The Design, Construction, and Testing of a Lighter and Stiffer Lacrosse Goalie Stick

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Abstract

The purpose of this research project was to develop a lighter and stiffer lacrosse goalie stick. Because of the limitations of the Prototyping Lab at TJHSST, it was decided that using conventional plastic materials, which also required a method of making a metal mold, would be inappropriate. Instead, the prototype goalie stick would be made out of easily workable foam core with a shell of composite materials. The first prototype featured a laser cut foam core with multiple layers of strips of bi-directional carbon fiber fabric wound around the sidewall, scoop, and neck. The fraying associated with strips cut from a larger piece of fabric resulted in various weak spots and bubbles between layers of carbon fiber. The second prototype featured a multiple layers of unidirectional tape running along the length of stick while bi-directional tape was wrapped around the sidewall, scoop, and neck. The stiffness of the sticks was tested by placing the stick on a shaft, and clamping the shaft in such a manner that the stick was held with its face parallel to the ground while a force was applied to the center of the scoop, perpendicular to the face of the head. This was intended to mimic the force of a hard shot hitting the scoop while making a save, as well as the force felt while pressing the stick down and forward into the ground while saving a low shot. Of the sticks tested, the second prototype goalie stick was the stiffest and the heaviest, the DeBeer Web was the least stiff, and the Brine X-Treme was the lightest. The STX Eclipse was the stiffest of the non-prototyped heads tested. It is inconclusive whether a stick can be made lighter *and* stiffer. It is the author's recommendation that further research be conducted into finding an appropriate balance between layers of carbon fiber, stiffness, and weight.

Introduction

Lacrosse is one of the fastest growing sports in the United States. An article published online by LaxPower cited the National Federation of State High School Associations as saying that there were 41,822 varsity high school boys and 35,186 varsity high school girls playing lacrosse. This was a 10.5% increase for the boys and an 8.6% increase for the girls. When *all* players are considered, including youth, junior varsity, varsity, club, and collegiate, for both the men's and women's game, in the United States and internationally, there is a fair sized market. Furthermore, if it is estimated that one in fifteen players is a goalie, and that men's and women's goalies use the same kind of goalie heads (unlike field players), the specialty market for goalies is significant.

Because the author is a lacrosse goalie, and has personally witnessed the amount of flex in current goalie sticks available on the market, and experienced two sticks breaking mid-season, the author decided to conduct research into developing a better lacrosse goalie stick.

The first quality of a better lacrosse goalie stick is weight. A lighter stick allows the goalie to move faster to the ball when making a save, and also makes passing and shooting easier.

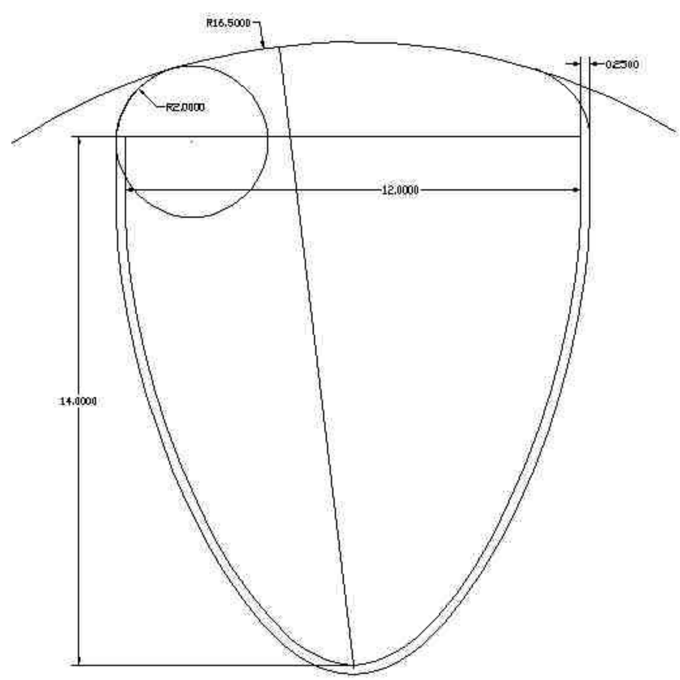
The second quality of a better lacrosse goalie stick is stiffness. In a flexible stick, the stick bends when catching a shot. Mostly the goalie's hands and arms absorb the impact of the ball, but a good deal of the energy goes into bending the stick. The farther the stick bends the more energy is absorbed. When the stick unbends and snaps back to its original position, the energy is released and is transferred to the ball, and can result in a rebound. If the stick is stiffer, the impact of the ball should be absorbed more directly by the goalie.

