Redesign of the Standard Bicycle Seat to Prevent Male Impotence

Jaspal Singh Sandhu

Submitted to the Department of Mechanical Engineering
in partial fulfillment of the requirements for the degree of

Bachelor of Science in Mechanical Engineering

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 1999

Author ....
Department of Mechanical Engineering
December 18, 1998

Certified by ....
Peter Griffith
Professor Emeritus of Mechanical Engineering
Thesis Supervisor

Accepted by ....
Professor Ernest G. Cravalho
Department of Mechanical Engineering
Chairman of the Undergraduate Thesis Committee

Redesign of the Standard Bicycle Seat to Prevent Male Impotence

by

Jaspal Singh Sandhu

Submitted to the Department of Mechanical Engineering on
December 18, 1998, in partial fulfillment of the requirements for
the degree of Bachelor of Science in Mechanical Engineering

Abstract

Standard bicycle seats inflict injury to the perineum, the center for arteries and nerves feeding the penis, through repeated compression loading. Though harmless in low cycles of loading, the result for many high-mileage, male riders is sexual dysfunction. Recumbent bicycle seats prevent damage to the perineum by shifting the compressive loads to other parts of the anatomy.

The object of this project was to design an upright bicycle seat that gave the same benefits as recumbent seats in terms of protection of male sexual functionality. A seat design utilizing similar principles of the recumbent seat and preventing damage to the perineum was proposed. This design maximized stability and comfort, while maintaining the rider's ability to generate pedaling power. Additionally, a streamlined process for rapid prototyping of bicycle seats was developed.

Thesis Supervisor: Peter Griffith
Title: Professor Emeritus of Mechanical Engineering

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

Dr. Irwin Goldstein of the Urology Department at Boston University Medical Center has examined the long-term effects of bicycle riding on male impotence. In the May 1997 issue of *Bicycling*, he published results of a study that correlated saddle pressure to compression of the perineum. Defined as the "somewhat lozenge-shaped [surface] . . . limited on the surface of the body by the scrotum ventrally, by the buttocks dorsally, and laterally by the medial side of the thighs," the perineum is the anatomical center of nerves and arteries feeding the penis [1]. The arteries - under repeated loading - can become permanently damaged, leading to male sexual dysfunction. Dr. Goldstein estimates that 100,000 men have become impotent through damage caused by either the bicycle seat or its top tube [2]. He ventures to say:

> Men should never ride bicycles. Riding should be banned and outlawed. It's the most irrational form of exercise I could ever bring to discussion [3].

With the exception of those who work with recumbent seats, few have tackled the issues involved in inflicting damage to the perineum. The purpose of this project was to analyze the cause of this arterial compression and design a new bicycle seat preventing damage to the arteries.

A detailed look at the male anatomy reveals that the perineum is compressed mainly by the nose of the saddle (see Figure 1.1). This was a key assumption in designing the new seat. The new seat would displace load away from this section of the anatomy to more suitable locations, such as the buttocks.

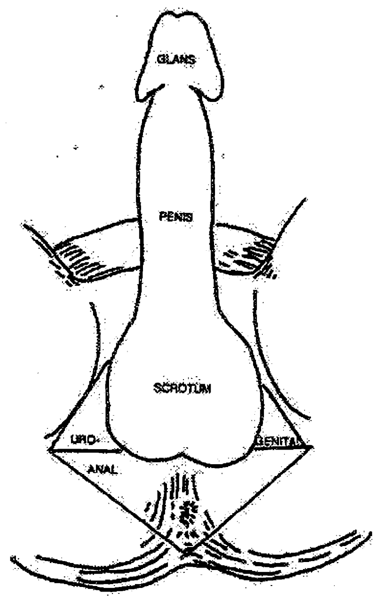

Figure 1.1: The Male Perineum. The diagram shows its two subsections, the uro-genital and anal triangles [4].

1.2 Project Scope

This project concerned itself not only with the design of the bicycle seat, but also with an efficient prototyping process. The cost and time invested in using standard manufacturing processes was much too great for the purposes of creating testing prototypes. After determining a process design, it was necessary to go through two iterations of product design. One seat was designed, built and tested. The data compiled from the user testing was used to design the second seat and to go through the same process. The testing results from the beta-prototype are presented here as evidence of a successful design.

