

The Prone Position Bicycle

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Abstract -- In this paper we present a new design for a prone position triathlon bicycle frame that is light weight, ergonomically efficient, and requires minimal use of muscles that are used in swimming and running. The main idea is to place the cyclist in an aerodynamic position that is comfortable, supported by the human skeleton, and efficient. The design consists of an aero bar style handlebar, an adjustable noseless seat, crank, chainless drive and gearing system and skeletal support from a hip sling, and armrests

Index Terms -- aero bar, crank, sling, prone, bicycle, hip sling, noseless bicycle seat.

I. INTRODUCTION

THE triathlon cycling association requires modification of the current bicycle design used in competitions in order to minimize strain on the athlete's muscles, leading to susceptibility to injury. The final design must take into consideration the overall weight of the bicycle, the materials used, and frame dimensions which will produce a safe, sturdy lightweight design. To ensure cyclist comfort, bicycle components must be ergonomically efficient. In order to reduce wind resistance, the bicycle geometry and position of the cyclist should be aerodynamic. The design is constrained by the visibility of the cyclist because this compromises safety, the tubular elements of the bicycle must be round, oval, flattened, or tear drop shape in cross section as outlined in the Triathlon Cycling Association rules [1]. For the purpose of this design, it is assumed that non-traditional style bicycles are permitted in Triathlon Cycling Association competitions.

Currently there are countless traditional frame triathlon bicycle designs that are used in competition. These designs differ by using different handlebar systems, tubing shapes, gear ratios, and seat designs in order to attempt to maximize aerodynamics, power output per work input (pedaling efficiency), and comfort. Prone and recumbent style bicycles are not typically designed for use in a triathlon because the competition rules have previously precluded such designs. The proposed design is a prone position frame, distinguished from other bicycles by its ability to position the cyclist at small angle relative to the ground which increases aerodynamic efficiency. The position also minimizes the learning curve for triathlon athletes because it is not radically different from the traditional triathlon bicycle as is the recumbent bicycle. The design also removes the use of a chain to minimize maintenance, and increase efficiency and safety.

Preliminary research, body position testing, and comparison methods were used to determine the bicycle frame configuration that best suits the application. Critical components of the

bicycle were then analyzed separately using loading calculations, body position testing, sensitivity analysis, and literature comparisons to determine the optimal configuration and efficiency of each component.

A milestone will be delivered as a product to accompany the final design report. The milestone will consist of an assembled 3D model of the frame and other bicycle components using I-DEAS 11.

II. OVERALL DESIGN

The conceptual design is a prone bicycle placing the cyclist in a forward leaning position. The major design components of the bicycle that were considered were the handlebars, seat, crank, drive and gearing system, and hip support. Components that were not considered were tires and pedals as they provide little room for optimization.

III. DETAILED DESIGN

A. Handlebars

The handlebar on the proposed design is a single stem aero bar that separates into two handles at the end where the cyclist's hands are placed. A single stem aero bar was designed instead of a double stem in order to maintain the lightweight criteria of the Association. The material chosen to construct the bar was carbon fiber because the material is light weight and has the ability to suppress vibrations.

The aero bar protrudes horizontally at the front of the bicycle from the head tube. At the base of the aero bar, the cyclist's arms are supported by armrests which can be adjusted along the horizontal plane perpendicular to the cyclist's trunk to alter the distance between the elbows for different sized individuals.

Bar end shifters and brakes were chosen in order to allow the cyclist to maintain the very aerodynamic aero position at all times (see Figure 1).

B. Bicycle Seat

The seat consists of two semi-circular pads that can adjust to the sit bones of the cyclist via a rack and pinion system. The seats are padded using FlexGel™ created by the CrossGel Company (see Figure 1).

C. Crank

The crank in this design has independently moving crank arms which are designed by Rotor™. This crank system eliminates the dead spot, the position where the crank arms are vertical and all the cyclist's leg force is applied along the axis

of the crank instead of being applied as torque, allowing for torque to be consistently applied to the crank (see Figure 1).

D. Drive and Gearing Systems

The gearing system uses an enclosed hub gear box located in the center of the rear tire covering the axle, replacing the traditional derailleur system which is not compatible with a drive shaft system.

E. Hip Support

The hip is supported by a nylon sling, which is held in place by specially designed clips. The sling supports the lower back of the cyclist, and maintains the rider angle at 44°. The Hip Support connects to the top tube of the bicycle and is fully adjustable.