The overall strength of the stick should not be confused with its stiffness. Strength refers to the point at which a thing actually breaks. An eggshell is very hard and stiff, and will not flex, but not very strong. Once enough pressure is applied, it breaks completely. Conversely, a popsicle stick will bend and bow under slight pressure, but is fairly strong and will not break until a significant amount is applied. It was decided not to try design a stronger stick as long as it was strong enough. A good analogy is a bridge. A bridge capable of holding 1,000,000 pounds is not necessarily better than a bridge that can hold 100,000 pounds if all it ever needs to hold is 10,000 pounds.

With that in mind, the author began research into developing a lighter and stiffer lacrosse goalie stick.

Materials and Methods

Design of the goalie stick began with a two dimensional drawing made in AUTOCAD, shown below.



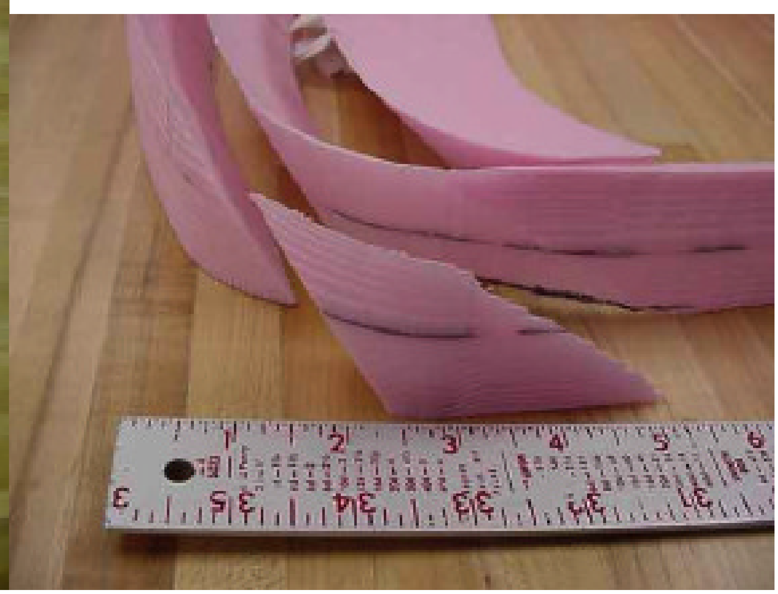
The top scoop is described as an arc segment with a 16.5" radius, with filleted corners with a 2" radius. At its widest internal measurement, the stick is 12" across. The sidewalls are 0.25" thick, however after the thickness of the cutting beam makes this closer to 0.125". There is excess material drawn at the bottom of the scoop to allow for ease of cutting in later steps.

Once the general drawing of the stick was done, a manufacturing method was considered. It was decided to use lightweight insulation foam to make a "core" for the stick. Layers of carbon fiber could be wrapped around the core, building the stick from the innermost layers, outward.

Insulation foam, readily available in the classroom, was used as the core. Four identical pieces of 1" thick foam were cut out on the laser cutter. Adjusting the laser cutter to the proper settings took some experimentation. Cutting the foam in a single pass was impossible, because the foam would melt. Instead, fifteen passes were made at high speed, cutting only a little bit of the foam at a time.

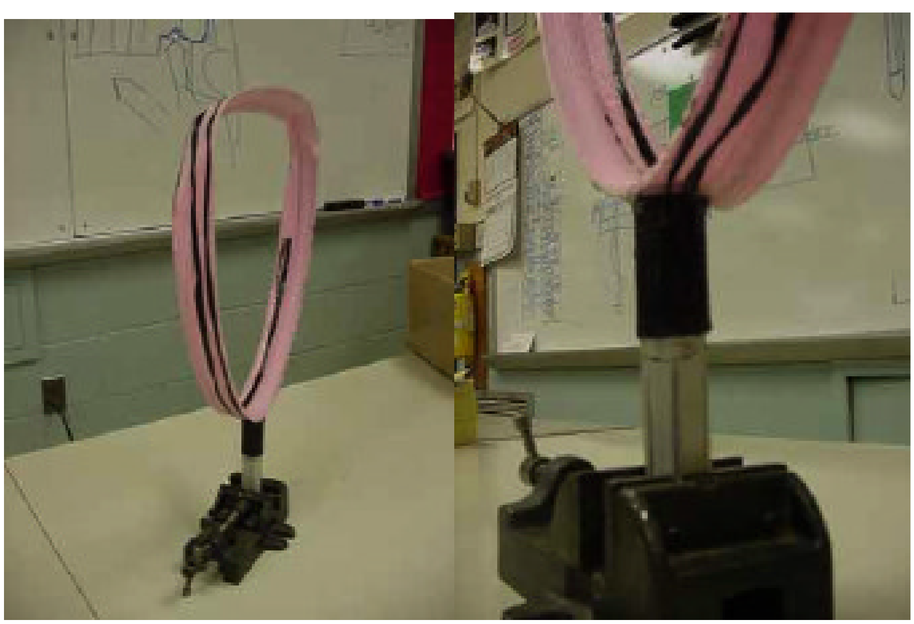
The four pieces of foam were then hot glued together, two sets of two side-by-side, and then stacked on top of each other. This gave an exact copy of the AUTOCAD drawing above, with sidewalls that were the NCAA 2” limit. Because later layers of carbon fiber would add to the thickness of the sidewalls, an X-Acto knife was used to remove 0.125” from the sidewall.