Based on the findings, the general design methodology was to remove the nose of the saddle, thereby relieving the pressure on the perineum. The design challenge was to redistribute the pressure in a manner that would allow for greatest stability and comfort.

Chapter 2

Existing Designs

2.1 Patent Research

Patent research revealed a host of related claims, presented here for comparison to the current design. It is important to note that their direct intention was not to protect the perineum, given the recent nature of Dr. Goldstein's findings. Five patents in particular tackled the issue of seat comfort by displacing the load away from the male sex organs.

A patent from 1978 (refer to Figure 2.1) described a seat with support ribs placed to allow different areas of the seat to flex [5]. The net result was that certain parts of the anatomy would take more of the seated load, thereby displacing uncomfortable stresses.

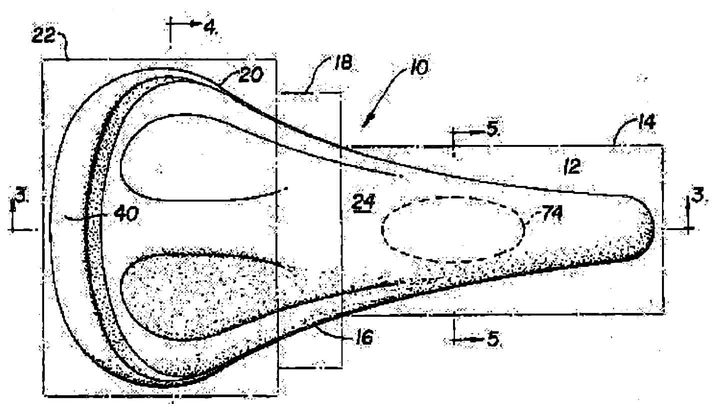

Figure 2.1: U.S. Patent No. 4,098,537, July 1978 [5].

Another pair of patents - one from 1983 and one from 1998 - presented split seats, with each half supporting one of the rider's legs (refer to Figure 2.2 for a drawing of the 1983 patent) [6,7]. The older patent provided immovable supports while the more recent one incorporated sections that moved with the rider's pedaling motion.

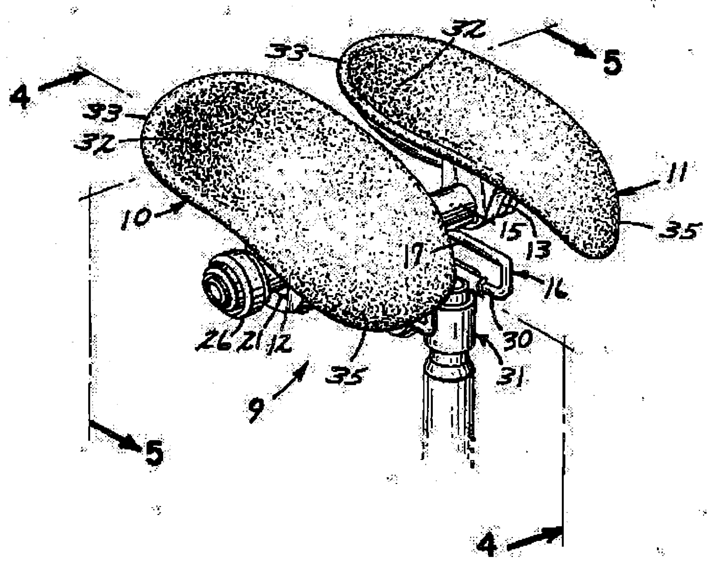

Figure 2.2: U.S. Patent No. 4,387,925. June 1983 [6].

A 1978 filing described a U-shaped member mounted transversely of the frame [8]. The support mechanism (shown in Figure 2.3) was a padded webbing. Though this may have alleviated the perineal discomfort, it introduced various other problems, such as ease of use, high pressure points, and poor cushioning.

