Materials Engineering

The Design and Manufacturing of a Composite Bicycle Saddle

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A proper bicycle saddle design provides high comfort and performance advantages in the cycling industry. A high-performance saddle is suitable for competition because of its flat, lightweight frame and minimal additional padding. However, there has been a rise in health concerns linking high-performance saddles to soft tissue damage. Factors such as hip bone width, nose length, and soft tissue are important in saddle design. The goal of this project was to design and manufacture a composite bicycle saddle that reduces the amount of soft tissue damage while maintaining performance, cycling saddle regulations, and competitive pricing.

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Project Background

Sit bones, or ischial tuberosities, are the main support system when sitting properly on a bicycle saddle. These bones should be centered on the saddle on either side. Without proper support, load is transferred to soft tissue areas in the inguinal region. Areas of higher pressure can be shown in red when using a pressure mapping system (Fig. 1).

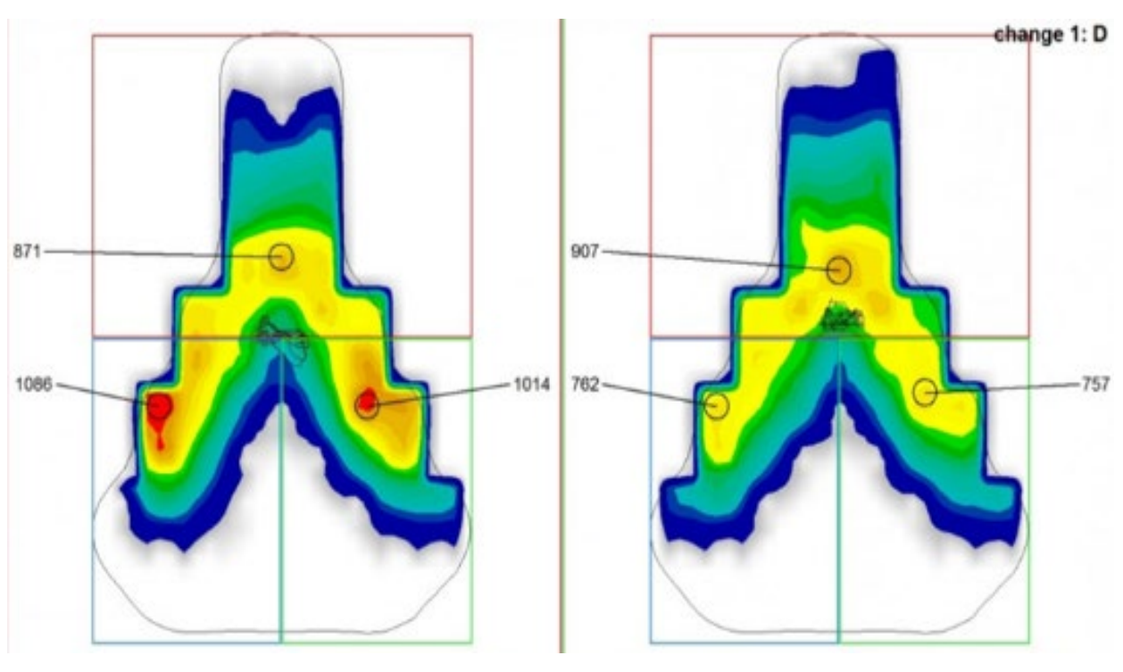

Figure 1. Typical pressure distribution of a bicycle saddle design.

According to Union Cycliste Internationale (UCI) regulations, a bicycle saddle must not be angled more than 9°, encouraging professional cyclists to continuously move forward on the nose to achieve a competitive advantage. This position causes a decrease in blood circulation in the inguinal region. Long term, sustained pressure in this region has been investigated as a possible cause of the increased rate of prostate cancer in male cyclists.

Design Methodology

Shell Design:

The design of this shell was based on bicycle saddle pressure distributions from multiple case studies. Multiple saddle concepts were generated and refined to meet project goals. The final concept was translated into a SolidWorks model incorporating UCI compatible dimensions (30 cm length, 12 cm width). (Fig. 2). Cutouts were based on compiled pressure distributions and the forked nose seen in triathlon seats.

