Braided Composite Pointe Shoes

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Introduction

- Pointe shoes were invented in the 19th century and are used by ballet dancers when dancing en pointe [1].
  - The block/box and the shank of the pointe shoe are typically made of layers of cardboard, paper, fabric, and paste.
  - The rest of the shoe is made of satin, leather and other fabrics [2].
- Pointe shoes need to be 'broken in', where the shoe is softened and moulded to the dancer's foot.
  - However, this also causes pointe shoes to 'die', as pointe shoes will eventually lack the necessary support to be usable.

The goal of this project is to determine the feasibility of designing the box and shank of a pointe shoe using braided composite materials.

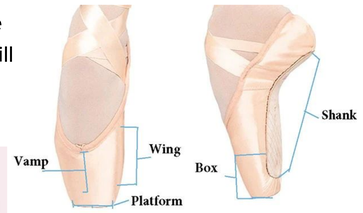

Fig. 1. Anatomy of a pointe shoe. Adapted from https://centralschoolofdance.co.uk/wp-content/uploads/2017/02/Fitting-Pointe-Shoes.pdf

Design

Tubular braided composites are created using yarns of fiber, which are interwoven together, then coated with resin [3].

The forces acting on the box and shank of a pointe shoe were determined, as illustrated in Fig. 2.

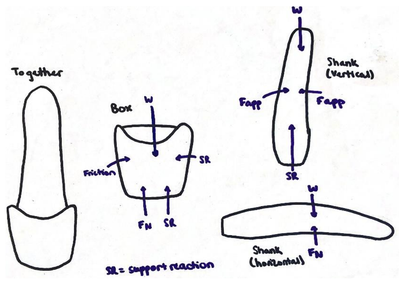

Fig. 2. Force diagram of the box and shank

- Kevlar®, a type of aramid with a high tensile strength-to-weight ratio, was chosen as the fiber. When cured, it is strong, yet lightweight [4].
- The dominant force acting on the pointe shoe was compression, so a braid angle of 35° was chosen to withstand this force.
- Ecopoxy and polyurethane were chosen as the resin, as they can both be cold-cured. Polyurethane is used for the shank as it is flexible.

Part	Fiber	Matrix (resin)	Braid angle	Fiber volume fraction
Box	Kevlar	Ecopoxy	35°	60% fiber 40% matrix
Shank	Kevlar	Polyurethane	35°	60% fiber 40% matrix

Manufacturing

Design for the box and shank of a pointe shoe was modeled using SOLIDWORKS® [Figure 3]

Designs were 3D printed using the Prusa MK3S+ printer and PLA (polylactic acid) filament [Figure 4]

Yarns of Kevlar were braided by the maypole rotary braider to create preforms [Figure 5 and 6]

One of the boxes and shanks were wrapped in paper before applying preforms, so that the 3D printed parts could be removed

Preforms were cut open and applied either to the surfaces of the box and shank, or to a box and shank wrapped in paper

Preforms were coated with resin, at a 4:1 ratio of resin and hardener for ecopoxy, and a 10:3 ratio (by volume) for polyurethane

The braided composites were cold-cured, and the 3D parts wrapped in paper were removed from the braided composites

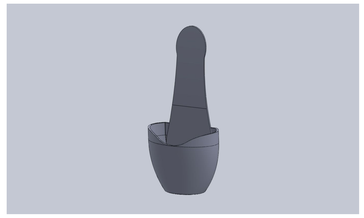

Fig. 3. SOLIDWORKS model of the box and shank

Fig. 4. Pointe shoe and 3D printed box and shank

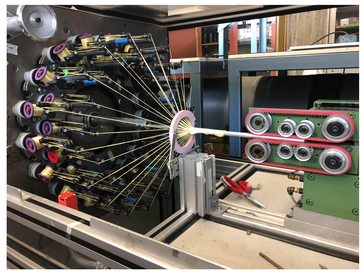

Fig. 5. Maypole rotary braider

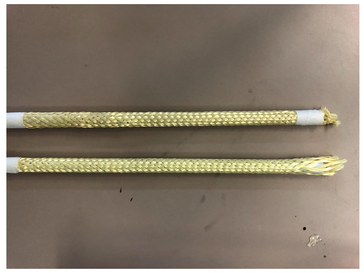

Fig. 6. Preforms of tubular braid samples

Conclusion

- Using SOLIDWORKS, the box and the shank of a pointe shoe were 3D printed and then created using braided composites.
- For one set of the box and the shank, the preforms were applied directly to the 3D printed parts, while a second box and shank were wrapped in paper before hand, so that the 3D printed parts could be separated from the braided composite. These parts should be removable, in order to be realistically used as pointe shoe parts.
- By using materials other than densely packed layers of cardboard, paper, fabric, and paste, pointe shoes could be constructed to be longer lasting and more durable.
- In order for braided composites to be practically used in pointe shoe construction, it would need a certain level of flexibility once cured.
- For future considerations, use braided composite sheets (for example, from a loom rather than a maypole braider).

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