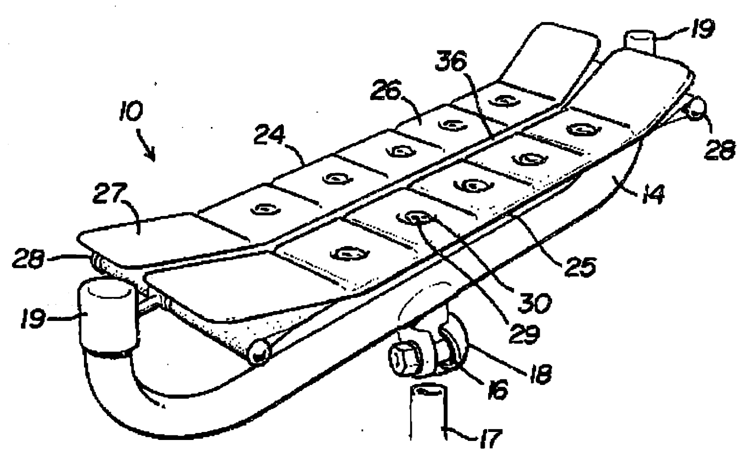

Figure 2.3: U.S. Patent No. 4,176,880. December 1979 [8].

Two patents resembled the intended design. One was a design patent from 1992 and had no functional basis (see Figure 2.4) [9]. Another, from 1988, had the intention of creating a more comfortable bicycle seat (see Figure 2.5) [10]. The difference in this patent and the intended prototype design was that the patented design included contours for the buttocks, whereas the prototype design did not. The new design allowed for more freedom by enabling the rider to easily shift positions during riding.

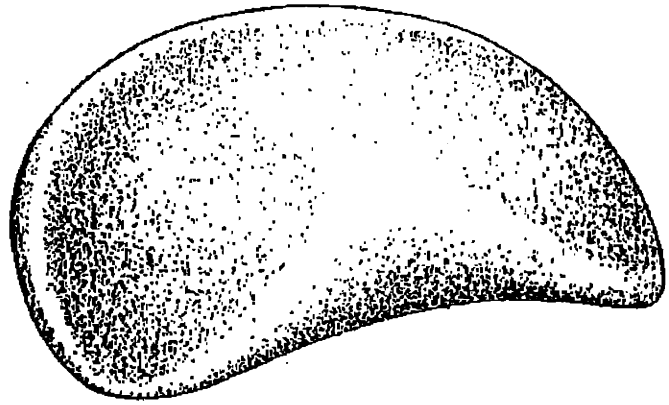

Figure 2.4: U.S. Patent No. D 326,782. June 1992 [9].

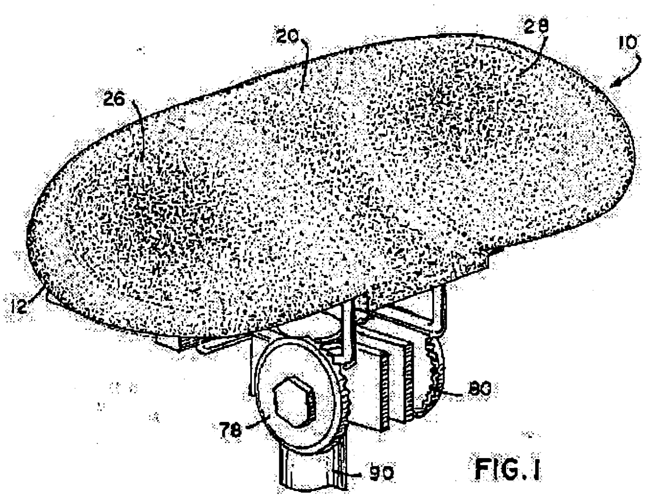

Figure 2.5: U.S. Patent No. 4,773,705. September 1988 [10].

2.2 Market Research

A market analysis extracted many useful data for the design of the new seat. Information was gathered on materials, manufacturing, and design of bicycle seats, as well as on designs intended to protect against male impotence.

Bicycle seats fall into two major classifications: performance saddles and cruiser saddles. Performance seats provided too many barriers to designing an ergonomically safe seat. Concerns about weight, width, and appearance kept racers tentative about new designs. The other issue was maintaining technological advances in the face of redesign, including variable density shells, composite materials, and titanium rails.

Cruiser seats are generally much larger and more basic, with emphasis on comfort instead of technology. Consequently, this was the market to pursue, despite the lower costs of the seats.

Seats ranged in price from \$13-\$90. Cruisers maintained the low end of this scale with a range of \$13 to \$35. Racing saddles varied from \$30 to \$90.

