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BIOKNIT BUILDING: STRATEGIES FOR LIVING TEXTILE ARCHITECTURES

Jane Scott[1]
Dilan Ozkan [1]
Aileen Hoenerloh[1]
Romy Kaiser[1]
Armand Agraviador[1]
Ben Bridgens[1]
Emily Birch[1]
Elise Elsacker[1]

[1] Newcastle University | UK
Corresponding author: jane.scott@newcastle.ac.uk

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Abstract
The urgent need for a more sustainable built environment is leading researchers to investigate biohybrid strategies utilizing living materials within composite material systems. Mycelium, the root network of fungus, has been successfully developed as a binder in the production of bulk composite elements, grown as bricks or other preforms. Research undertaken by our group is focused on the biocompatibility of knitted fabrics as a scaffold for growth, highlighting the potential to tune material properties and create complex forms using textile fibres, yarns, and fabrics as a hierarchical structuring system.

Alongside developments in mycelium BioKnit composites, our group is investigating the potential for bacterial cellulose knit composites. Bacterial cellulose is a form of cellulose produced by certain kinds of bacteria, and is of interest to the building sector because there is established manufacturing capability via industrial fermentation processes. Whilst commercial applications have been focused on the food industry (Nata de Coco is a well know South-East Asian food), the ability to synthesize functionalised cellulose from microbes has great potential within construction.

The research presented in this paper is focused on bringing these two biomaterials together using textile thinking and knitting technologies. Analysis of the development of an architectural BioKnit prototype reflects on the success and challenges of the composite system and demonstrates how this new BioKnit composite system can be applied at a building scale. This will establish a new fabrication system for living textile architectures and demonstrate the significance of textiles as a tool to transform the understanding of biomaterials in the built environment.

1. INTRODUCTION

The transition to net zero energy use in the building sector requires a fundamental rethink of material strategies, moving away from traditional construction materials such as cement, steel and mineral fibre insulation and exploring alternative materials including bio-composites and textiles. Mycelium, the root network of fungus, grown within a composite system, has emerged as a potential low impact alternative for construction [1][2]. In addition, bacterial cellulose (BC) can be grown for a range of applications using various nutrient sources including food waste [3]. This research brings together an interdisciplinary team drawn from textiles, architecture, and engineering with different perspectives on sustainable building to investigate how textiles, specifically knitting, can act as a scaffold for mycelium and BC, unifying these biomaterials at an architectural scale.

The emergence of knit as an architectural material has occurred over the last 10 years as international groups explore the potential for material expression, computational modelling and CNC knit technologies to develop hyper-specified materials [4][5]. Knitting is a unique way of fabricating material that enables the production of 2D and 3D scaffolds knitted to shape with no waste [6]. However, there are significant challenges to the application of knitted fabric in architecture including the material's high levels of extensibility, lack of compressive strength and size restrictions limited by conventional machine technology (although the scale of knitted components is similar standardised construction materials such as engineered wood boards). To bring together textile design, knit technologies and biomaterials, a project was developed to prototype a BioKnit composite structure at an architectural scale for exhibition in the OME, an experimental building at Newcastle University. The prototype tests the BioKnit composite constructed with bacterial cellulose and mycelium, using different knitted fabric structures as scaffolds. Scale is a key design tool within the composite system, and knitting is explored at different scales within the prototype. This is investigated using alternative knitting technologies, including flat knitting and off machine loop construction processes. In addition, knit composites have been developed with substrate materials (fig 1) and without a substrate (fig 2) to produce varying structural and aesthetic properties.

Figure 1: knit mycelium composite using substrate

Figure 2: knit mycelium composite no substrate.

2. MATERIALS AND METHODS

The methodology developed for the BioKnit prototype combines multiple research activities undertaken simultaneously, in a highly reflective process whereby bioinspiration, material experimentation and parametric design intertwine in an ongoing feedback loop to explore the potential of a knitted biocomposite at an architectural scale.

