Braided Composite Biodegradable Tennis Racket

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Introduction

- Tennis had around 87 million players around the world in 2021 [1].
- As a result, around 7 million rackets are produced and sold every year [2].
- The majority of these rackets will end up in landfill.
- These rackets are made of carbon fiber or graphite [3], creating waste as they are non-biodegradable.
- **The goal of this project is to determine the feasibility of designing a working tennis racket using biodegradable braided composite materials.**

Methods

The principle forces acting on a tennis racket are first determined and then added to a force diagram (see figure 1).

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Taking those forces into consideration, the materials used in the construction of the racket are chosen (see figure 2).

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Using SOLIDWORKS, a 3D modeling software, the tennis racket is designed and its dimensions are determined (see figure 2).

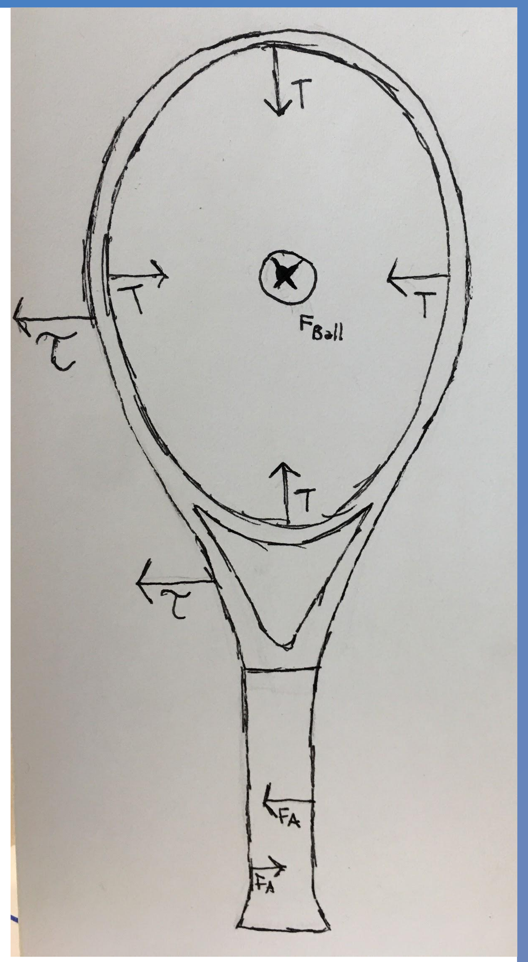

Figure 1: Force diagram of the tennis racket

- Racket face shape uses the Wilson Stable Smart Geometry seen in the Clash 100 racket.
- Racket face is essentially egg-shaped, which minimizes the elevated net torque caused by a more flexible frame.
- Flexibility in racket frames is crucial in giving players better control over the ball while hitting more powerful shots.

Hemp Fiber (frame): Biodegradable, flexible, vibration dampening

Polyhydroxyalkanoate (resin): Biodegradable, UV light resistant, stiff, easy to manipulate (in liquid form)

Fiberglass (handle): Compression resistant, shock absorbing, high tensile strength

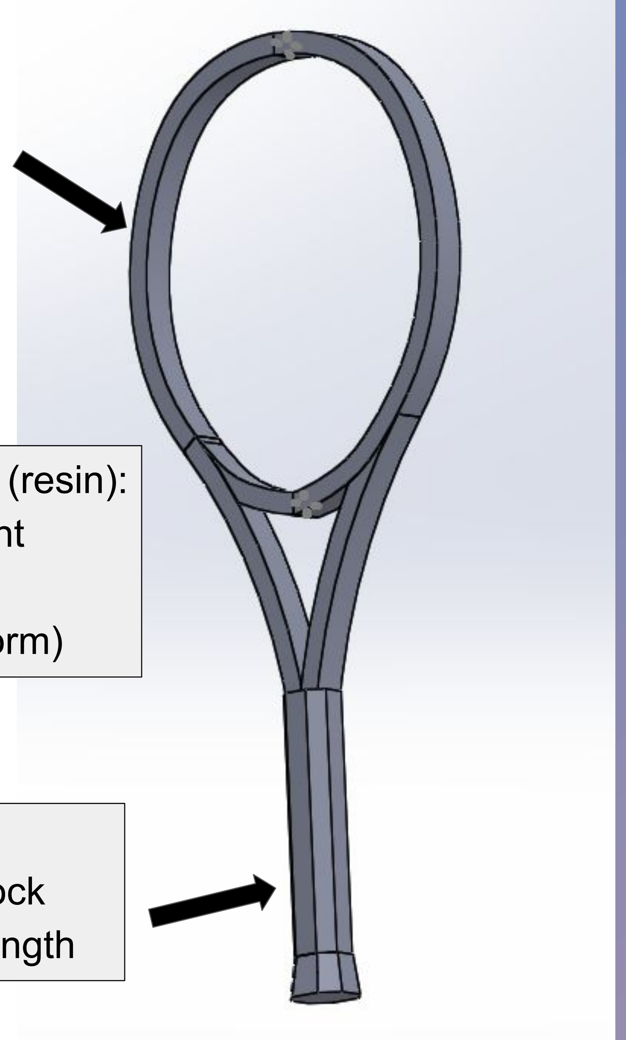

Figure 2: 3D model of racket in SOLIDWORKS. Labels show the reasoning behind the chosen materials