Shown below details of the laser cut foam core. The scoop of the lacrosse stick was cut by hand on a band saw. All along the inside of the scoop, from the point where the fillet in the corner meets the straight part of the sidewall, a 45° cut was made relative to the plane of the face of the head. On the outside edge, between the fillets, a 30° cut was made, and along the fillets on the outside edge, a 20° cut was made. A diagonal freehand cut was made with an X-Acto knife from 2” below the fillet towards the neck from the bottom sidewall edge, to the top corner of the fillet 0.5” into the sidewall. This completed the foam core.

The neck of the stick was made by wrapping a segment of a BRINE F-22 shaft with wax paper, then wrapping the wax paper with carbon fiber tape and brushing on epoxy. The cured carbon fiber slid off, the wax paper was removed, and the neckpiece still had a snug fit with the shaft. The neck was then attached to the foam core using hot glue.

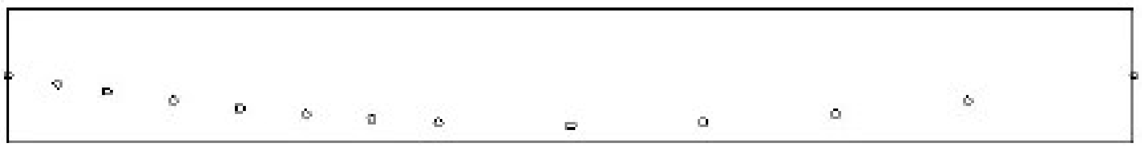
Three strips of 0.5" wide mono-directional fiber were brushed with epoxy and placed on the foam core. Two strips traversed outside, parallel to the sidewall. The third strip was placed on the inside surface of the stick, parallel to the sidewall. It was hoped that the linear fibers would help to connect the short cross fibers of the bi-directional tape in the next layer.



The next layer on top of the mono-directional fiber was a wrap of 2” wide bi-directional tape. The tape was wound around the foam core in a clockwise direction, in a manner very similar to taping someone’s wrist, then epoxied. Each time the tape was passed around the sidewall, it overlapped by about 0.75” the piece of tape underneath it.

The next layer used bi-directional carbon fiber tape wrapped in a counterclockwise direction. Another layer of three strips of mono-directional tape was placed down, exactly as described above. On the advice of Mr. Warwick from Warwick goalie masks, the second to last layer was Kevlar to make the stick less brittle. The bi-directional Kevlar layer was wrapped exactly like the bi-directional carbon fiber layers. One last bi-directional carbon fiber layer was wrapped in the opposite direction of the Kevlar. Please note that due to time constraints of the classroom, the layers were put on one at a time, and there was a two or three day period in between layers to allow the epoxy to cure.

A design for the stringing holes and a separate one for the scoop was drawn in AUTOCAD and a paper pattern was cut out. The placement of the wholes follows an arc segment stretching from the midpoints of the sidewall. The stencil was placed on the stick and the stringing holes were cut out using a 3/16th" drill bit.

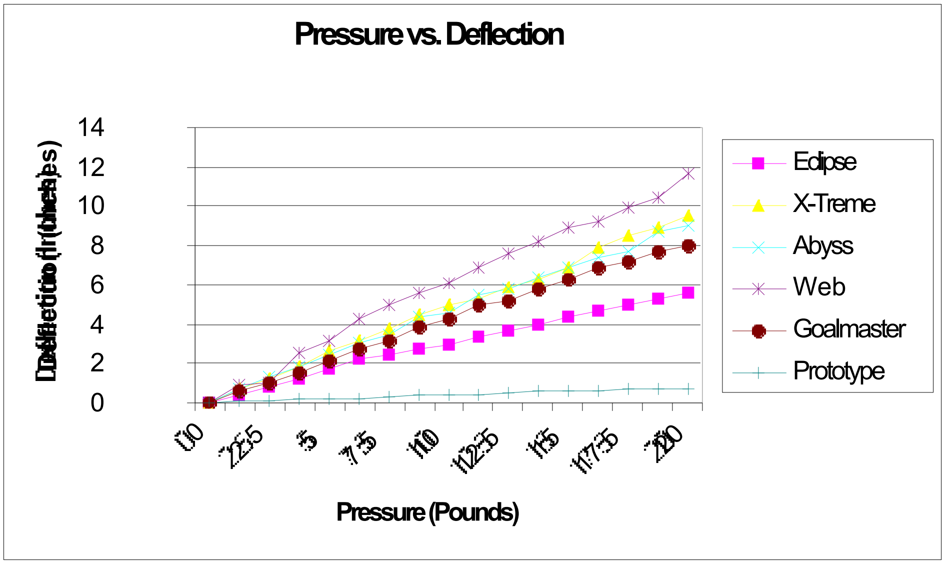


This completed construction of the stick.