Seats in bicycle stores generally consisted of four parts: the rails connecting the seat to the post; the plastic shell; some form of padding; and a cover for the padding. Irrespective of seat type, the rails were of a uniform diameter and distance apart. Most often they were constructed of spring-grade steel or titanium. The plastic shell was generally 1/8" to 1/4" thick, was most often injection-molded, and was the structural support for the system. All seats included integrated forms for fixturing of the rails. The padding took on the form of an air cushion, foam, or a viscoelastic gel. The covering for the padding ranged in complexity from Lycra to a carbon-fiber reinforced material.

Bicycle store employees emphasized the importance of shell flexibility, citing that it was as important as good cushioning, and narrow seats, complaining that the noses of some seats were too wide for comfort.

Two general designs targeted the prevention male impotence in their products. The first, prevalent in many stores, consisted of a standard saddle shape with a hole in the location of the perineum (see Figure 2.6). The most common complaint regarding these seats was that riders tended to "bottom out" on the hard edges of the hole (in other words, the padding was insufficient in cushioning the stresses induced by the shell at that location).

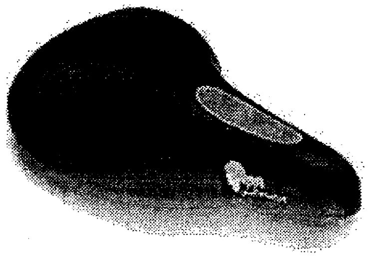

Figure 2.6: The Liberator Bicycle Seat [11].

Another design, the Super Saddle, from ABS Sports, similarly eliminated the area under the perineum (see Figure 2.7). By shortening the nose and creating two raised pads on which to sit, the rider's perineum was not in contact with the seat. Though this design achieved the goal of protecting the perineum, it did not address the issue of maintaining rider stability.

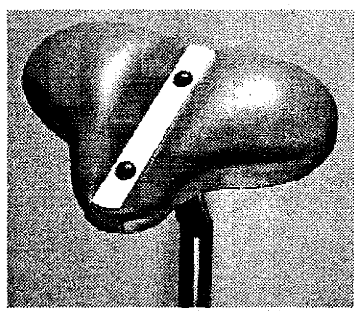

Figure 2.7: The Super Saddle Bicycle Seat [12].

Traditional stability is maintained by straddling the nose of the seat. In this design, the nose was removed and no additional provisions were made for restoring rider stability.

Chapter 3

Material Selection

3.1 Shell Material

The material used for forming the prototype of the shell would be a plastic because of its low weight and ease of use in manufacturing. The functional requirements of the plastic were threefold: high stiffness, high strength, and formability using vacuum forming. As the support structure for the entire bicycle seat - and thus for much of the rider's weight - the seat shell needed a high stiffness. A low stiffness would yield an unsafe riding condition. High material strength would ensure that failure did not occur; failure of the seat would inflict serious injury on any rider. That the material be capable of vacuum forming was a decision based on the prototyping design process (see Chapter 5).

The top three materials for prototyping the shell were: PVC (polyvinylchloride), ABS (acrylonitrile butadiene styrene), and Kydex (a commercial name for acrylic-modified PVC). Relevant material properties are given in Table 3.1.

Table 3.1: Material Properties of Different Thermoplastics [13]

Material	Density (kg/ m^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Relative Cost
ABS	1040	38	2.2	2.4
Kydex	1300	55	3.0	4.6
PVC	1400	50	3.0	1.0

Because of their superior thermoforming properties, ABS was used with the alpha-prototype, and Kydex was used with the beta-version. Kydex provided better mold details along with superior strength, weight, and stiffness; however, the PVC content of Kydex resulted in poor adhesion between the shell and fiberglass reinforcement. This added the step of bonding the two pieces together with epoxy. For the purposes of early prototypes, ABS - with its lower cost - is sufficient. For production runs, where fiberglass will not be used, Kydex is the preferred material, though this is only valid for designs utilizing vacuum forming to construct the shell.

3.2 Padding Material

The choice of padding material varied according to the market research. Various foams, viscoelastic gels, and air systems were used on the market; some seats even went without padding. For the sake of determining the functionality of the shell design, the best choice was a standard cushioning material, one that would provide additional comfort, but still allow determination of the seat's core functionality.

