Review on A Comparative Analysis of Different Cross-Sectional Bicycle Frames

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Abstract - To fulfil the research goal, a literature evaluation of existing research is conducted in order to gather additional information, techniques, and to serve as a guideline for current study. The contents of the review comprise the most recent research conducted by various researchers for mechanical and property investigation of bicycle frames. A range of rider weights has been examined for the analysis when biking on level terrain conditions. The goal of this review is to assess the impact of important geometric elements such as frame cross section (profile) on mass, strength, stress, and strain characteristics, and to compare these varied cross sections to an optimized solution for a standard diamond "safety" framed bicycle on the basis of previous study.

Keywords: bicycle frame, safety, mass, strength, stress, and strain characteristics etc.

I. INTRODUCTION

Bicycles and human-controlled machines in a variety of configurations are now the staple of individual transportation in the twentieth century, in the supposed third universe of developing and emerging nations, where four-fifths of our planet's six billion people live. Developing countries account for 80 percent or more of the current global bicycle armada. Surge hour in a major Indian metropolis, with thousands of bikes travelling in continuous streams - many transporting entire families or alarming burdens - is a spectacular sight. A substantial number of these bikes are mechanically minimum, not precisely the same as those built around 1910, for ease of manufacture and ongoing maintenance. Simple, well-made workhorse machines transport the vast majority of the world's kin and light goods. The bike witnessed even more remarkable technological improvement in the twentieth century in industrialized countries, but its public image was modified by two world wars and considerably influenced by the rise of the vehicle. General bike manufacturing was halted during the 1914–18 and 1939–45 wars to create war materials, but in a period when petroleum and mass transit were scarce, bikes proved more valuable than at any other time in recent memory.

1.1 Bicycle Frames

Bike outlines were often works in many types of plans and geometry. It is due to the fact that the bike was operated by the number of clients and according to their preferences. The cylinder size of the edge is also affected by the breadth and thickness of the divider. Similarly, as seen in Figure: 1.1, the bicycle outline has numerous substructures.

The image's head tube edge represents the distance between the head tube and the ground. The head tube edge can be balanced by riding technique and tracks; the more extreme the head point, the less effort is required to steer it, implying that the bicycle can be controlled more quickly. The good-for-nothing head point, on the other hand, will take more effort to manage, and the bicycle will steer you more slowly. For the purpose of examining the head tube plot for various bikes as a model 71-72 degrees for touring cycles, 73-74 degrees for road bikes, and 72-73 degrees for cyclocross or CX bikes.

When the fork rake is expanded, the guiding is faster; nevertheless, when the fork rake is reduced, the guiding is slower. It is obvious that the head tube point and the fork rake are used to estimate the directing speed. To enhance their wheelbase length, allow more toe leeway, and expand the forks comfort, touring bikes feature higher rake than street and cyclocross bikes. The wheelbase length is the distance between the front tire's focal point and the back tire's focal point.

The chain-stay length is one of the most important measurements on an edge bicycle. A longer chain stay length is appealing because it expands the wheelbase (making the bicycle more stable) and provides ample heel freedom from the panniers. Impact point freedom is especially important for riders with large feet. The back focus is more properly called as the chain-stay. This is the equal estimation between the back haggle focal point and the Bottom Bracket focal point (BB). Short back finishes aren't exactly something to be thankful for, given that they help a bicycle circle out more easily on journeys and, contrary to popular belief, don't resist cornering. It's a perplexing topic, but the chainstay length, together with the front focus, determines where you are on the bicycle (focal, further back, further forward). There is no hard and fast rule here, although a longer wheelbase can help a bicycle feel more stable when slipping and also keep the front end down when climbing. On most 29ers, 450mm is the standard, whereas on 650b bikes, 435mm is the standard. The top cylinder is also the primary geometry in the bike's design. Top Tube length (TT) and Effective Top Tube length (ETT) are two classifications for top cylinders (ETT).