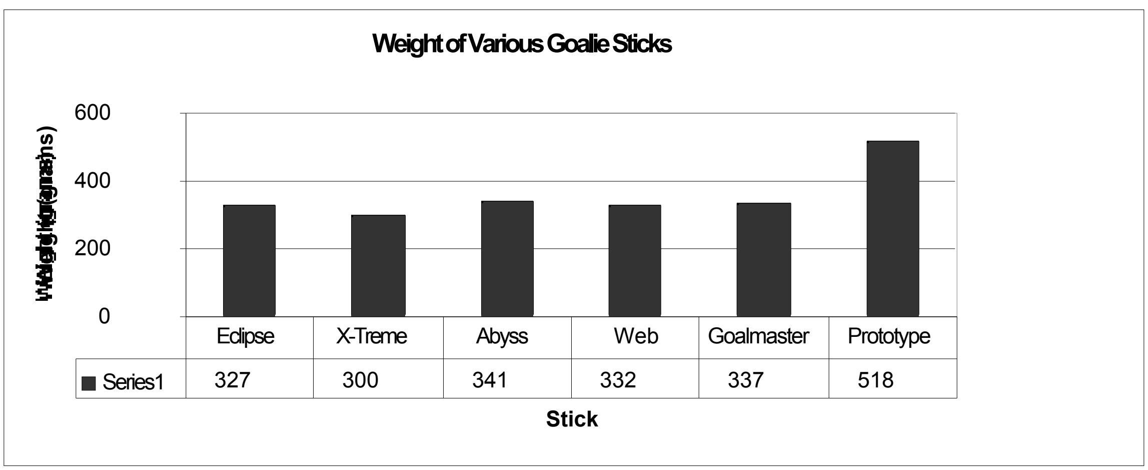
The sticks were tested by placing them on a shaft, and clamping the shaft to the table so that the face of the stick was parallel to the ground. Weights were then suspended from the scoop (from 0 to 20 pounds in 1.25 pound increments) to mimic the force felt by the stick when hit by a ball or forced into the ground, and the deflection was measured.

Results

The Prototype carbon fiber stick was clearly the stiffest, followed by the Eclipse, Goalmaster, Abyss, X-Treme, and Web. In addition, it should be noted that after pressure was removed, not all the sticks unbent to their original position. The Eclipse and the Protoype did not show any distortion, but the X-Treme and Goalmaster were temporarily bent to within 1" of their starting position, while the Abyss and Web were temporarily bent to 1 2/16" and 1 4/16" from their starting positions, respectively. After a few minutes they returned to their original shape. Shown below is a graph of the pressure applied vs. deflection measured.



The sticks were weighed, and it is quite clear that the X-Treme was the lightest, while the Prototype was the heaviest.



Conclusion

The title of this project was “The Design, Construction, and Testing of a Lighter and Stiffer Lacrosse Goalie Stick.” One of the goals of the project was met, one was not. It is possible to make a very stiff structure using carbon fiber and Kevlar composite materials. It is not conclusive, based on the research done here, whether it is possible to make a stiffer *and* lighter lacrosse stick.

There are also a number of factors that could have contributed to the weight of the stick. Because of the time constraints, only one layer was fabricated at a time, and an excess of epoxy may have been used between layers.

Another factor to be considered is the use of the foam core. There were six layers total of composite materials built over the foam core, but when you consider that the layers wrapped around the foam core, on the inside of the sidewall and the outside, it is more like having twelve layers with a piece of foam sandwiched between them. The foam made construction easier, but it is possible that it caused the stick to have the weight of twelve layers, but only the total strength of six. The inside to building outward method necessitated the use of a foam core, but it may be possible to use an outside inward method using a more traditional mold.

This project used a very specific definition of what makes a better goalie stick. Besides quantitative factors, such as cost, stopping area, strength, and stiffness that can be measured, there are other factors that contribute to the quality of the stick, such as stringing hole placement. While stringing ultimately determines the depth and release of a pocket, the locations of the stringing holes are still important.

It should be noted that due to time constraints, the test run on the sticks was very limited. None of the sticks were pushed to the breaking point, the effect of extreme temperature was not measured, neither was the effect of UV radiation on the degradation of the plastic or the epoxy. The sticks were only placed under load at a single point in the middle of the scoop, not along the neck, sidewall, or the corners.

Finally, all the sticks tested were equivalent to straight off the factory floor, with the exception of the Eclipse and Goalmaster, which had not been used for more than three months.

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