IV. DISCUSSION

The design of the frame involved consideration of anthropometrics, aerodynamics and biomechanics combined with standard frame design. The angle of the cyclist's trunk was determined from subjects effective frontal area versus neck comfort testing at three incremental angles between 0 and 90°. A rating of out 10 was chosen by each subject. 0° was considered horizontal and 90° perpendicular to the ground. Three angles were thought to be sufficient for this design. See Figure 2 for sample of the results from one subject. A 44° cyclist trunk angle was found to be the optimal body position regarding aerodynamics and comfort.

Examining Figure 1, the rear segment of the top tube is at an angle of 44° from the horizontal. The head tube and forks make an angle of 72° from the horizontal. This is the standard head tube angle which provides optimal steering sensitivity during racing.

All of the forks provide appropriate tire width and radial clearance. Observing the front view in Figure 1, the width clearance is 130 mm and the height is 360 mm, accommodating a standard 750c bicycle tire. The tubing used is elliptical with a diameter of 50mm/32mm. The long axis is oriented longitudinally for optimal stress absorption. Elliptical tubing oriented in this manner will create a larger moment of inertia, I , which will decrease stress in the tubing according to the formula $\sigma = Mc/I$. The tubing thickness utilized is 1.1 mm which was chosen through the optimization of multiple worst cased scenario loading analyses. The geometry of the middle of the frame was constructed as a standard double diamond frame bicycle without a tube connecting the top tube to the bottom tube. Since the cyclist's load is distributed along the entire horizontal axis of the bike at the seat, hip and shoulder supports and the aero bars, its removal is justified.

Upon researching numerous bicycle configurations and frame designs, it was determined that the optimization of a bicycle is dependent on numerous factors. If any aspect of the bicycle is altered, other components are subsequently affected. Therefore a holistic approach must be taken when designing components. Also, it was determined that changing the cyclist position had a minimal affect on the muscles used when cycling which are similar to the muscles used when swimming and running. The pedaling motion is always the same and

hence always uses the same muscles. A completely different drive mechanism, such as a hand pedaled bicycle, would be required in order to utilize different muscles. This however is counter productive as arm muscles are used extensively when swimming. It is recommended that clinical, laboratory, and field testing be conducted in order to provide further insight into the performance capabilities, cyclist comfort after extended use, and power efficiency of a prone position bicycle since few studies have previously been conducted.

ACKNOWLEDGMENT

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REFERENCES

- [1] Triathlon Canada. "Competition Rules". May 2006. <<http://www.triathloncanada.com/en/committees/technical/TriathlonCanadaCompetitionRules.pdf>> (01 February 2007).

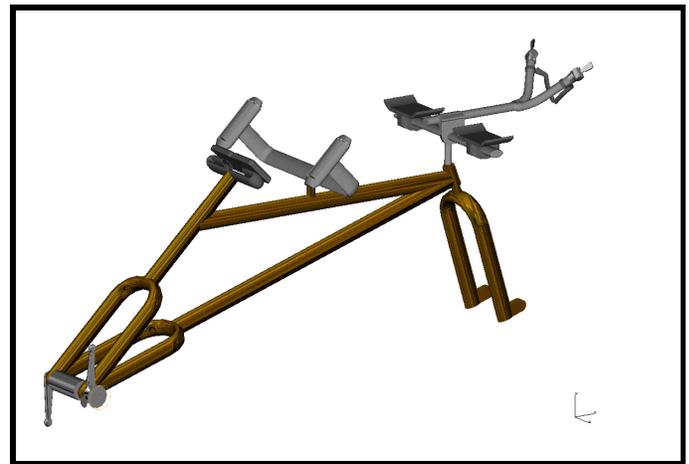


Figure 1: Prone Position Bicycle Frame Design

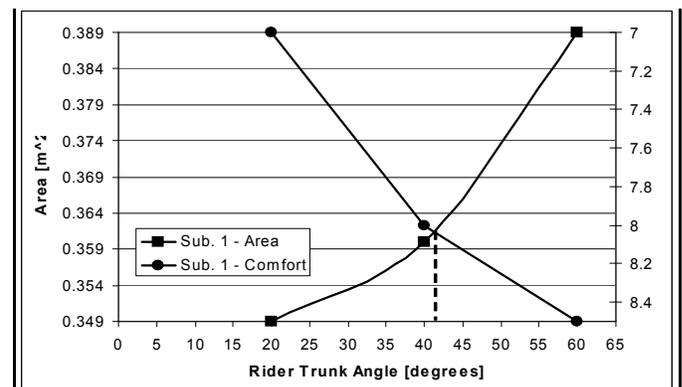


Figure 2: Subject 1 - Effective Frontal Area and Neck Comfort versus Cyclist Trunk Angle