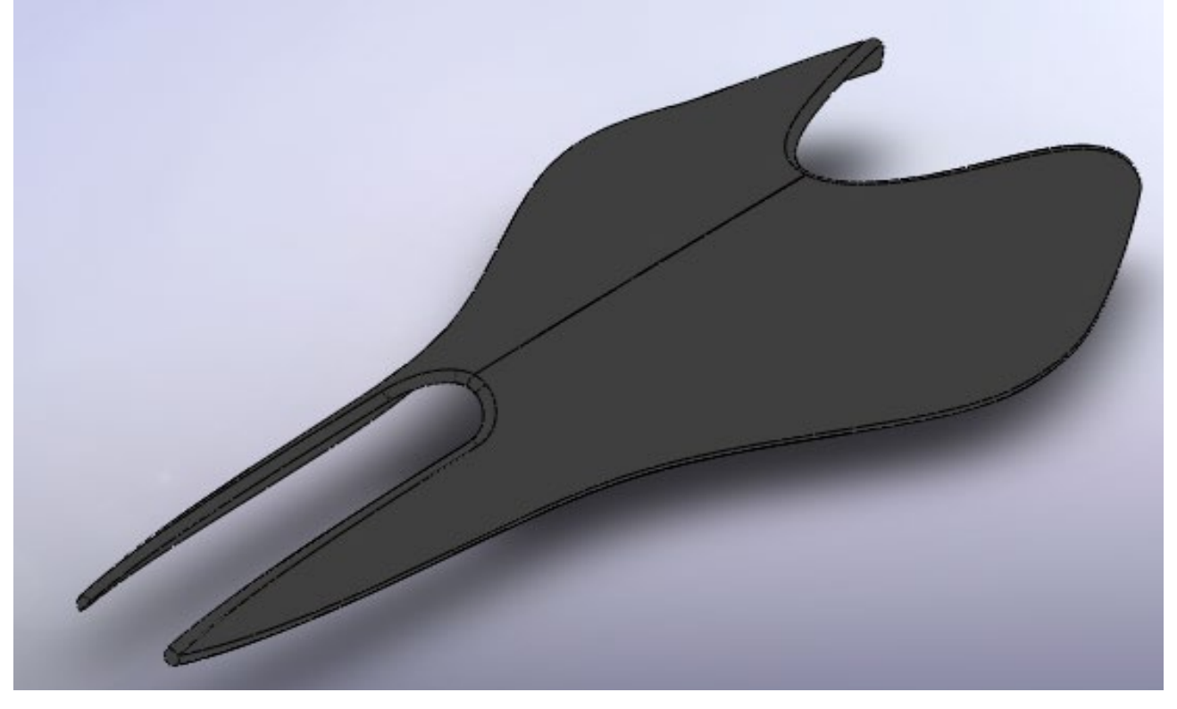

Figure 2. SolidWorks shell with cutouts.

The saddle rail was designed to achieve the highest amount of contact area to ensure appropriate load bearing support and to prevent nose deflection.

Mold Design:

Both the shell and rail molds were created out of aluminum for ease of machining and relative thermal expansion compatibility (Fig. 3). A female mold was created for the shell by importing a negative of the SolidWorks model within CATIA V5. The rail design was created in CATIA V5 to conform to saddle geometry.

