Fabrication of Recyclable Magnetic Filaments for Fused Deposition Modeling Technology

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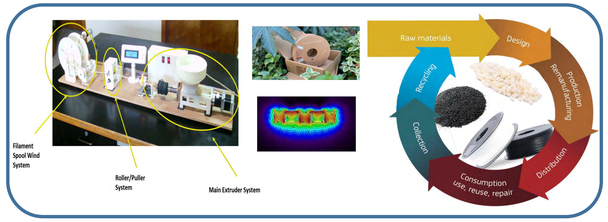
Motivation of the Capstone Project

Fabricate a **custom-designed low-cost extruder** for sustainable manufacturing of **recyclable magnetic filaments** for use as feedstock in existing **Fused Deposition Modeling (FDM) 3D Printing Technology**

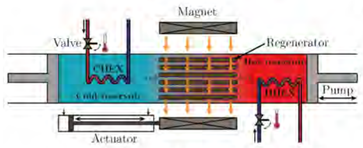


Use-case: Magnetic Heat Exchangers for Solid State Caloric Cooling Technologies

Magnetic refrigeration: Cooling technology based on the **Magnetocaloric effect (MCE)**

- Enhanced energy efficiency (by 30-50%)
- Environmentally friendly

MCE: Temperature change of **magnetocaloric materials (MCMs)** induced by the application and subsequent removal of the magnetic field.



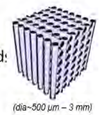
Mugica, Ibai, et al. Entropy 19.9 (2017): 464.

Ideal MCMs should have:

- Large MCE response
- High thermal conductivity
- Non-toxic, abundant elements
- Excellent in-operando stability
- Low cost, large scale production in channeled geometries

Regenerator must be designed to accelerate heat transfer between the working MCM & the heat exchange fluid, while minimizing the pressure loss.

Channeled structures are preferred but conventional machining method: lead to defects that destroy the functional response



(dia~500 μm – 3 mm)

Additive Manufacturing for Sustainment?

Conventional laser-based Metal 3D Printers are expensive and bulky, with a limited library of precursor materials

MacLean Additive, in Mundelein, Ill., prints with metal on the SLM Solutions; SLM 280 Production Series 3D printer (Source: SLM)

Fig 5: Conventional Metal Printer. 102" L, 48" W, 141" H - 4000 lbs

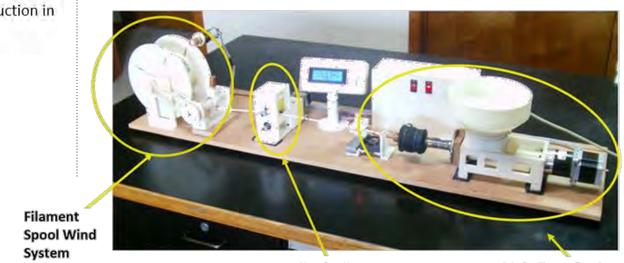
Fused Deposition Modelling 3D Printers are cheap, compact and portable; Compatible with a wide range of polymers

Fig 4: Creality Ender 3 S1 Pro. 19" L, 18" W, 25" H - 19 lbs

https://ultimaker.com/3d-printers/ultimaker-s5

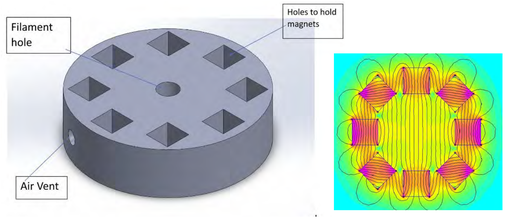
Metal 3D printing with FDM technology is fairly new; Urgent need to expand capability *via* fabrication of custom-designed filaments for niche DOD-related applications.

Proposed Solution: Modified Lyman Extruder



Novelty: Halbach Array around the Extruder Nozzle

- Produces a high magnetic field utilizing permanent magnets, arranged with a spatially rotating magnetic field vector which has the effect of focusing and augmenting the magnetic field on one side
- Used in sophisticated high-torque motors, beam focusing, research and magnetic particle separation equipment for industry



Composition of Magnetic Filaments

The Polymer

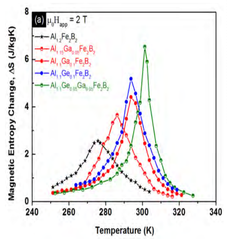
PLA (Polylactic acid) or PBSA (Polybutylene succinate-co-adipate)

Criteria: Good thermal and chemical resistance; biodegradable (compostable; industrial conditions)

Magnetic Nanoparticles

Lanthanum Iron Silicide $La(FeSi)_{13}$

Criteria: Excellent magnetocaloric properties at room temperature



Progress to Date

Efforts are underway to build the modified Lyman Extruder (Estimated cost: < $ 1500, with magnetic field rig)

- Structural components of the extruder have been completely printed
- Main extruder subassembly has been assembled
- LCD controls subassembly has been assembled

Immediate next steps:

- Finish Halbach design iterations
- Finish remaining subassemblies
- Test proof of concept by extruding Iron-based PLA filament
- Test Halbach magnetic strength

Beyond the Project

- **Lyman Extruder is merely the starting point**
- Hopes for future teams/contributors:
  - Interchange and upgrade hardware to meet different demands
  - Research more into different polymer/metal composites
  - Research and Develop an additional grinder aspect to the extruder