Department of Materials Science and Engineering,
Ph.D. Dissertation Defense

12:30pm, May 22nd, 2019
The Center for Functional Fabrics, 3101 Market Street Suite 150

"Tools to Predict and Understand the Self-Folding Behavior of Knitted Textiles"

Chelsea Knittel
Advisors: Genevieve Dion and Caroline Schauer

This dissertation aims to develop a fundamental understanding of the self-folding behaviors of weft knit fabrics. Weft knit textile machinery is a manufacturing technology that has existed since the sixteenth century but is now being repositioned as a twenty-first century advanced manufacturing tool. Using only basic stitches, the knit stitch and the purl stitch, weft knitting provides a unique structure-based behavior, *self-folding,* which allows for the creation of complex dimensional textiles in a *single* manufacturing step, without the need for secondary processes to add dimensionality. These folded textiles are similar to origami and kirigami structures that have been studied for a variety of engineering applications, including

architecture and space exploration devices. The self-assembly behavior of the weft knit structure could be used to further expand the potential of these designs, using automated production processes in wide variety of materials.

To date, how the self-folding occurs in weft knit textiles is not well understood. Methods for modeling these behaviors do not currently exist, preventing their use in advanced manufacturing design. Unlike the systems developed for common engineering materials, design of these structures currently relies on trial and error, through development of numerous prototypes. Although self-folding can be easily created, controlling the type of folding that occurs is often unpredictable and difficult to understand. While similar to origami and kirigami, their folding principles are not directly applicable. Modeling tools for weft knits are commercially available, however they were developed mainly for the garment industry, resulting in a lack of systems for modeling complex structures such as those with self-folding behavior.

This work set out to understand how self-folding behavior is created, and how it is affected by machine processing parameters and changes in yarn material. In

this dissertation, a top down approach was used to develop a fundamental understanding of self-folding in weft knits, and to create tools to allow for improved predictive design of engineered textiles. The developed tools include a system of mapping the folding directions of knit and purl stitch patterns, a method of scaling stitch patterns to alter their folding behavior, and equations to predict the scaling factor. The combined use of these tools allows designers and engineers to more efficiently control the outcome of the fabrics they produce. Additionally, this work led to the development of a novel topological modeling platform for the weft knit structure, furthering the knowledge of how the geometries and topologies of the loop structure create self-folding, and deepening the understanding of the physics driving this behavior. This dissertation uses fundamental knowledge of self-folding behavior in weft knit structures to allow designers and engineers to move beyond trial and error, towards an engineered system of design that will facilitate their use in real world applications.