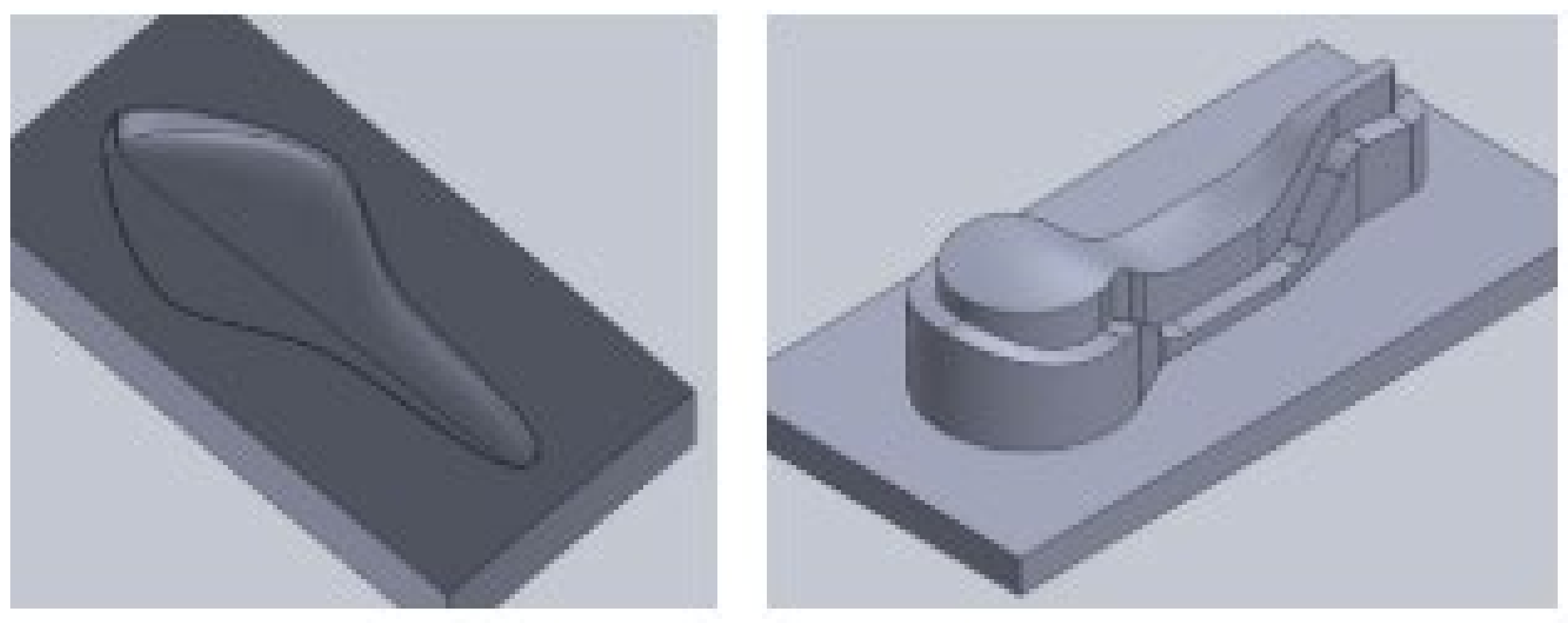

Figure 3. Female mold renderings of shell design (left) and rail mold (right).

Manufacturing Procedure

Shell Manufacturing:

The shell mold surface was prepared by successively sanding the mold surface from low to high grit. The mold surface was then cleaned and a polymeric mold release solution was applied in 4 coats with two minute wait times between each coat. Two ply designs were created with darts; incisions which allow for curvature without the buildup of excess material. A braided carbon fiber pre-impregnated material was used with a [0, 45, -45, 90]$_s$ stacking sequence. Plies were cut on a Gerber table cutter and laid up sequentially in the mold with alternating dart configurations.

Figure 4. Completed shell layup.

Completed lay ups (Fig. 4) were vacuum bagged by wrapping the mold sequentially in release film, breather, and the vacuum bag. Vacuum was pulled in the bag and cured in either an oven or autoclave.

Rail Manufacturing:

A strip of [0, 90] braided carbon fiber composite (21" x 8") was cut at a 45° orientation and rolled around a (24" x 1/16" d.) copolymer rod. Thus the fibers are at ±45° with respect to the horizontal, promoting damping in the rails. The rod and composite were inserted into high temperature heat shrinkable tubing. Tubing formed to the rod and composite via heating. The copolymer rod was extracted leaving a hollow tube. Rail preforms were conformed to the rail mold shelf (Fig. 5) and secured using a vacuum bag.

Figure 5. Rail conformed to rail mold shelf inside vacuum bag.

Rails were cured in either an oven or autoclave.

Extraction and Assembly:

Vacuum bags were removed and discarded after curing. The shell mold was preheated to reduce thermal compression on the shell. Shells were extracted using prybars and hammers. Excess trim was removed and cut outs were made via diamond cutter. Rails were removed from the mold. The heat shrinkable tubing was softened using a heat gun and removed. Shell and rail contact surfaces were sanded to increase contact area and epoxy adhesion. The rail apex was adhered to the forked nose, bridging the tip (Fig. 6). Rail ends were adhered to the rear of the shell.

Figure 6. Assembled saddle mounted to a Giant brand bicycle.

Results and Discussion

Characterization:

Two shells were cured in an oven and one was cured in an autoclave. Oven cured shells were connected to a vacuum tube and subjected to heat. Autoclave curing was similar to the oven process with the addition of 80 psi of pressure (Table 1).

Table 1. Autoclave and oven curing schedule for bicycle saddle components

Curing Method	Hold Temperature (°F)	Hold Time (hours)	Ramp Rate (°F/minute)	Pressure (psi)
Oven	250	2.0	5.0	0
Autoclave	250	2.0	5.0	80

The shell cured in the autoclave saw an increase in the overall surface finish quality. The rail cured in the autoclave was crushed by the external pressure. Shells cured in the oven exhibited open pores indicative of insufficient pressure for resin flow. Rails cured in the oven appeared nominal. Cross sectional samples were cut from shells cured in the oven and autoclave for optical microscopy (Fig. 7).

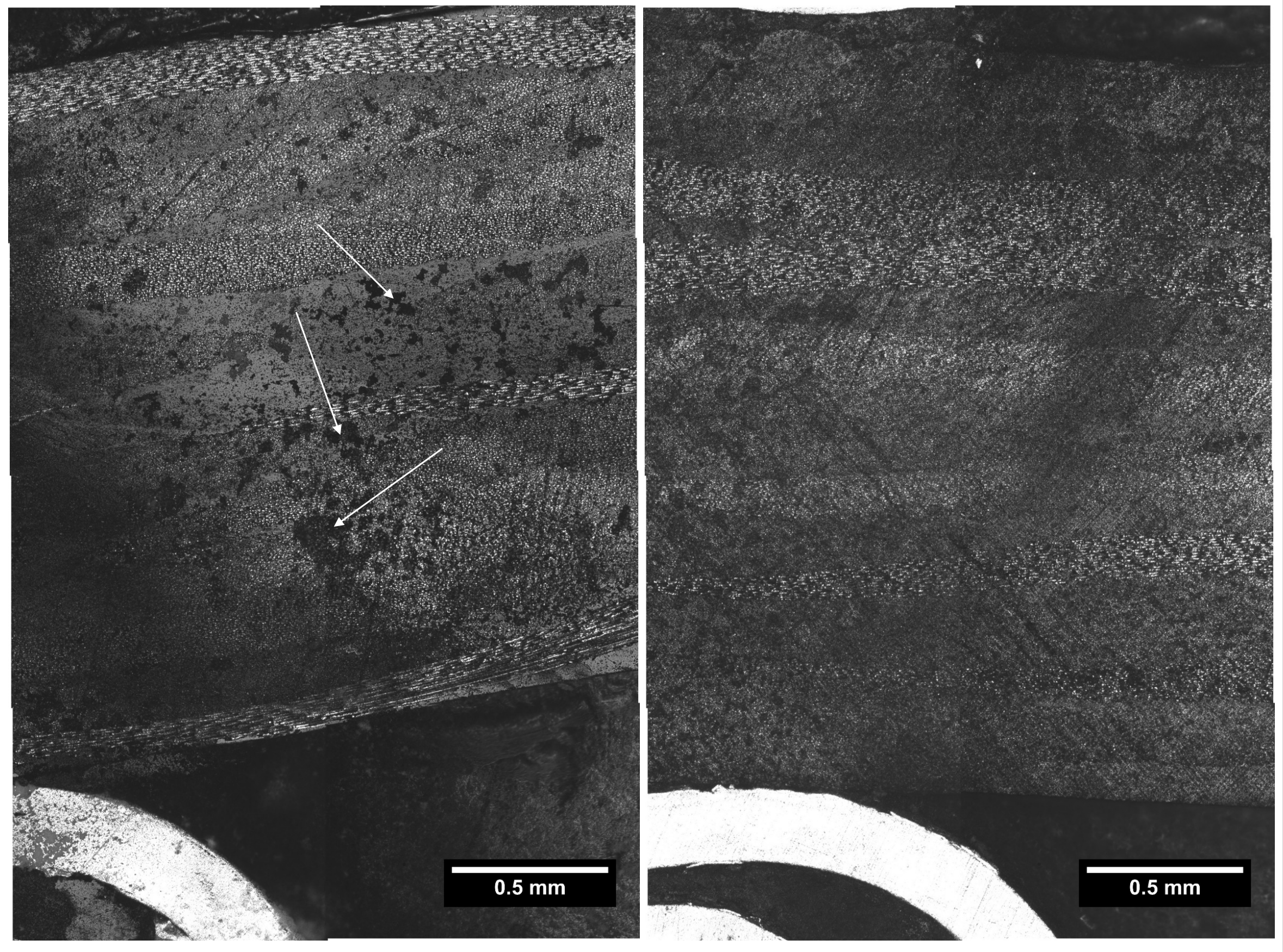

Figure 7. Optical micrographs for oven (left) and autoclave (right) cured shells in cross section. White arrows indicate major porosity.

