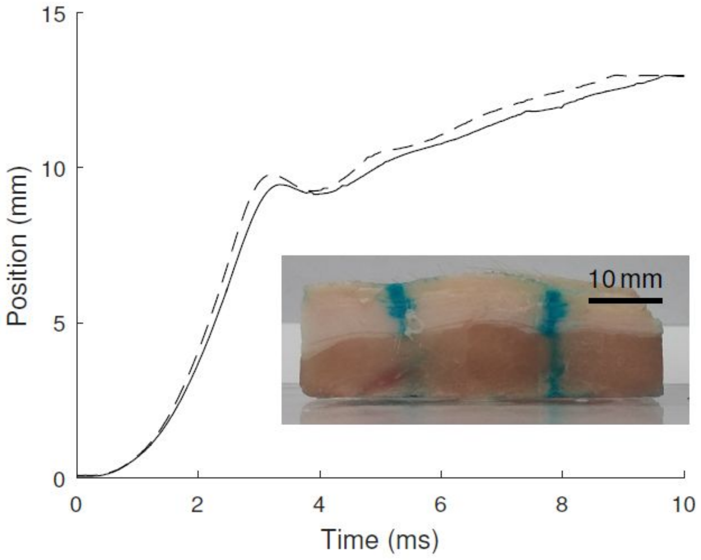


Fig. 12. Two injections performed with the miniaturized injector to different depths: a 25 % duty cycle injection (solid) remains in the subcutaneous fat, while a 27 % duty cycle injection (dashed) reaches the muscle. The inset shows the injection results in tissue, with the 25 % duty cycle injection on the left and the 27 % duty cycle injection on the right.

The Really Specific Challenge

3 important things to consider if you were designing an electromagnetic actuator for needle-free injection

