Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2025-2026

Supervisor	Axel Guenther
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Number of Positions	1
Open to	Mechanical Engineering Students
Term Offered	Full-year
Research Area	Mechanics & Design
Research Topic	Continuous Feed for Biofabricating Load Bearing Structures

Project Description

Filament winding is a standard industrial composite manufacturing process where continuous carbon fibers are wound around a mandrel, usually in a helical pattern, e.g., for producing high strength carbon fiber tubes and pressure vessels.

In this project, we investigate the formation of composite structures from completely biological materials, where the load-bearing fibrous material is collagen. Our group has in the past developed extrusion-based methods [1-2], such as those illustrated in Figure 1, for the formation of long, ultrathin collagen sheets.

The consistent manipulation of these highly dense and aligned sheets of micron-size thickness (~2 microns) and high aspect ratio (~1:5000) is challenging and requires unique approaches to be developed that consider elastocapillary phenomena. Upon successful rolling, these sheets promise to become suitable substrate materials for fabricating cm-scale, load-bearing biological tissues.

This project aims to improve the consistency of tubular structure fabrication compared with a preliminary setup, by enabling the continuous rolling of meter-long collagen sheets into largerdiameter, human-scale constructs within a ~15cm x 15cm x 15cm built volume–targeting applications such as vascular grafts and other load-bearing tubular structures. The approach involves modifying an existing setup to support a fixed, continuous feed of collagen sheets mounted on a support film.

Key engineering objectives include:

- Designing a continuous feed system capable of delivering collagen sheets wrinkle-free from a roll while maintaining alignment, hydration and applying a well-defined and consistent pre-stress;

- Integrating a motorized collection mandrel for the support film to drive the rolling process and integrate 90 deg peeling for collagen and support film separation;
- Conducting peel tests to characterize interfacial forces between collagen and different support film materials, guiding design of a robust feed mechanism with priority for 90 deg peeling;
- Incorporating robotic manipulators and Python-based control to automate rolling, regulate feed speed, and prevent misalignment, mechanical disruption, or mismatch in speed of rolling vs support film collection during fabrication;
- Enabling composite structure fabrication by integrating a second gel layer (e.g., via deposition on a conveyor belt system) into the rolling process, supporting multilayer construct formation.

The project requires mechanical design and automation development, with preferred experience in CAD software (e.g., SolidWorks, AutoCAD), robotics, and mechatronics. The final goal is to deliver a scalable, modular system capable of producing long, aligned collagen-based tubes with potential for composite reinforcement, and applicable to advanced biomedical engineering applications.

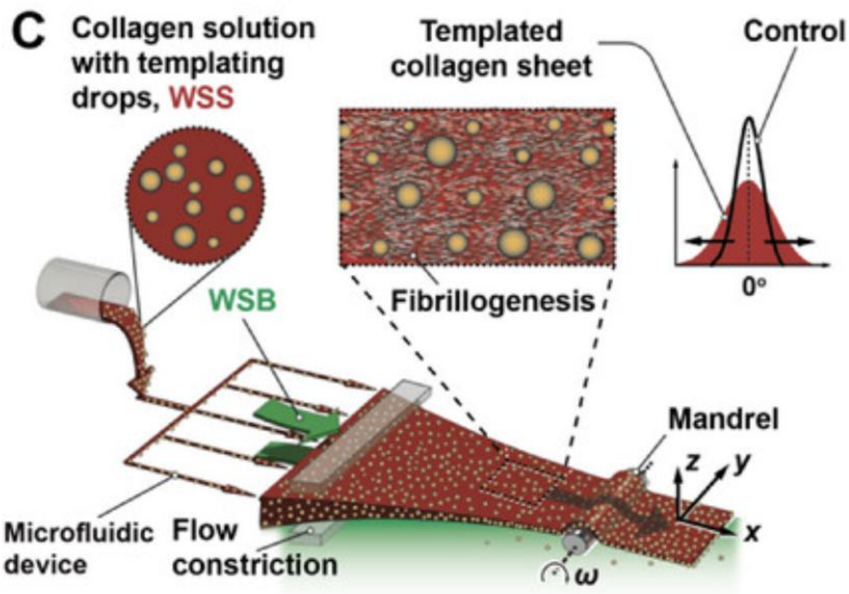

Fig 1. Schematic illustration for wet-spinning/extrusion approach for collagen sheet formation [1], where "WSS" indicates a "wet spinning solution" consisting of acidic collagen and microscale oil droplets, and "WSB" indicates a "wet spinning buffer" solution.

References:

[1] Y. Zhang, S. Malladi, B. Wang, D. O. Son, B. Hinz, E. L. Chaikof, A. Günther, Microfluidic Production of Ultrathin, Handleable Collagen Sheets Exhibiting Toe-heel Tensile Behavior. *Adv. Mater. Technol.* 2025, 2401810. https://doi.org/10.1002/admt.202401810
[2] S. Malladi, D. Miranda-Nieves, L. Leng, S. J. Grainger, C. Tarabanis, A. P. Nesmith, R. Kosaraju,

C. A. Haller, K. K. Parker, E. L. Chaikof, and A. Günther Continuous Formation of Ultrathin, Strong Collagen Sheets with Tunable Anisotropy and Compaction *ACS Biomaterials Science & Engineering* **2020** *6* (7), 4236-4246, https://doi.org/10.1021/acsbiomaterials.0c00321

Additional Information	N/A
Application Instructions	Please submit CV, unofficial transcript, to Prof. Axel Guenther, e-mail: axel.guenther@utoronto.ca