Autoclave is preferred for manufacturing high performing composites because the applied external pressure reduces porosity. Reduced porosity was found in the shell cured in the autoclave (Fig. 7) as expected. Autoclave is proposed as the curing method of choice for this bicycle shell. Oven cured rails also exhibited significant porosity (Fig. 8). Hollow rails should not be cured in the autoclave without central support.

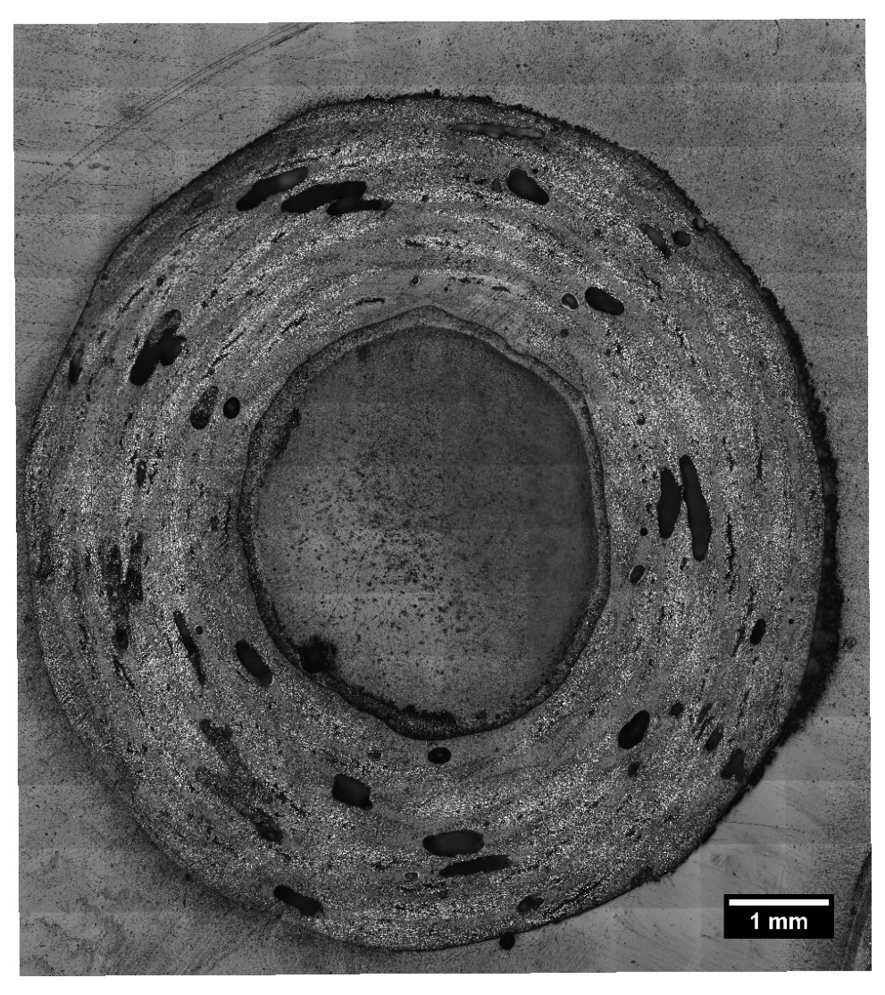

Figure 8. Optical micrograph of rail in cross section.

Recommendations:

More care should be taken in constructing a proper vacuum bag. Creating a mold from carbon fiber or a material that shares a similar coefficient of thermal expansion will prevent thermal compression of the shell. Sufficient pressure should be applied to uncured shell material to ensure maximum contact with the mold and underlying plies. Furthermore, standardization of the manufacturing process would decrease human error. Alternative options should be explored for mechanically validating the saddle.

MSE 430-440: Materials Processing and Design