Generation 1 - large voice coil actuator

problems: size

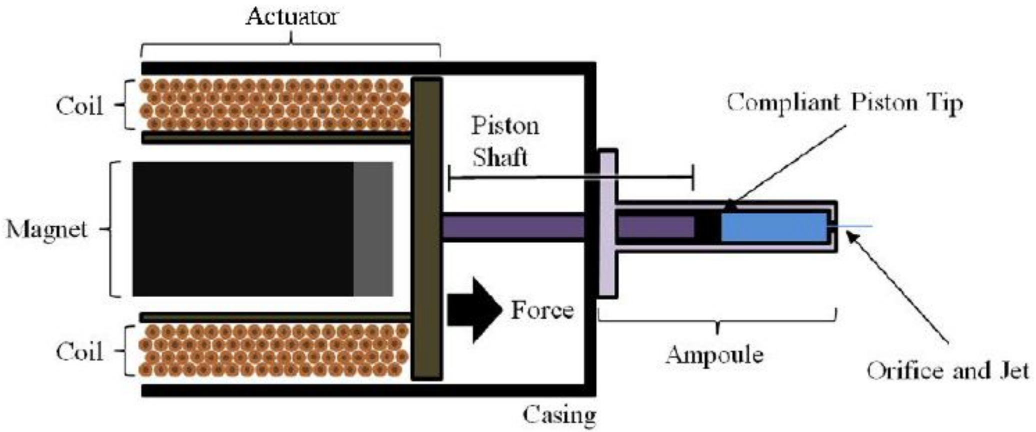


Fig. 1 - Diagram of moving-coil injector system

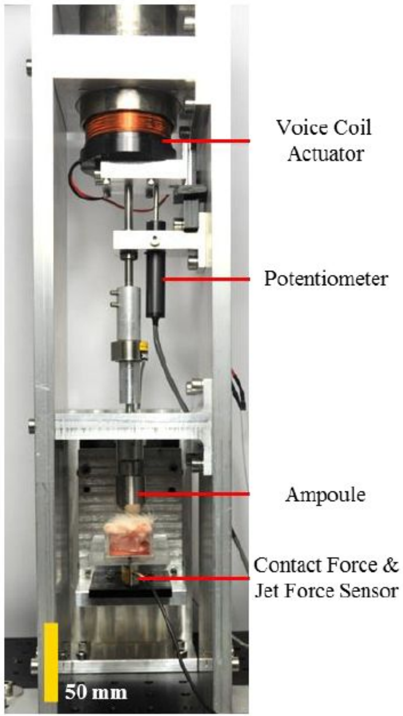


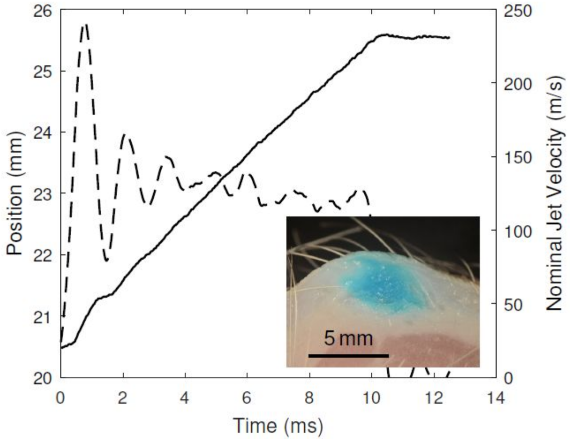
Fig. 2. The high power, large volume, controllable injection device. The voice coil actuator can be seen at the top of the image with the ampoule below pressed against a sample of porcine tissue.

Williams, R. M., Ruddy, B. P., Hogan, N. C., Hunter, I. W., Nielsen, P. M., & Taberner, A. J. (2016). Analysis of Moving-Coil Actuator Jet Injectors for Viscous Fluids. IEEE Transactions on Biomedical Engineering, 63(6), 1099-1106. doi:10.1109/TBME.2015.2482967

Mckeage, J. W., Ruddy, B. P., Nielsen, P. M. F., & Taberner, A. J. (2016). A device for controlled jet injection of large volumes of liquid. In 2016 IEEE 38th Annual International Conference of the Engineering in Medicine and Biology Society (EMBC) (pp. 553-556). Orlando, FL: IEEE. doi:10.1109/EMBC.2016.7590762

Generation 2 - Small voice coil actuator

Fig. 5. Complete jet injector hand-piece. It has a mass of 178 g, and is connected to its power amplifier via the cable shown.



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Generation 3 - Permanent Magnets

As a result, hand-held injectors delivering volumes of over 0.5mL

free flux

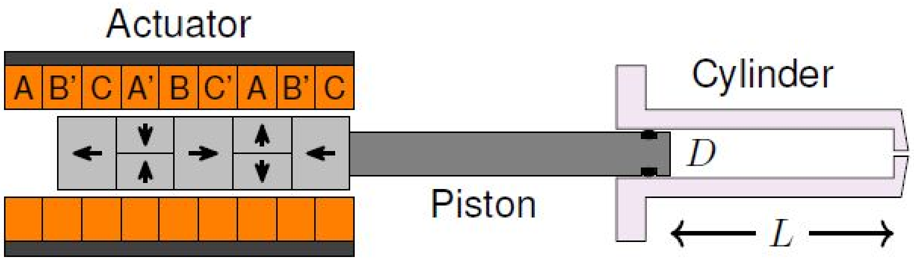
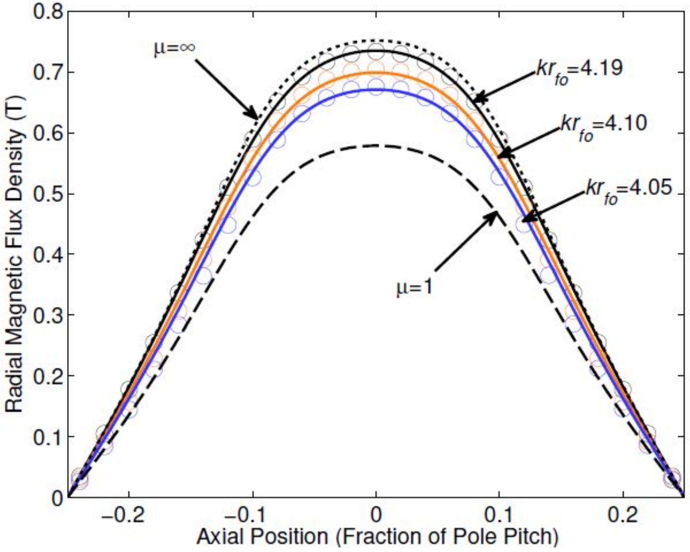
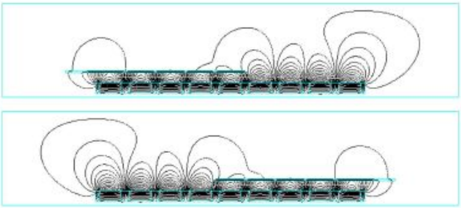