Given this constraint, any type of gel or fluid substance was impractical. Foams remained as the general category from which to choose. Based on the importance of providing firm support - to prevent the phenomenon of "bottoming out" - a firm polyethylene foam was used. Manufactured in slab stock, this was a cross-linked, closed-cell foam. The slab stock offered easy manufacturing and assembly. The closed-cell property ensured support and resiliency over the lifetime of the bicycle seat (refer to Table 3.2 for a comparison of material properties for different foam types).

Table 3.2: Material Properties of Different Foams [14]

Material	Cell Type	Density (lbs/ cu ft)	Compression (psi)*	Tensile Strength (psi)
Polyethylene	closed	2	12.7-15.0	55
Polyurethane	open	3.7	5.6	8
EVA	closed	2	5	50

*Compression given is for 50% deflection in Polyethylene; 25% deflection in Polyurethane, EVA.

Chapter 4

Seat Design

4.1 Geometry

The design was fairly basic in overall geometry. For a sense of scale and understanding, AutoCAD drawings are shown in Figure 4.1. The seat consisted of two axes, a major axis transverse to the frame of the bicycle and a minor axis along the frame axis. Together they outlined the shape of the seat. The seat had no nose, but instead a slight bowl shape to provide some stability. The rear was curved up to ensure placement along the minor axis while the front was curved down to prevent pinching of the legs. A picture of the seat is shown in Figure 4.2. This was the design of the beta-prototype (refer to Appendix A for a discussion of the alpha-prototype).

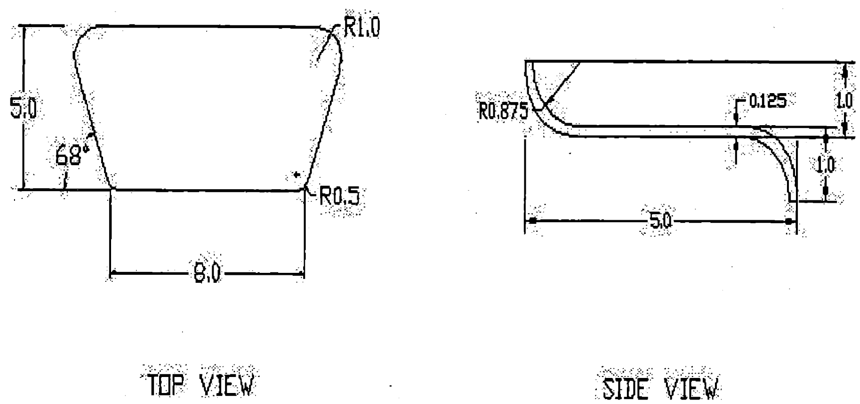

Figure 4.1: AutoCAD Drawings of the Prototype Seat.

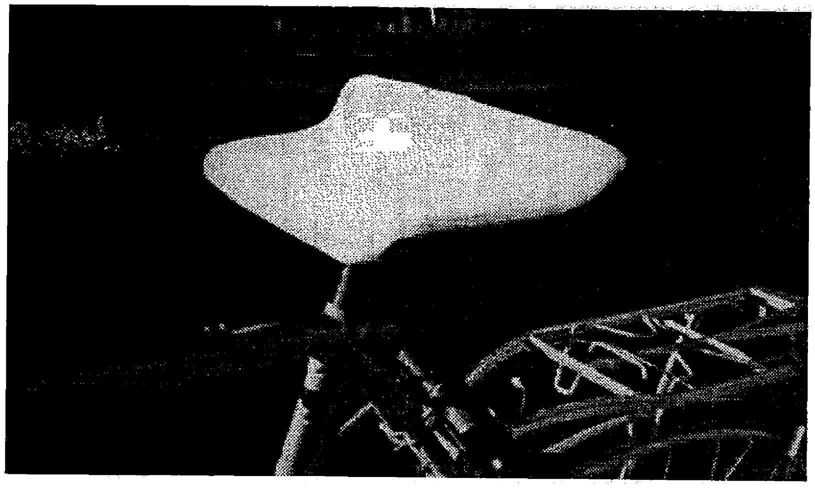

Figure 4.2: Photograph of Prototype Seat.