2.1. MYCELIUM + KNITTING

For mycelium growth tests, knitted fabrics were manufactured from 2/17nm lambswool yarn on a Dubied 7gg flat-bed knitting machine. Fabrics were knitted using circular plain to produce seamless tubes of fabric with no requirements for seams. To test the impact of fabric density, different stitch lengths were generated through changes to machine settings, creating looser and tighter fabric structures. Mycelium was grown within the tubes to form a composite structural element. Three different mycelium species were used for initial tests: *Pleurotus ostreatus*, *Trametes versicolor* and *Ganorderma lucidum.* These species were conserved on a grain mixture, called spawn, at 4°C. For the final prototype the species *Ganorderma lucidum* (strain M9726, purchased from Mycelia bvba) was selected based on preliminary studies and other studies [2]. During the preliminary studies we experimented with different types of fibres including straw and wood shavings. Finally, beechwood sawdust HBK 750-2000 (J. Rettenmaier & Söhne, Rosenberg, Germany) was selected as the mycelium substrate for the final prototype.

2.2. BACTERIAL CELLULOSE + KNITTING

For the Bacterial cellulose (BC) growth experiments knitted fabrics were manufactured from approx. 2/20nm linen on a dubied 7gg flat-bed machine. Fabrics structures incorporated tuck and miss with different structural organisation to test attachment. BC was grown in lab conditions using a kombucha SCOBY culturing method with a black tea-based liquid medium. The BC grown in a static setting will appear at the air-liquid interface where the bacteria have access to oxygen and nutrients. Good attachment and integration of the BC to the knit is essential to functionalise the knit as scaffold and transform the otherwise 2D BC sheets into complex shapes. A series of experiments explored this attachment on fabric samples with varying knit patterns and stitch sizes, utilising a specifically designed scaffold to hold the fabric at the air-liquid interface through the growth process. A separate set of experiments tested the compatibility of growing BC in the presence of mycelium by fixing tiles of mycelium half submerged into the growth medium of the BC. Mycelium in an oven-dried, air-dried, and living state was used. In a combined experiment, the potential of growing mycelium in the presence of wet BC with knit as a form-giving mediator showed promising results.

2.3. FORMFINDING + KNITTING

Bioinspiration provided the initial design strategy to shape the formfinding investigation (fig 3). In defining an architectural scale within the OME experimental building, the design of the prototype intends to allow for an element of inhabitation as well as tactile interaction. At the same time the prototype needed to engage with the double-height volume of the OME's interior and intersect with its structure for support. To balance these requirements, the concept for the prototype took the form of a "snug" element into which visitors could enter and find a comfortable sitting position and experience the tactile and visual qualities of the BioKnit structure. The structure of this snug will be self-supporting once the mycelium has grown within the knitted scaffold. To supplement the support of the structure earlier in the installation, the snug form will be tethered to various parts of the OME's exposed steel and timber frame structure by means of tensile knit tethers that will be biocomposited to varying extents. This "snug and tether" concept provided the basis for exploring architectural expression.