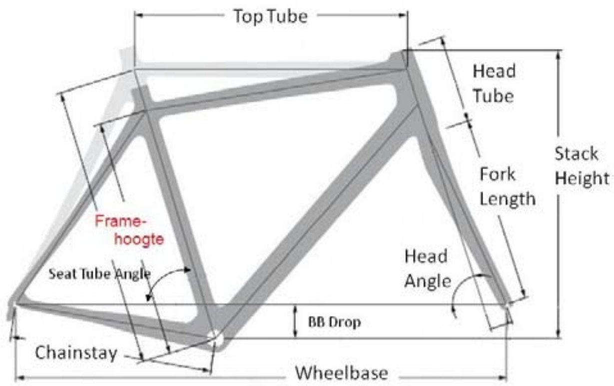

Figure 1.1 Frame for a Bicycle

1.2 Cycles of Various Types

Sport bikes with drop handlebars and derailleur gears and standard roadsters with level handlebars and center gearing were the only two types of motorcycles available. Game bikes are divided into two groups: lightweight races with no frills and more solidly built tourers with pannier racks and mudguards. Roadsters were plentiful, and most featured a chainguard, mudguards, a carrier rack, and possibly implied lighting and a prop stand. There were more sub-types inside each categorization, except that just looking at a bicycle was enough to understand its type and purpose. Today, there are a growing number of broad classes and sub-types, and refinements are usually lost in translation; an off-road bicycle designed and prepared for visiting, for example, can be identical to a street visiting bicycle in all but the tiniest details. A nice lightweight roadster city bicycle with centre point riggings might be able to show its heels to a game bicycle or two (different things being equal). Human-fueled vehicles (IHPVs) are a catch-all designation that encompasses a wide range of designs, from smooth, fast streamliners to large four-wheel quadricycles designed to transport freight or passengers.

1.2.1 Commuter and City Bikes

Life begins to become semantically unstable at this point, because the distinctions between a worker bicycle, a town bicycle, and a city bicycle are very fine, and manufacturers quickly merge them in their inventory. The core concept is a lightweight bicycle with a cromo or aluminium frame and full-size 26-inch or 700C composite wheels, as well as a semi-sleeping cushion seat and level handlebars for a completely upright riding position.

These bikes typically weigh 11 to 13 kg and have a delightfully energetic execution. They can be used for day trips and light visiting (11 to 15.8 km), as well as standard driving and neighbourhood utilization.

Commuter Bike

Derailleur gears, part-chainguard, 700C wheels with genuinely light 1.125-inch-wide tyres, calliper V or cantilever brakes, mudguards, transporter rack, and maybe implicit lighting are all included. The preference here is for the construction of a swift street sports bicycle, which is necessary for routine journeys of some distance, such as express 7 to 8 kilometres or more. A good model should weigh no more than 12 kg. See also the section below on Cross or Hybrid Bikes.

A few manufacturers have attempted to create top-of-the-line worker models with carbon-fibre or other cutting-edge lightweight edges and light wheels for loads of 15 kg or less. Such machines are a real delight, but they're expensive, and there's not enough demand for them to be available all the time - perhaps a chicken-and-egg problem.

Figure 1.2 Commuter

City Bike

As with the worker bicycle above, but with 26-inch haggles or 1.75-inch broad tyres - a seemingly little but crucial difference. The city bicycle is clearly derived from the extreme, go-anywhere trail blazing bicycle, and can adapt all the more capably to the spiky surfaces and extensive pot-openings of harsh metropolitan roads, where the worker bicycle is related to the swift street bicycle. A city bicycle requires strong, sturdy maintenance. On a dreary night nearby, when the weather has suddenly turned horrible and the roadway has devolved into a perilous network of roadworks and potholes, with various automobiles breathing down your neck, an unwavering and solid, certainty rousing bicycle is a welcome friend.

1.3 The Bicycle's Components

A bicycle is made up of the following components:

- Frame.
- Suspension (optional).
- Wheels (hubs, spokes, rims, tyres).

• Transmission (pedals, chain set, gear changes, chain, freewheel).