4.2 Closed-Form Load Analysis

To determine the functionality of the prototype, a load analysis was performed. The seat was modeled as a simply supported rectangular plate. A concentrated load was applied over a rectangular area in the center of the seat [15]. The area of the load concentration was approximately 6% of the total seat area. This modeled a worst case scenario of loading since the rider's weight was more evenly distributed than this and because the rails offered more support than simple pins. Maximum loads were calculated assuming yield as the failure condition.

This analysis was performed for Kydex and ABS with the geometry outlined in Chapter 3.1. The result for Kydex was a maximum load of 198 lbs., while the result for ABS was 137 lbs. This first-order analysis offered sufficient confidence to proceed with prototype development, though it suggested reinforcement of the plastic was absolutely necessary.

4.3 Finite Element Analysis

Using the ABAQUS finite element package, a 240 element model of the seat was constructed to determine the maximum load capacity of the seat. The model was pinned at

These two materials supplied enough stiffness to minimize deflection and enough strength to easily support a standard-sized rider. The analysis reinforced the choice of 1/8" ABS and Kydex as the prototype materials. It also supported their use without reinforcement, which would benefit large-scale production, if that became necessary.

Chapter 5

Prototyping Process

5.1 Shell Construction

The key to manufacturing during this project was to achieve the most accurate and robust product in a quick and easy method. For the shell this primarily involved vacuum forming. Vacuum forming - or thermoforming as it is sometimes called - is a simple, quick and cost-efficient manufacturing process. It involves heating a thermoplastic sheet, bringing a mold into contact with the softened sheet, and applying a vacuum to draw the sheet over the mold.

A high-density, rigid polyurethane foam was used for constructing the mold. The ease of machining this material made it more attractive than wood or fiberboard. This foam was able to withstand the heat generated by the thermoforming process, but was much more expensive than other potential materials. Upon design, the foam slab was rough cut on a bandsaw. A belt sander was used to smooth edges, add features, and create a relief angle for the vacuum forming process. Hand sanding finished the mold-making features.

One-eighth inch thick ABS and Kydex sheets were used as forming materials. Upon completion of the vacuum-forming process, the mold was cut out; this would be the final shape of the seat.

5.2 Reinforcement and Rail Attachment

In order to create a functioning bicycle seat from this shell, two more steps remained: shell reinforcement for extra safety and rail attachment.

Both these steps were completed with the same process. Fiberglass matting saturated in epoxy resin (with MEKP hardener) reinforced the shell and attached the rails to the seat.

The excess was removed using a bandsaw, belt sander, rasp, and file. Advantages to this process included relatively quick processing time, a flexible substrate for the shell, good strength, and freedom in rail placement. The major disadvantages were poor finish, toxicity of the resin, and highly dangerous fiberglass dust discharged during machining.

The steel rails were obtained from other bicycle seats, though they could have been purchased from an OEM rail supplier. They were too long for the seats produced during this project. Consequently, they were machined down to size using a hand-held rotary cutter.

5.3 Integration and Testing

To increase the level of comfort, a 1/4" closed-cell polyethylene foam was cut to fit the shape of the seat. A quick-drying epoxy affixed it to the shell. The rails were attached to the bicycle post, after which seat pitch and height were adjusted for the individual rider.

Refer to Figure 5.1 for an overall view and description of this prototyping process.

After complete integration, the rider was allowed to ride the seat over an extended period of time. This enabled him to undergo a variety of riding conditions and to thus provide more comprehensive commentary on seat performance.

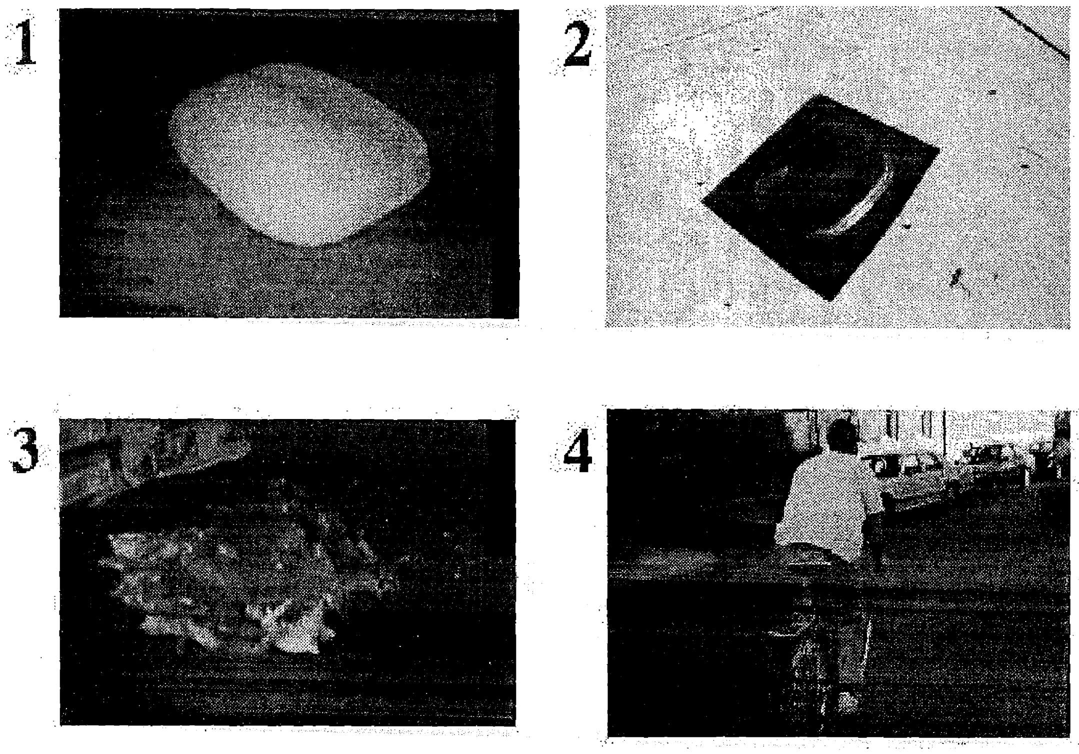

Figure 5.1: The Prototyping Process. 1. Mold formation, 2. Vacuum forming, 3. Fiberglass reinforcement and rail attachment, 4. Integration and testing.

Chapter 6

Conclusions and Recommendations

This seat provided good insight into the key design issues of bicycle seat design. Comfort and stability were obvious concerns; however, the ability to generate power; to easily "stand and sprint"; and to lean back were subtle concerns that were not initially addressed by interviewed cyclists.

This seat compared well to a standard saddle. It redirected the loads away from the perineum, as was the intention of the design. Stability was not as good as for the standard seat, though the riders acknowledged it may only have been a matter of their unfamiliarity with the new seat. Power attainability in this design was on par with the standard seat, and was much improved over the alpha-prototype. The short minor axis, along with a non-enclosed design, made standing and sprinting easy. Leaning back was actually more comfortable than with the standard seat. This was likely due to the support offered by the back edge.

There were only two evident shortcomings in the design. First, stability may have been an issue. It was not that the bicycle felt unstable with the new seat, but was more unstable than usual. One example given was that the rider could not pedal without using his hands to maintain control of the bicycle. This issue could have been addressed by having a more enclosed design. The support provided by the outside edges would likely be sufficient to maintain bicycle stability.

The second issue with the design was its similarity to patents already produced, namely the two patents shown in Figures 2.4 and 2.5. The design patent, though similar, is only a design patent, defined by the U.S. Patent and Trademark Office as follows:

> A design consists of the visual ornamental characteristics embodied in, or applied to, an article of manufacture. A design patent protects only the appearance of the article and not its structural or utilitarian features [16].

Thus the functionality of the prototype could potentially be patented barring other similar utility patents. The only other similar utility patent found involved contours for the buttocks. The design presented here has a similar shape but lacks the contours. This difference is essential in that the lack of contours allows: the rider to shift during riding and one seat to easily conform to multiple body types.

This design was a success, in terms of avoiding compression of the perineum while maintaining the positive attributes of traditional seats. Whether this constitutes a novel design is an issue to discuss with patent attorneys. Though the concept is sound, it is recommended that at least one more prototype be produced before looking into patenting options.

Appendix A

Design of Alpha-Prototype

A.1 Design

The alpha-prototype design was similar to the beta-prototype in general form. It had the same major and minor axes, along with a bowl shape. It was much narrower (a short major axis) and longer (a long minor axis). Its maximum width was 9" and its length was 6.75". While it did have a curved back edge, it had no such edge on the front. A photograph of this design are given in Figure A.1.