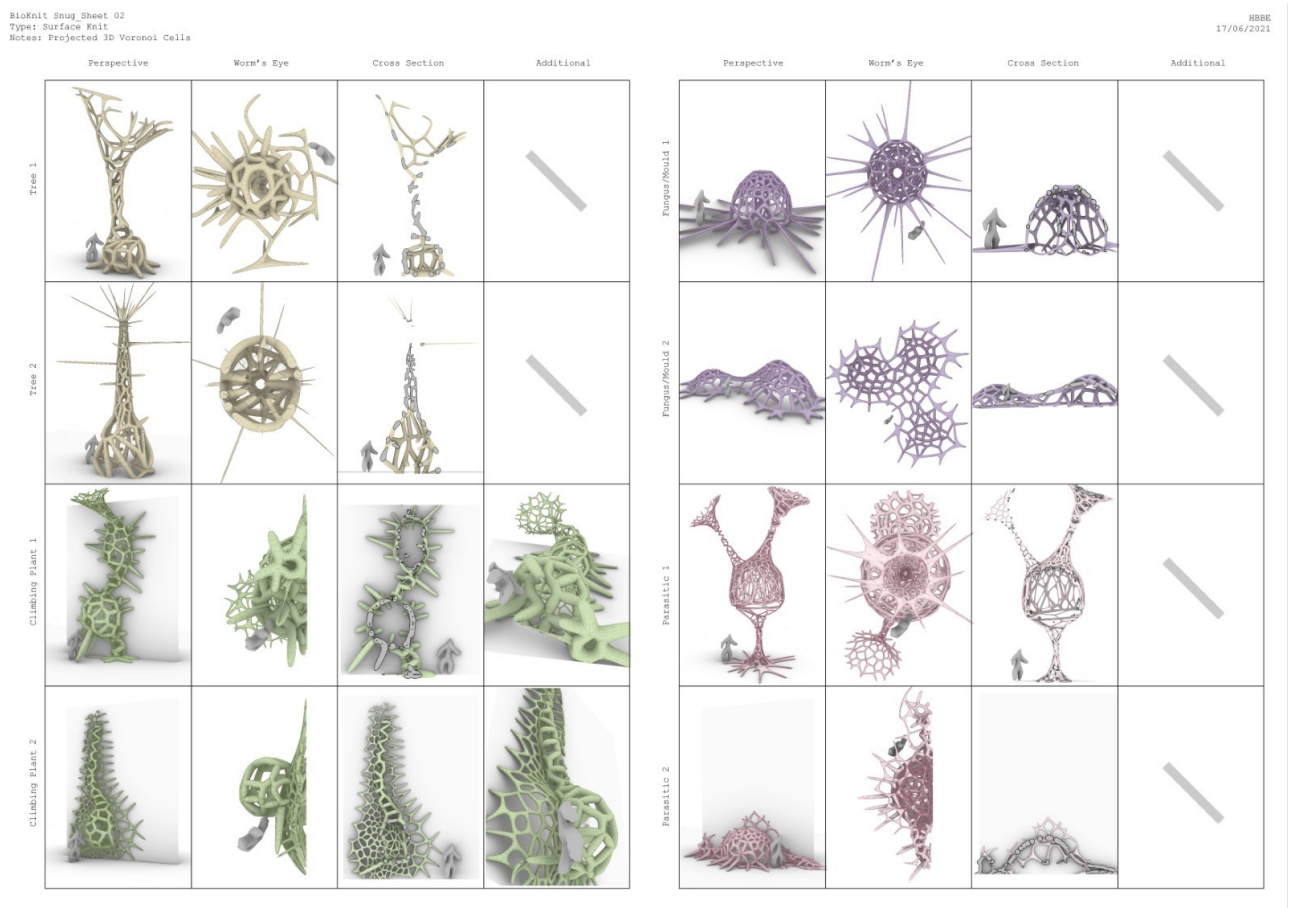

Figure 3: Design Experiments with Bio-Inspired Forms

3. RESULTS

The reflective process central to the BioKnit methodology has helped to identify opportunities and address challenges working with both mycelium and BC using a knit scaffolding system. The results will discuss how preliminary experiments helped to address key problems related to the application of knit as a composite for biomaterials; with specific reference to knit variables and the translation of the preliminary experiments to a 1:1 scale. Specifically, results address change of scale using knitted fabric processes, and the adaptions necessary to maintain the integrity of a BioKnit composite beyond standard growth parameters specified in literature [2]. These results reflect on all aspects of the investigation, integrating bioinspiration, material experimentation and design intention into the prototyping process.

4. CONCLUSIONS

The BioKnit composite prototype project highlights the potential to generate biocomposite material systems with both bacterial cellulose and mycelium using knitted fabric scaffolds to support the growth of the microorganisms. The prototype demonstrates how textile processes constitute an important method to translate biofabrication techniques to an architectural scale. Textiles provide a broad framework for biofabrication, utilising the inherent complexity in the hierarchical material system with robust fabrication technology adaptable for novel materials, and as such, offer a compelling approach to the development of low environmental impact material strategies for the built environment.

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