Raleigh, Trek, Giant, Fisher, Cannondale, Condor, and other manufacturers' brands are on the frame, while the rest of the components are known as the specification. Some bicycle companies create their own frames, while others purchase them from outside vendors, and still others do both. Frames are made by a variety of companies, ranging from lone builders to large factories, and range in quality from crude to ultra-fine. Specialist companies provide components in a variety of designs and quality levels. Some companies make single components, such as rims or brakes, while others make group sets that include all of the parts of a comprehensive specification.

A bike's weight is almost everything, and the frame is the most important aspect in this department. For the same or even greater strength, the better the frame, the smaller the weight. Two attributes are related to this. One is resilience, twang, or flex, which improves the springiness and life of the bike. The dynamic difference between heavy, unyielding cast iron and light, flexible tempered steel is inherent in the materials from which the bike is created. The second characteristic is stiffness, which is determined by materials, shape, and weight. In a word, a frame with too little stiffness will bend and twist excessively, whereas a frame with too much stiffness will lack the give needed for comfort. Don't mix up stiffness and strength: a frame constructed of very heavy, weak tubing can be stiff, while a frame composed of very light, stiff tubing can be weak. Essentially, frame design is the process of achieving the best possible balance of strength, stiffness, and weight.

II. LITERATURE REVIEW

2.1 Kailas Khutal, Kathiresan G, Ashok Kb, Bade Simhachalam, Davidson Jebaseelan (2020)

Two simulation approaches were investigated in this study: linear static analysis with test rig boundary conditions and fatigue with harmonic analysis. The results of both approaches were compared to those of a laboratory test rig. The stress amplitude computed using harmonic fatigue analysis was one-third of the stress amplitude measured on the test rig (experimental). Furthermore, the stresses computed using FE static analysis were consistent with the results of the experiments. As a result, prior to prototype testing utilizing a "rapid vibration test rig" a fatigue employing harmonic stress calculations is recommended for reliability. These findings should assist the bicycle industry benchmark its design and testing, as the business is predicted to grow multi-fold and its design validation criteria could incorporate more limits.

2.2 G. Hernandez–Melgarejo, D.A. Flores–Hernandez, A. Luviano–Juárez, L.A. Castaneda, I. Chairez, Di Gennaro (2020)

The goal of this research is to create and test a virtual reality bicycle system using a functionally oriented mechatronic design methodology. To provide consumers with immersive experiences, the development of virtual reality technologies with haptic systems necessitates a proper integration of the related disciplines. The proposed design method establishes a formal method for assembling the subsystems in the mechatronic device. For the design process, the developed system is divided into a Virtual Reality System (VRS) and a Physical System (PS). In the former, an Avatar is animated using a simple kinematic bicycle model in an interactive virtual environment. An adapted mountain bicycle with haptic feedback mechanisms to communicate with the user and provide the appropriate inputs for the bicycle model is included in the latter. Both systems are linked by a control behavior system that operates in two modes: virtual tours with input from a stereoscopic display system, acoustic cues, and haptic mechanisms, and virtual tours with no feedback.

A multibody simulation verifies the physical system's consistency and integration. Furthermore, a series of experimental results demonstrate the performance of instrumentation elements, control techniques, and feedback mechanisms in providing the user with an immersive virtual environment experience. A quick poll was conducted to gauge user perceptions of the virtual bicycle tours and provide suggestions for future enhancements. The many developed modules and sub-systems enable for the modification and enhancement of the VRS without requiring major changes to the PS, or for the enhancement of the physical platform without impacting the virtual environment's operation.

2.3 Joseph Kurebwaa and Tawanda Mushiriba (2019)

The design and simulation of an integrated steering system for SUVs, with a focus on Toyota, is the subject of this article. In the spirit of Kaizen, the article investigates ways to improve SUV handling characteristics while conserving energy. A thorough examination of the existing systems on the Toyota Fortuner AN160, which served as the research's benchmark vehicle, as well as systems on cars with similar steering and suspension geometry, was conducted. Cheetah dynamics (biomimicry) were converted to the necessary solution as four-wheel steering, inspired by the amazing stability of cheetahs in high-speed movements (4WS). The first design process involved consulting with Toyota Zimbabwe to produce concepts and detailed designs for the rear-wheel steering axle geometry and actuation. Innovative system combining Toyota's Variable Gear Ratio Steering (VGRS) and Electric Power Steering (EPS) on a single electric motor has also been envisaged, and thorough design for this system will be carried out as the second design phase, with extensive experimentation. Static simulations for design correction and weight optimization confirmed the theoretical design of the axle assembly elements. Finally, financial, sustainability, and impact analyses were performed on the design. Improved vehicle handling, long-term steering system improvement, and better compliance with the next significant stage in automobile evolution – autonomous driving – are three key outcomes of this work.