Fig. 1. A basic schematic of a synchronous-motor-driven jet injector, illustrating a schematic LPMSM with an injector ampoule. The piston diameter D and stroke L in the ampoule are illustrated.



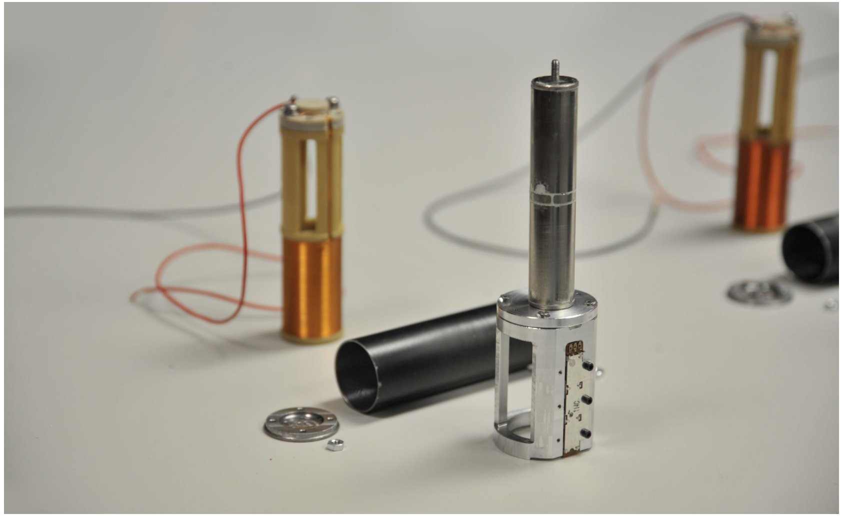
Ruddy, B. P., Hunter, I. W., & Taberner, A. J. (2014). Optimal voice coil actuators for needle-free jet injection. In Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE (pp. 2144-2148). Chicago, IL. doi:10.1109/EMBC.2014.6944041

Generation 3 - Permanent Magnets



(b)

Fig. 6. Cogging force optimization setup with elongated back-iron length $L_f = L_C + \lambda$, where λ is extra back-iron length, Δ is motor axial position (a); and axisymmetric FEA model to work out cogging force for each L_f over the range of $\Delta = 0 \rightarrow L_s$ at no current mode (b).



N. N. L. Do, A. J. Taberner and B. P. Ruddy, "Design of a linear permanent magnet synchronous motor for needle-free jet injection," *2017 IEEE Energy Conversion Congress and Exposition (ECCE)*, Cincinnati, OH, 2017, pp. 4734-4740.
doi: 10.1109/ECCE.2017.8096806

Images courtesy of Bryan Ruddy (https://unidirectory.auckland.ac.nz/profile/brud999

Summary

Electromagnetic devices are finding new applications, particularly where small size and precise control are required.

Some of the actuators you are studying today have direct applications.

Where high power density is required, permanent magnet actuators should be considered

size and control

pressure and volume are hard to control

LR: