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Deriving steps per mm for an LVE system V.1

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We are still developing and optimizing this protocol.

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Abstract

Modification of off-the-shelf fused filament fabrication (FFF) 3D printers with a syringe pump, used as a large volume extruder (LVE) is a common method for the creation of low-cost laboratory 3D bioprinters. Open-source syringe pumps with accompanying firmware exist, however they require researchers to choose accurate control of the syringe pump over rich control over the 3D printer system. The combination of open-source syringe pump hardware controlled with 3D printer electronics and firmware gives the best of both worlds, however this firmware is not designed to control fluids, consequently some parameters may need to be calculated differently. FFF printer firmware (such as RepRapFirmware) uses E-steps-per-mm to translate the movement of the stepper motor into the extrusion of filament pre-nozzle. This method finds the value of this parameter for a bioprinter with a bowden-tube based LVE.

Guidelines

This method is for an LVE that is based around the MOST Open Source Syringe Pump [1], or similar syringe pumps such as the Poseidon from Patcher Lab [2], connected to the printer carriage and print head via a bowden tube.

[1] [Joshua M. Pearce](#), [Bas Wijnen](#) (2016). "[Open-source syringe pump](#)". Appropedia. Retrieved October 13, 2022.

[2] A. Sina Boeshaghi, Eduardo da Veiga Beltrame, Dylan Bannon, Jase Gehring and Lior Pachter, "[Principles of open source bioinstrumentation applied to the poseidon syringe pump system](#)", Scientific Reports 9, Article number: 12385 (2019)

Materials

Equipment	
Open Source Syringe Pump	NAME
Syringe Pump	TYPE
MOST OSSP	BRAND
n/a	SKU
https://www.appropedia.org/Open-source_syringe_pump	LINK



Take measurements

- 1 Take the following measurements:

Required

Thread Pitch (mm)

Required

Thread Starts

Required

Internal radius of the syringe (mm)

Required

Internal radius of the bowden tube (mm)

Required

Motor Steps

Required

Micro-Stepping

Finding the thread's lead

- 1 Most lead screws are single start, and the one recommended in the MOST OSSP is single start, this means that the lead (the distance the carriage travels with one rotation of the lead screw) is equal to the pitch (the distance between the crests of the thread).



If you are using a multi-start lead screw the following formula should be used to calculate the thread's lead:

$$\text{Lead} = \text{Pitch} \times \text{Number of Starts}$$

Deriving the revolutions per mm

- 2 The ratio between the syringe and the Bowden tube can be calculated as follows:

$$\begin{aligned}\pi l_s r_s^2 &= \pi l_b r_b^2 \\ l_b &= \frac{l_s r_s^2}{r_b^2} \\ \therefore \\ l_s &: \frac{l_s r_s^2}{r_b^2}\end{aligned}$$

Where l_s is the distance travelled by the syringe plunger, l_b is the resultant distance the gel travels through the bowden tube, r_s is the internal radius of the syringe, and r_b is the internal radius of the bowden tube.

The ratio between the motor and the syringe is equal to the ratio between the motor and the linear distance travelled by the syringe plunger is:

$$1 : \text{Lead}$$

From this we know, when $l_s = \text{lead}$, the ratio between the lead screw and the Bowden tube, is:

$$1 : \frac{l_s r_s^2}{r_b^2}$$

This makes the revolutions per mm:

$$\frac{r_b^2}{l_s r_s^2}$$

Finding the E-Steps-per-mm

- 3 Multiply the motor steps by the micro-stepping by the length of filament produced through the bowden tube with one revolution of the stepper motor



$$espm = MotorSteps \times Micro\ Stepping \times \frac{r_b^2}{l_s r_s^2}$$