2.4 Devaiah , Rajesh Purohitb ,R. S. Ranac and Vishal Parashar (2018)

Stress analysis is a key part of product optimization, and when combined with Finite Element Methods, it makes solving complex structures much faster. The stress analysis of a bicycle frame was performed using ANSYS Workbench 14.5 with varied boundary conditions and the findings were compared to theoretical results in this work. All of the stresses were determined to be considerably below the material's yield stress, putting them in the safe zone. FEM (Finite Element Methods or Analysis) is a numerical approach for obtaining approximate solutions to differential equation boundary value issues. It further divides the domain into smaller sections where the finite element's stiffness matrix can be obtained. The global or assemblage of the stiffness matrices must fulfil the load-displacement equation (F=k*d) during assembly. In commercial software, the K matrix is inversed to yield displacements, stresses, and strains, as well as the relationships between them. Interpreting FEA findings is critical, and intuition is also necessary. As a result, a model must be empirically checked or verified against previous research to ensure that the process being used is error-free. Steel (E=205 GPa ,= 0.29) was chosen as the material for preliminary analysis in this study. Various boundary constraints are applied to the frame. The goal of this paper is to determine if the theoretical and FEA results are in close agreement. CATIA V5 was used to model the bicycle frame. The FE study was carried out using Ansys Workbench 14.5 software. A structural static analysis was carried out. Mesh optimization was not conducted, although it is advised that it be done before any analysis.

2.5 Bert Blocken, Thijs van Druenen, Yasin Toparlar, Fabio Malizia , Paul Mannion, Thomas Andrianne, (2018)

Bert Blocken (2018) studies the drag discounts in pelotons of 121 cyclists in a scientific manner. A cycling peloton is a large group of riders who work together to reduce aerodynamic drag and power consumption. Previous study on small groups of in-line drafting cyclists found discounts of up to 50% on the drag of a remoted rider travelling at the same speed, and those Figure have been applied to pelotons. Large drag discounts can be expected inside a tightly packed peloton with a handful of rows of riders providing a safe refuge. The RANS equations and the Transition SST-okay-model are used to perform high-resolution CFD simulations. The length of a cyclist's wall-adjacent cell is 20 meters, and the total number of cells in a peloton is over 3 billion. The simulations are put to the test in four wind tunnels, one of which has a peloton of 121 fashions. The results show that as compared to a remoted rider, the drag of all cyclists in the peloton lowers. It drops to 5%–10% of that of a remoted rider near the back of the pack. This translates to "equivalent riding speed" of 4.5 to 3.2% slower than the peloton's average speed. These findings could be utilized to improve cycling strategies.

