Department of MECHANICAL ENGINEERING
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Modernized Telemark Ski Boots

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Introduction

Telemark skiing is a technique that combines elements of alpine and Nordic skiing. While it was very popular in the late 1800's, the excitement wore off around the end of the century. During the 1980's, telemark skiing regained its popularity. Even though telemark skiing is popular again, the existing gear used is inferior when compared to alpine ski gear.

The objective of modernizing telemark ski boots is to reduce the weight of the boots while maintaining a similar stiffness to existing solutions. Specifically, this is to provide increased performance in backcountry and skimo racing applications. To accomplish this, we chose to update the construction of the telemark boot shell by replacing the traditional plastic construction with carbon fiber. Doing so allows for the construction of a boot that is sufficiently stiff, while being substantially lighter and stronger than current telemark ski boots.

Problem

We were tasked with designing, constructing, and testing a telemark ski boot that meets the metrics provided below.

- The weight of a single boot will weigh less than 1000g.
- The walk range of the boot will not be less than +/- 60 degrees.
- The boot will not fracture or disform under loaded conditions.
- Stiffness of the boot will be around 5.6 kN/m under bending load.

Methods

For designing the shell of the boot, an iterative process was used. We measured the boot liner that was being used, designed and 3D printed molds, then repeated these steps. We ran through this process until our shell had the correct geometry to fit the liner while also providing the desired 60-degree range of motion in the ankle joint.

To determine the optimal stiffness for the sole of the boot, we used finite element analysis (FEA). We ran many simulations that helped us determine the sole thickness needed to provide our desired stiffness, while maintaining rigidity that prevents fracture.

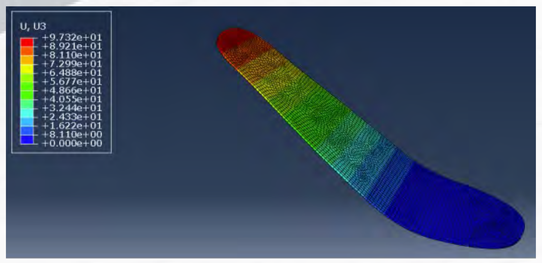

Figure 1: FEA model in ABAQUS representing the max displacement in the sole before fracture occurs.

Figure 2: Initial iteration of the boot shell molds.

Manufacturing Process

Once our molds had been perfected, we cut carbon fiber fabric to size and laid it into the molds. We then applied resin to the carbon fabric to harden the carbon fiber.
The sole and walk mode components for the boots were milled out of polyurethane and aluminum, respectively.

Figure 3: Shell manufacturing process: Cutting carbon fabric to size (left), finished lay up of the lower boot shell (middle), and finished lay up of the upper cuff shell (right).

Manufacturing History	
Iteration	Major Design Changes
TB-1.1	Preliminary Fiberglass Design
TB-2.1	Geometry adjusted to meet average human anthropometrics
TB-2.2	Geometry adjusted to suit clients' specific biometrics
TB-2.3	Geometry adjusted to suit specific client concerns
TB-3.1	Final lower shell geometry solidified
TB-3.2	Walk mechanism redesigned to provide better function
TB-3.3	Sole dimensions updated to provide better fit in telemark bindings
TB-3.4	Cuff geometry modified to provide enhanced range of motion
TB-3.5	Sole dimensions split to increase machinability
TB-4.1	Functional Proof of Concept Carbon Boot

Table 1: Summary of major revisions made to telemark boot design

Results

We have met the required design specifications that were provided to us by our client/advisor. We have also managed to finish our design and manufacturing process while coming in under our budget of $300.

Item	Quantity	Cost
Carbon Fiber Fabric	25 sq ft	Free (donated)
PLA Filament	7 kg	Free (donated)
Resin	2 gal	Free (donated)
Polyamide Plastic	24 in^3	$74
Gore-Tex Fabric	4 sq ft	$68
Aluminum 6061	54 in^3	$37
Ski Boot Buckles	4	Free (donated)
Ski Boot Liner	1	Free (donated)
Velcro Strap	1	Free (donated)
Total	N/A	$179

Table 2: Project budget, including total prototype cost.

Conclusion

We designed and manufactured a telemark ski boot that is lighter and more capable than existing telemark ski boots due to the rigid carbon fiber shell, polyurethane sole, and aluminum walk mode assembly. We are delighted to have met all our clients' requests and required metrics for the boot.