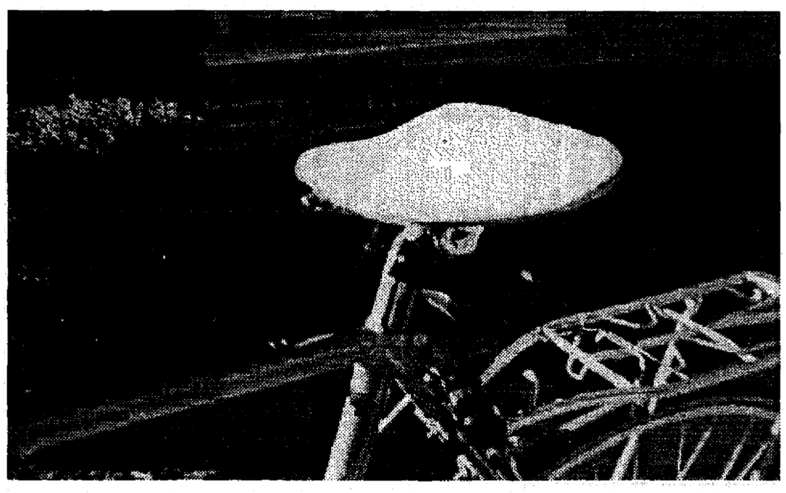

Figure A.1: Photograph of Alpha-Prototype.

A.2 Issues

Problems encountered with this first design were many. Stability was lacking in comparison to the standard seat. The front edge - since there was no relief angle on the front of the seat - tended to dig into the rider's legs. Standing and sprinting was made difficult because the length of the seat created interference with the legs during this process. Additionally, this problem made it very difficult generate power.

The beta-prototype adequately addressed all of these issues with the exception of stability. The issue of stability remains unclear pending more extensive testing of the prototypes.

References

[1] Henry Gray. *Anatomy of the Human Body.* Philadelphia: Lea and Febiger, 1973. 435.

[2] Joe Kita. "Men Riding Bicycles, the Unseen Danger." *Bicycling*, August 1997.

[3] Kita.

[4] "Dissection: Pelvis and Perineum." *Emory University.* Online. Internet. 10 Dec 98.

[5] Joel A. Barker and Jeffery Birch. *U.S. Patent 4,387,925.* IBM Intellectual Property Network, 14 Jun 83. Online. Internet. 1 Dec 98.

[6] Josef Bergmeister. *U.S. Patent 5,725,274.* IBM Intellectual Property Network, 10 Mar 98. Online. Internet. 1 Dec 98.

[7] John L. Marchello. *U.S. Patent 4,176,880.* IBM Intellectual Property Network, 4 Dec 79. Online. Internet. 1 Dec 98.

[8] Nicholas J. Scarcella. *U.S. Patent Des. 326,782.* IBM Intellectual Property Network, 9 Jun 92. Online. Internet. 1 Dec 98.

[9] Joseph M. Terranova. *U.S. Patent 4,773,705.* IBM Intellectual Property Network, 27 Sep 98. Online. Internet. 1 Dec 98.

[10] David L. Jacobs. *U.S. Patent 4,098,537.* IBM Intellectual Property Network, 4 Jul 78. Online. Internet. 1 Dec 98.

[11] "The Liberator Bicycle Seat." *Business Week Online Archives*, 1 Sep 97. Online. Internet. 10 Dec 98.

[12] "Bicycle Seats by ABS Sports - Super Saddle and Accessories." *ABS Sports, Inc.* Online, Internet. 1 Dec 98.

[13] R.J. Crawford. *Plastics Engineering*. Oxford: Butterworth-Heinemann, 1998. 22.

[14] Daniel Klempner and Kurt C. Frisch. *Handbook of Polymeric Foams and Foam Technology.* Munich: Hanser Publishers, 1991. 69-70, 188, 213.

[15] Raymond J. Roark and Warren C. Young. *Formulas for Stress and Strain.* New York: McGraw Hill, Inc., 1975. 386-387.

[16] "A Guide to Filing a Design Patent Application." *U.S. Patent and Trademark Office Home Page*. Online. Internet. 1 Dec 98.