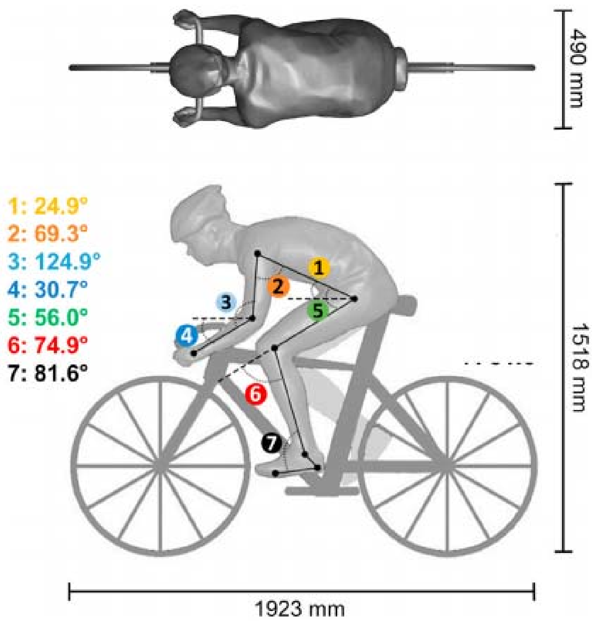

Figure 2.1 Cyclist model geometry in dropped position with definition and values of (1) sagittal torso angle; (2) shoulder angle; (3) elbow angle; (4) forearm angle; (5) hip angle; (6) knee angle; (7) ankle angle. (Reported on Bert Blocken et. al. 2018)

2.6 Sukmaji Indro Cahyono, Miftahul Anwar, Kuncoro Diharjo, Teguh Triyono, Abdul Hapid and Sunarto Kaleg, (2017)

A simulation Finite Element Analysis (FEA) model of electric trike frames is presented in this work. The electric trike frame is based on a regular bicycle frame with modifications on the back side to accommodate the battery pack and passenger loads. For easy maintenance, the electric motor is operated to put in the front wheel. The frame is made of round steel tubes on the front side and square steel tubes on the back side to ensure optimal passenger safety and ease of assembly.

An appropriate model based on steel tube profile has been investigated using FEA simulation. Steel tubes with circular and spheroid profiles are used. 1.65mm thickness, front diameters of (1, 12 and 12) inches, and square steel tube in the rear, 2 mm thickness, 30x30, 40x40, and 50x50 mm size. The electric bicycle frame's support tube is identical to that of a National Standard Road bicycle (SNI). For optimizing iteration duration and accuracy, this simulation is validated using the experiment method and the adaptation approach. The simulation's outcome is a safety factor. The important area in joining tube beneath driver of the frame structure is revealed by Von misses stress distribution from simulation results. The spheroid tube achieved a higher safety factor than the round tube, and it performed better under vertical stress. The best variable is the variable 3 spheroid tube, which has a diagonal size of 56.6x40 mm and a thickness of 1.65 mm. It can carry a maximum of 700 kilograms of passengers. It could be a suggestion to alter the electric bicycle's frame in the future.

2.7 Derek Covilla, Philippe Allardb, Jean-Marc Drouetb, Nicholas Emersonc, (2016)

The use of a finite element model to simulate the behavior of typical steel bicycle frames under a variety of measured load scenarios is described in this work. These load instances contain loads transferred at critical regions such as the dropouts and hub, the bottom bracket and drive, the headset and handlebars, and the seat post and saddle, which have been measured both in the lab and in the field. Static representations of dynamic bump situations that occur irregularly, as well as those that occur continually or routinely, such as those created at the drive and handlebars during climbing or cruising, are among the load scenarios examined. The resulting stresses within the bicycle are analyzed in relation to frame performance in terms of static and fatigue strengths, as well as compared to analogous load instances in the literature. To comprehend the implications of design on safety, more research is needed to understand the influence of tube profiles on frame strength and to analyses the modes of failure for various bicycle designs and materials used under ordinary and excessive usage.

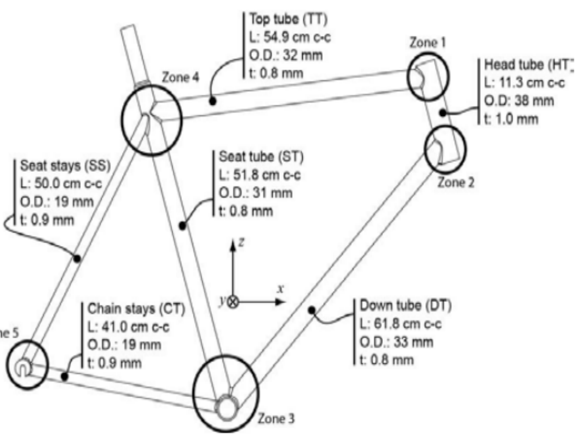

Figure 2.2 Details of the frame/tube geometry used in this study's road bicycle frame