Hemp Fiber	
Elastic modulus x (GPa)	12.031533825081143
Elastic modulus y (GPa)	4.074156193108786
Shear modulus (GPa)	2.110014315730031
Poisson's ratio	0.5214406695035149

Figure 3: Properties of hemp

E: Measure of stiffness; stress/strain
G: Measure of shear stiffness, shear stress/shear strain
nu: transverse strain/axial strain

Fiberglass	
Elastic modulus x (GPa)	17.197246173891998
Elastic modulus y (GPa)	4.131912651901065
Shear modulus (GPa)	1.9114978294379252
Poisson's ratio	0.46243245934543903

Figure 4: Properties of fiberglass

Due to restrictions in lab technology, a 3D printed core was required to achieve the desired structure and shape. (See figure 5).

- The braided preform is braided around to envelop the 3D printed core.
- To make this possible, the racket was broken down into components.
- This is the only way the braided preforms can be made into a closed circle.

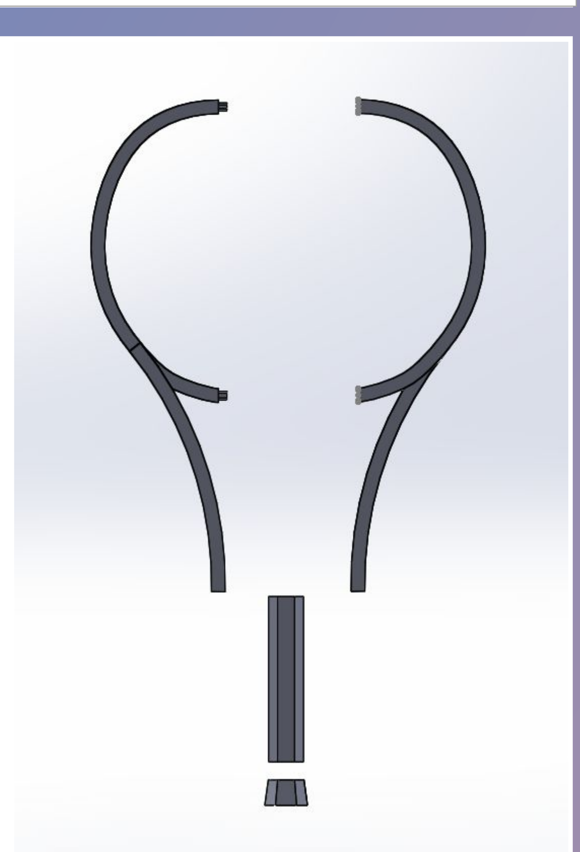

Figure 5: The solid model of the racket is split as shown

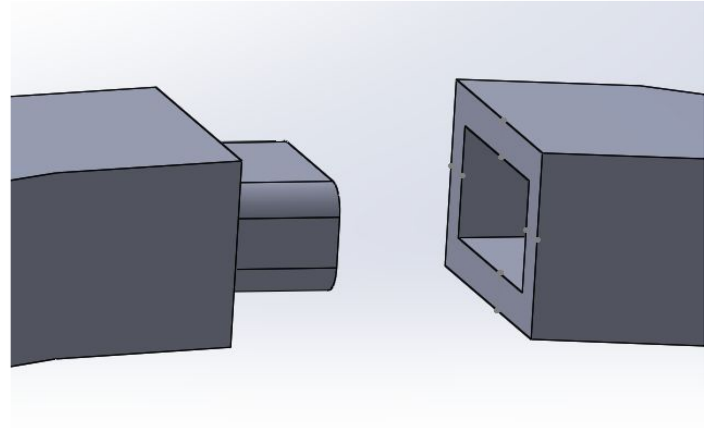

Figure 6: Connecters at the top of the racket

Connectors are used to connect the top and bottom of the racket frame. (see figure 6).

Using Python, the optimal braid angle was calculated in order to achieve the best ratios of physical properties. (See figures 3 and 4)

15 degrees was chosen for fiberglass and 20 degrees was chosen for hemp fiber

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The racket core, designed using SOLIDWORKS, is 3D printed in pieces to be put together (see figure 7).

Figure 7: The 3D printed pieces of the racket

The dry preforms that will cover the tennis racket were made in the Maypole Rotary Braider, braided at 15 and 20 degrees. (See figure 8)

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The braids were first covered in a 4:1 ratio of resin to hardener and then cured. The ratio of material to resin is 3:2. (See figure 9)

Figure 8: Maypole Rotary Braider making preforms

Figure 9: Process of covering assembled racket with braided preforms

Results and Conclusions

- A tennis racket was designed using SOLIDWORKS, 3D printed, covered in composite material and resin, then cured.
- The design and materials used resulted in a racket fit to withstand the forces in tennis.
- This racket is a suitable replacement for the commonly used graphite racket.
- It is more sustainable and biodegradable.
- Hemp contains hemicellulose, making it water absorbent. Using alkali treatment fixes this problem as it removes the hemicellulose [4].
- For future production, use braided composite sheets, place them in resin containing molds, then cure them in the mold.
- This results in a more sturdy product and is how tennis rackets are made in the industry today.

Literature Cited

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