2.8 Derek Covill, Alex Blayden, Daniel Coren, Steven Begg (2015)

This work uses beam elements with changing tube profiles to create a parametric Finite Element model of road bicycle frames. To investigate the effect of tube profiles on the lateral stiffness and vertical compliance of existing frame geometries, a variety of existing frame geometries were subjected to varied in plane and out of plane loading circumstances. This was a follow-up to previous research that looked at the effect of overall frame geometries (tube lengths and angles) on the stiffness of frames. Parameters were utilized to establish specifications for circular tube profile forms, variable wall thicknesses associated with butted tubes, for a subset of frame sizes (with seat tube lengths ranging from 490-630mm). Only steel tubing was used in this study in order to isolate and focus on the effect of tube profile geometries on the stiffness characteristics of the frames for a single material. More work is needed to validate this model using a frame stiffness jig, as well as to define the influence of material choice on stiffness and strength characteristics for steel, aluminum, and titanium frames using commercially available tube sets and their stated stiffness values.

2.9 Derek Covilla, Steven Begga, Eddy Eltona, Mark Milnea, Richard Morrisa, Tim Katz, (2014)

A beam element model was used to depict a basic road bicycle frame in this work. The model simulates two typical loading situations to determine the vertical compliance and lateral stiffness of 82 existing bicycle frames from the bicycle geometry project and compares these properties to an optimum solution in these settings. Smaller frames (490mm seat tube) perform best in terms of vertical compliance and lateral stiffness, whereas the shorter top tube length (525mm) and bigger head tube angle (74.5°) result in a laterally stiffer frame, which is consistent with previous findings. When compared to the best of the studied frames, the optimized values demonstrate a significant improvement over the best of the current frames, with a 13 percent gain in vertical displacement and a 15% decrease in lateral displacement. The model was created to enable for more detailed tube geometry, study of other frame geometries, different materials, and analysis of other structural properties to be added in the future.

2.10 Paolo Baldissera, Cristiana Delprete (2014)

Despite the extensive literature on the mechanical behavior of carbon/epoxy composites, actual methodological approaches in finite element design of laminate layup structural components are rare. This paper provides a reduced methodology as a starting point for educational and manufacturing objectives using the case study of a particular bicycle fork required in a Student Team prototype. A numerical model was used to compare two manufacturing solutions in terms of stiffness, strength, and failure mode. The model validation was relied on an a posteriori linear stiffness comparison with the manufactured component because the project requirements mandated that standard destructive testing be avoided. The little differences between experimental and numerical data were explored in order to determine their cause and assess the model's trustworthiness. Even if only a portion of the safety standard requirements are met, the overall methodology proves to be dependable enough to serve as a foundation for further development and refinement.

2.11V. Balasubramanian, M. Jagannath, K. Adalarasu, (2014)*

The goal of this study was to use surface electromyography to analyses muscle activity during pedaling on three different bicycle designs: rigid frame (RF), suspension (SU), and sports (SP) (sEMG). This study enlisted the help of twelve male volunteers. Extensor carpi radialis (ECR), trapezius medial (TM), latissimus dorsi medial (LDM), and erector spinae (ES) sEMG signals were collected bilaterally throughout 30 minutes of cycling on each bicycle and after cycling. From collected sEMG signals, time domain (RMS) and frequency domain (MPF) characteristics were retrieved. The tiredness in the right LDM and ES was considerably (p 0.05) higher in the SP bicycle, according to the sEMG study. A psychophysical evaluation based on the RBG pain scale confirmed this. The study also found that the SU bicycle caused much less tiredness than the RF and SP bicycles.

III. CONCLUSION

A bicycle frame is an important part of the bike's construction. The bike's endurance was assessed in terms of design and materials utilized to make the frame. Steel, wood, and composites are just a few of the materials that have been employed. The major goal of the bike, which is built of several materials, is to create a framework that is both durable and lightweight. This is due to the fact that cycling has evolved into a sport as well as a mode of transportation. Various parameters in the bicycle frame have been investigated in this review. As a result, the bike frame has been examined in the form of tubes before being transformed into a complete bicycle frame.

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